SUMMARY

— India has large mineral deposits of zircon in Kerala beach, silica in UP and Gujarat, Bauxite in MP, Gujarat, Orissa, Bihar and Maharashtra. Country can export value added high quality ceramic grade powder rather than export ore and import powders and products.

— Ceramic powders for advanced ceramic applications are not available indigenously and, hence they are imported in large quantities. It is suggested that companies like M/s Thermo Chemical Industry, Junagadh who are engaged in production of ceramic powders, may be financed by financial institutions or new entrepreneurs can think to join hand with the company for the project.

— Alumina is the most important material for many Hi-tech Ceramics. Bauxite, an important source of alumina is abundantly available in Gujarat. High purity calcined alumina and barium titanate prepared by Sol-gel method have obtained purity over 99.97 % with controlled particle size. Technology tried at Labscale can be tried for pilot plant.

— Ferric oxide (mineral), manganese dioxide, manganese carbonate and zinc oxide raw materials are amply available indigenously. So, manufacture of hard and soft ferrites in Gujarat by ceramic manufacture is ideal diversification.

— Technology tie up should be made with a supplier, whose interests are not restricted to single product, but has horizontal linkage and interest in other emerging area of advanced engineering ceramics.

— Preferences may be given to technology supplier which offers buy-back guarantees.

— New entrepreneurs must devote tremendous effort to stimulate the market.

— Threadguides, seals, nozzles are small in size, relatively complex in shape with high value and less bulk offers the advantage of easier handling. Items like threadguides have a range of several thousand patterns. It makes these products suitable for smaller volume production runs.
4.0 The Panel identified the following items on which the report was prepared:

01 Multilayer Ceramic Capacitors
02 Ceramic IC Substrates
03 Ferrites - Hard and Soft
04 Ceramic Sensors
05 Grinding Media & Nozzles
06 Thread Guides
07 Mechanical Seal Faces & Tap Seal Discs
08 Material Handling Liners
09 Special Refractories - Continuous Casting Refractories
10 Alumina Powder for Structural Applications

The Panel met five times to discuss the investment opportunities and for preparation of the report and its finalisation.

The report was approved in the sixth meeting of the Panel held on 5th February, 1993.
8. Dr. B K Sarkar  
   Director  
   Central Glass & Ceramics Research Institute  
   Calcutta  

9. Shri K D Sanghvi  
   Director  
   Inter Kiln Hi-Temp Ceramics Pvt. Ltd.  
   Ahmedabad  

10. Shri V D Patel  
    President  
    Gujarat Ceramics Society  
    Ahmedabad  

11. Shri P M Lodha  
    Jayashree Insulators  
    Halol  
    Panchmahals  

12. Dr. V C Joshi  
    Professor of Ceramic Engineering  
    Department of Ceramic Engg.  
    Banaras Hindu University  
    Institute of Technology  
    Varanasi, U.P.  

13. Dr. S Sensarma  
    Mineral Industries Directorate  
    DGTD, Udyog Bhavan  
    New Delhi 110 011  

14. Shri M P Palriwala  
    Managing Director  
    Swastik Sanitary Wares Ltd.  
    Ahmedabad  

15. Shri R J Shah  
    Chief Industrial Advisor  
    Industries Commissionerate  
    Ahmedabad  

16. Shri C K Joshi  
    Director of Geology & Mining  
    Ahmedabad  

17. Dr. M K Jain  
    Executive Director  
    INDEXTh  

18. Shri J V Bhatt  
    Sr. Development Officer (Minerals)  
    INDEXTh  

Copy fuc to:  
Chairman &  
All the Members of the Panel  

Sd/-  
P K LAHERI  
Industries Commissioner &  
Chairman, INDEXTh
<table>
<thead>
<tr>
<th>ANNEXURE/APPENDIX</th>
<th>PARTICULARS</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANNEXURE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>List of Companies Active in Commercialisation of Advanced Ceramics</td>
<td>55</td>
</tr>
<tr>
<td>2.2</td>
<td>Commercially Available Structural Ceramic Products</td>
<td>58</td>
</tr>
<tr>
<td>2.3</td>
<td>List of Existing Collaborations in the Field of Advanced Ceramics</td>
<td>59</td>
</tr>
<tr>
<td>2.4</td>
<td>Terms of Various Foreign Collaborations</td>
<td>60</td>
</tr>
<tr>
<td>3.1</td>
<td>World-Wide Research Centres in Hi-Tech Ceramics</td>
<td>63</td>
</tr>
<tr>
<td>3.2</td>
<td>Major Structural Ceramics Programmes Currently Under progress</td>
<td>65</td>
</tr>
<tr>
<td>3.3</td>
<td>Structural Ceramic Products Currently Under Development</td>
<td>66</td>
</tr>
<tr>
<td>3.4</td>
<td>Indian Organisations Active in R &amp; D</td>
<td>67</td>
</tr>
<tr>
<td><strong>APPENDIX</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>List of Ceramic Powder Manufacturers</td>
<td>68</td>
</tr>
<tr>
<td>2.</td>
<td>Electro-Ceramics Manufacturers</td>
<td>72</td>
</tr>
<tr>
<td>3.</td>
<td>Structural Ceramics Manufacturers</td>
<td>77</td>
</tr>
<tr>
<td>4.</td>
<td>High Purity Powders from Sol-Gel Method By Thermo Chemical Industry, Junagadh</td>
<td>82</td>
</tr>
</tbody>
</table>
Functional Applications of Advanced Ceramics

(Source: Fine Ceramics Office, MITI, Tokyo)
<table>
<thead>
<tr>
<th>CHEMICAL FUNCTIONS</th>
<th>Gas sensor (ZnO₂, Fe₂O₃, SnO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Humidity sensor (MgCr₂O₄, - TiO₂)</td>
</tr>
<tr>
<td></td>
<td>Catalyst carrier (cordierite)</td>
</tr>
<tr>
<td></td>
<td>Organic catalyst</td>
</tr>
<tr>
<td></td>
<td>Electrodes (titanates, sulfides, borides)</td>
</tr>
<tr>
<td></td>
<td>Gas leakage alarm, automatic ventilation fan, hydrocarbon, fluorocarbon detectors, etc.</td>
</tr>
<tr>
<td></td>
<td>Cooking control element in microwave oven, etc.</td>
</tr>
<tr>
<td></td>
<td>Catalyst carrier for emission control</td>
</tr>
<tr>
<td></td>
<td>Enzyme carrier, zeolites</td>
</tr>
<tr>
<td></td>
<td>Electrocoating aluminium, photochemical processes, chlorine production</td>
</tr>
<tr>
<td>THERMAL FUNCTIONS (ZRO₂, TiO₂, CERAMICS)</td>
<td>Infrared radiator</td>
</tr>
<tr>
<td></td>
<td>Cutting tools (Al₂O₃, TiC, TiN others)</td>
</tr>
<tr>
<td></td>
<td>Wear resistant materials (Al₂O₃ZrO₂)</td>
</tr>
<tr>
<td></td>
<td>Heat resistant materials(SiC,Al₂O₃,Si₃N₄ others)</td>
</tr>
<tr>
<td></td>
<td>Cutting tools, sintered SBN</td>
</tr>
<tr>
<td></td>
<td>Cermet tool, artificial diamond</td>
</tr>
<tr>
<td></td>
<td>Nitride tool</td>
</tr>
<tr>
<td></td>
<td>Material seal, ceramic liner, bearings, thread guide, pressure sensors</td>
</tr>
<tr>
<td></td>
<td>Ceramic engine, turbine blade, heat exchangers, welding burner nozzle, high frequency combustion crucibles</td>
</tr>
<tr>
<td>MECHANICAL FUNCTIONS</td>
<td>Alumina-ceramics implantation</td>
</tr>
<tr>
<td></td>
<td>Hydroxyapatite bioglass</td>
</tr>
<tr>
<td></td>
<td>Artificial tooth root, bone and joint</td>
</tr>
<tr>
<td>BIOLOGICAL FUNCTIONS</td>
<td>Nuclear fuels (UO₂, UO₂-PuO₂)</td>
</tr>
<tr>
<td></td>
<td>Cladding material (C, SiC, BC4)</td>
</tr>
<tr>
<td></td>
<td>Shielding material (SiC, Al₂O₃, C, B₄C)</td>
</tr>
</tbody>
</table>
1.2.3 The current processing of ceramic materials has not changed radically over hundreds of years, although many improvements have been made in the equipment used. Currently, the processing is batch and labour intensive. Rate processes i.e. the time dependent operations are not understood fully. Defects that results from heat and mass transfer into the three dimensional shapes and from chemical reactions are difficult to identify and eliminate. Therefore, process and quality control is extremely difficult, continuous processing has not been achievable and rejection rates are extremely high.

1.2.4 Table 1.1 shows cost distribution for various manufacturing steps in structural ceramics against other high performance metals and plastics. The distribution of costs is quite different for ceramics compared with other conventional structural materials. Cost of finishing, inspection and rejection are markedly higher for ceramics than metal. The reason for this, perhaps, is due to the difference in temperature profile for ceramic processes. The highest temperature to which ceramics are subjected occurs after the shaping has been done. Whereas, in metals, the highest temperature occurs before shaping. Therefore, there is a chance of correcting mistakes which might have occurred in metals, whereas such faults cannot be corrected easily in ceramics. As a result, the scrap value of ceramics is extremely low and rejection rates are extremely high.

Table I.
Comparison of Manufacturing Costs in High Performance Materials

<table>
<thead>
<tr>
<th>Process</th>
<th>Structural Ceramics (%)</th>
<th>Metals and Others (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting materials</td>
<td>5-10</td>
<td>5-10</td>
</tr>
<tr>
<td>Physical processing</td>
<td>5-10</td>
<td>10.20</td>
</tr>
<tr>
<td>Chemical processing</td>
<td>10-20</td>
<td>20-30</td>
</tr>
<tr>
<td>Shaping</td>
<td>5-10</td>
<td>10-20</td>
</tr>
<tr>
<td>Thermochemical processing</td>
<td>15-20</td>
<td>5-10</td>
</tr>
<tr>
<td>Finishing</td>
<td>15-20</td>
<td>5-10</td>
</tr>
<tr>
<td>Inspection and rejection</td>
<td>40-50</td>
<td>5-10</td>
</tr>
</tbody>
</table>

1.3.0 PROPERTIES OF ADVANCED CERAMICS

1.3.1 Advanced ceramics are hard, stiff, inert and extremely resistant to attack by chemicals. They can take a large amount of compressive load but exhibit poor tensile properties. They do not expand when heated, are poor conductors of heat and have very low densities as compared to metals - materials which they often substitute in many structural applications.

1.3.2 Ceramics derive these properties to a large extent from the way they are constituted both at the atomic level and at the macro-level. Ceramic materials have bonds between their atoms which are partly ionic and partly covalent. These special kind of bonds distinguish ceramics from metals, which have metallic bonds and organic compounds, which have been based covalent bonds.

1.3.3 The large number of possible crystal structures and the possibility of substitution of one element in the crystal with another, make possible a diverse range of possible ceramic substances. By varying the crystal structure of ceramics, it is possible to produce wide range of substances with different properties with the same starting materials.
INVESTMENT OPPORTUNITIES IN HIGH-TECH CERAMICS

INDEXTB
INDUSTRIAL EXTENSION BUREAU
(A GOVT. OF GUJARAT ORGANIZATION)
NANALAL CHAMBERS, ASHRAM ROAD
AHMEDABAD - 380 009
PREFACE

During the Eighth Five Year Plan, the Government of Gujarat has placed special emphasis on the development of High-tech Industries such as Biotechnology, Electronics and High-tech Ceramics. In this connection, the Industries Commissioner had constituted Technical Panels with a view to studying the scope for development of these sectors and to make suitable recommendations to Government. The Technical Panel on High-Tech Ceramics had been constituted under the chairmanship of Shri Achut Ganpule, Managing Director, Parshuram Pottery Works Limited and other experts.

I am happy to learn that the Technical Panel on High-Tech Ceramics has taken up its task and had several meetings and made considerable progress towards identifying raw materials availability, market potential for specific products and has identified investment opportunities in High-Tech Ceramic areas through a detailed study from a consultant. The Panel's decision to publish details on 10 specific projects on high tech ceramics having potential in Gujarat exploiting basic raw materials available in the State will be useful to prospective entrepreneurs and encourage the development of this specific sector of industry in the State.

I am thankful to M/s Dalal Consultants & Engineers Limited, Ahmedabad, who have done a detailed study to identify investment opportunities in the high tech ceramic sector in the State. I also compliment all the Panel members and Shri JV Bhatt, Senior Development Officer (Minerals), iNDEXTb, who is also the Member Secretary of the Panel for bringing out the report in its present form.

Ahmedabad
March 13, 1993

M.N.BUCH
Industries Commissioner and
Chairman, iNDEXTb
PREAMBLE

1.0 Industrial Extension Bureau (INDEX TB) renders assistance to new entrepreneurs in identifying suitable projects. INDEX TB has taken initiative to formulate a development programme for High Tech Ceramics in the State of Gujarat. For the purpose, Panel for High Tech Ceramics has been constituted comprising leading ceramic sector industrialists, research scientists, industrial development officials and planners by Industries Commissioner, Government of Gujarat.

2.0 The list of members were as under:

01 Shri Achutrao Ganpule  
02 Shri Rupeeshbhai Shah  
03 Shri B D Kothari  
04 Shri Nimeshbbhai S Bachkaniwala  
05 Shri H S Sethuram  
06 Shri Ganashyambhai Bhatt  
07 Shri B M Sedalila  
08 Dr. B K Sarkar  
09 Shri K D Sanghvi  
10 Shri V D Patel  
11 Shri P M Lodha  
12 Dr. V C Joshi  
13 Dr. S Sensarma  
14 Shri M P Paliwala  
15 Shri R J Shah  
16 Shri C K Joshi  
17 Dr. M K Jain  
18 Shri J V Bhatt

Chairman
Member
Member
Member
Member
Member
Member
Member
Member
Member
Member
Member
Member
Member
Member
Member
Member
Member
Member

The panel has identified that there is considerable availability of bauxite in Gujarat and alumina is clearly most significant starting material for several High Tech Ceramic Projects. The study was awarded to Dalal Consultants and Engineers Limited, Ahmedabad for identifying and evaluating project opportunities in the area of High Tech Ceramics for development in Gujarat.

3.0 The aim of the study was as under:

1. Study of advanced ceramics with production process, properties and problems associated with it.
2. Analysis of industry status in terms of products, the technologies employed, present and likely manufacturers, research centres involved.
3. Estimation of market size of various products based on the market potential.
4. Discussing the raw material scenario in terms of their availability.
5. A general comparative evaluation of various high tech ceramic products.
6. Recommendation for selected relevant projects based on the analysis.
7. Preparation of project profiles for selected high tech ceramic products.
ORDER

State Government attaches great importance to the development of a High-tech Ceramics in the State. Working Group on Large and Medium Industries for VIIIth Plan, recommended creation of special dispensation for development of High-tech Ceramics in the State.

In order to make recommendation to the Government and initiate various steps to be taken for speedy development of High-tech Ceramics in the State, a Technical Panel is constituted under the aegis of Industrial Extension Bureau. Appointment of the Technical Panel is for 2 years from the date of this order. The Panel may function through any sub-group formed by it. Expenditure, which may be approved as necessary by Industrial Extension Bureau, will be met from funds of the Industrial Extension Bureau.

Constitution of the Technical Panel on High-tech Ceramics is as under:

1. Shri Achutrao Ganpule
   Chairman & Managing Director
   Parshuram Pottery Works
   Morbi, Rajkot

2. Shri Rupeshbhai Shah
   Managing Director
   Soniya Ceramics Ltd, Ahmedabad

3. Shri B D Kothari
   Managing Director
   Madhusudan Ceramics Ltd, Ahmedabad

4. Shri Nimeshbhai S Bachkaniwala
   Managing Director (Ceramics Division)
   Himson Techno Services Pvt. Ltd.
   Ahmedabad

5. Shri H S Sethuram
   Chief Executive
   Bell Ceramics Ltd.
   Baroda

6. Shri Ghanshyambhai Bhatt
   Electro Porcelain Industries
   Ahmedabad

7. Dr. B M Sedalia
   Consultants in Ceramic Technology
   Rajkot
SECTION - 1
<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Advanced Ceramics - An Overview</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Industry Status</td>
<td>8</td>
</tr>
<tr>
<td>3.</td>
<td>Research and Development Status</td>
<td>13</td>
</tr>
<tr>
<td>4.</td>
<td>Demand Scenario</td>
<td>20</td>
</tr>
<tr>
<td>5.</td>
<td>Raw Material Scenario</td>
<td>28</td>
</tr>
<tr>
<td>6.</td>
<td>Comparative Evaluation and Selection of Relevant High-Tech Projects</td>
<td>44</td>
</tr>
<tr>
<td>7.</td>
<td>Hi-Tech Ceramics - Prospects in Gujarat</td>
<td>51</td>
</tr>
<tr>
<td>8.</td>
<td>Policy Matters</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Annexure</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Appendix</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>Project Profiles</td>
<td>83</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PARTICULARS</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Comparison of Manufacturing Costs in High Performance Materials</td>
<td>6</td>
</tr>
<tr>
<td>2.1</td>
<td>High Tech Ceramics Products Current Status - India</td>
<td>10</td>
</tr>
<tr>
<td>4.1</td>
<td>Advanced Ceramics Market</td>
<td>21</td>
</tr>
<tr>
<td>4.2</td>
<td>World Market for Electronic Ceramics</td>
<td>21</td>
</tr>
<tr>
<td>4.3</td>
<td>World Market for Structural Ceramics</td>
<td>22</td>
</tr>
<tr>
<td>4.4</td>
<td>World Market for Ceramic Castings</td>
<td>22</td>
</tr>
<tr>
<td>4.5</td>
<td>Demand Estimates : Hi-Tech Ceramics in India</td>
<td>24</td>
</tr>
<tr>
<td>4.6</td>
<td>Demand Estimates : Hi-Tech Ceramic Powder</td>
<td>27</td>
</tr>
<tr>
<td>5.1</td>
<td>Properties of Several Advanced Structural Ceramic Materials</td>
<td>28</td>
</tr>
<tr>
<td>6.1</td>
<td>Comparative Evaluation (Electro Ceramics)</td>
<td>45</td>
</tr>
<tr>
<td>6.2</td>
<td>Comparative Evaluation (Structural Ceramics)</td>
<td>47</td>
</tr>
</tbody>
</table>
1.1.0 INTRODUCTION

1.1.1 Advanced ceramic materials are a relatively new class of high performance materials with significant potential for the future economic impact. Advanced ceramics are differentiated from traditional ceramics by the specialised properties they possess as well as by the sophisticated processing they require. Because of these special properties, advanced ceramic materials are expected to be used increasingly in a number of high performance commercial applications ranging from heat and wear resistant parts to electronic and optical devices.

1.1.2 Traditional ceramics are associated with clay products such as bricks and tiles. One typical characteristics of these traditional ceramics is that all of them use materials/minerals occurring in their natural state. Various ceramic products which fall under this category are bricks, tiles, chinaware, sanitaryware, refractories such as alumina and silica. In contrast to these traditional ceramics, "Advanced Ceramics" are manufactured from highly refined specially prepared raw materials using chemical prosessing techniques, rather than techniques of mineral extraction which characterise the traditional ceramic industry.

1.1.3 The properties of ceramic products are determined by various elements such as purity, the roundness or sphericity of the powder particles, their size and size distribution.

1.1.4 Ceramics can also be combined with other materials like plastics, metals and alloys to form composites. For these applications, ceramic in the form of long fibres, short fibres or small whiskers is desired.

1.1.5 In the essence, the distinguished features of advanced ceramics are:

* A substantially higher level of performance.
* Much more stringent requirements on composition control and processing.
* A market value based on unique performance which justifies a much higher cost.

1.1.6 Advanced ceramics have certain unique properties enabling it to be used for high performance applications, like:

* High degree of hardness
* High temperature, mechanical strength
* High corrosion and erosion resistance
* High piezo-electric coupling coefficient
* High magnetic permeability
* High melting point
* Low density
* Optical transparency
* Fast ion conduction
* Low thermal conductivity

1.1.7 Functional applications of advanced ceramics is presented in Chart 1.1 and Chart 1.2.
Thermal spary, chemical vapour Deposition (CVD) and Ceramic Physical Vapour Deposition (PVD) are the techniques in use. PVD Coatings are most durable and abrasion resistant. Their current production is small but is expected to increase.

**Sol-Gel Technology**

Sol-gel derived products gave a very small market at present. However, faster growth rates have been envisaged in the coming years. The products made by sol-gel include powders, fibres, coatings and monoliths. Currently, the largest product is non-metallic abrasives. In the near future optical fibre preforms are expected to be the most important application of sol-gel technology.

**Ceramic Matrix Composites (CMCs)**

The Current applications of Ceramic matrix composites are wear resistant parts made of toughened zirconia, whisker and other fibre reinforced ceramic composites used in cutting tools and aerospace applications. Faster growth has been envisaged in the market of Ceramic Matrix Composites.

2.2.6 Major thrust of R&D activities is in the development of products for structural applications. Efforts are on to develop ceramics for intensive engines, nuclear application and ceramic composites. A list of commercially available structural ceramic products are listed in Annexure 2.2.

2.3.0 **INDIAN INDUSTRY STATUS**

2.3.1 The manufacture of products using Hi-Tech Ceramics is still in the nascent stage of development in India. Most of the ceramic manufacturers are in the traditional or Low Tech areas, including traditional refractories.

2.3.2 There are very few players in the Hi-Tech Ceramics market and most of them are in Electro Ceramics. Manufacturers of structural ceramics are very few in number. In addition to lack of know-how regarding high volume processing, non-availability of high quality ceramic powders is the major factor preventing developments in this sector.

2.3.3 Most of the domestic manufacturers have tied-up with foreign companies for technology/know-how. A list of such existing collaborations is given in Annexure 2.3. Annexure 2.4 describes various terms and conditions agreed upon for few foreign collaborations.

2.3.4 Ceramic powders for advanced ceramic applications are not available in the country and need to be imported. The efforts are being made at various national laboratories and institutes for synthesis of these powders at laboratory scale. Such efforts need to be evaluated and the techniques scaled up to pilot size. Laboratory scale synthesis of powders is generally not too difficult, but producing large quantities on economic scale is much more difficult.

2.3.5 India has enough mineral deposits. In fact, we export Zircon, Silica, Low grade Alumina and Bauxite. Even if ceramic products development is difficult, we can export value added high quality ceramic grade powders, rather than ore and import powders and products.

2.3.6 The current status of Hi-Tech Ceramics based products is described briefly in Table 2.1.
### Chart 1.2

#### Classification of High-Technology Ceramics by Function

<table>
<thead>
<tr>
<th>Electric Functions</th>
<th>Insulation materials (Al₂O₃, BeO, MgO)</th>
<th>IC circuit, substrate, packaging, wiring, resistor, electronics, interconnection, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ferroelectric materials (BaTiO₃, SrTiO₃)</td>
<td>Ceramic capacitor, vibrator, oscillator, filter, etc.</td>
</tr>
<tr>
<td></td>
<td>Piezoelectric materials (PZT)</td>
<td>Transducer, ultrasonic humidifier, piezoelectric spark generator, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NTC thermistor, PTC thermistor, CTR thermistor, Thick film thermistor, Varistor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sintered CdS material, SiC heater, Solid electrolyte for sodium battery, ZrO₂ ceramics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Temperature sensor, temperature compensation, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat element switch, temperature compensation, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infrared sensor, noise elimination, surge current absorber, lighting arrestor, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solar cell, electric furnace heater, miniature heater, etc.</td>
</tr>
<tr>
<td></td>
<td>Icon conduction materials (-Al₂O₃ZrO₂)</td>
<td>Oxygen sensor, pH meter, fuel cells</td>
</tr>
<tr>
<td>Magnetic Functions</td>
<td>Soft ferite</td>
<td>Magnetic recording head, temperature sensor, etc.</td>
</tr>
<tr>
<td></td>
<td>Hard ferite</td>
<td>Ferrite magnet, fractional horse power motors, etc.</td>
</tr>
<tr>
<td>Optical Functions</td>
<td>Translucent alumina, Translucent magnesium, etc.</td>
<td>High pressure sodium vapor lamp, for lighting tube, special purpose lamp, infrared transmission window materials, laser material, light memory elements, video display &amp; storage system, light modulation elements, light shutter, light valve</td>
</tr>
<tr>
<td></td>
<td>Translucent Y₂O₃, -ThO₂ ceramics PLZT ceramics</td>
<td></td>
</tr>
<tr>
<td>Sl. No.</td>
<td>Area/Product</td>
<td>Present Manufacturers</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2.</td>
<td>Ceramic Cutting Tools</td>
<td>Sandvik, Widia supplies coated ceramic inserts.</td>
</tr>
<tr>
<td>3.</td>
<td>Ceramic Grinding Media</td>
<td>Several manufacturers i.e. Jyoti Ceramics, NTB International etc.</td>
</tr>
<tr>
<td>4.</td>
<td>Ceramic Nozzles for Welding</td>
<td>IVP Ltd, the only supplier. Others supply tungsten carbide nozzles.</td>
</tr>
<tr>
<td>5.</td>
<td>Ceramic Thread Guides</td>
<td>Himsons, NTB, IVP, Widia are major suppliers.</td>
</tr>
<tr>
<td>6.</td>
<td>Mechanical Seal Faces and House-</td>
<td>IVP, Widia supplies mechanical seal faces. Household tape seal discs are not manufactured.</td>
</tr>
<tr>
<td>7.</td>
<td>Liners for Material Handling</td>
<td>BHET and Garden City Engineers</td>
</tr>
<tr>
<td>8.</td>
<td>Refractories</td>
<td>Several manufacturers. Major are Carborundum, Grind-wel Norton, Tata Refractories.</td>
</tr>
<tr>
<td>9.</td>
<td>Insulating Alumina Fibres</td>
<td>Carborundum, Orient Cerwool, Lloyds Insulation.</td>
</tr>
</tbody>
</table>
1.3.4 The strong bonds between the atoms in a ceramic gives them strength as well as chemical stability, which makes them relatively impregnable to attach from other chemical since many ceramics are already oxidised to form oxides. The strength of ionic-covalent bond is also responsible for the high melting point, hardness and strength of ceramics.

1.4.0 TECHNICAL PROBLEMS ASSOCIATED WITH USE OF ADVANCED CERAMICS

1.4.1 The main problem concerning with the use of ceramics in high performance applications, as its extremely poor fracture toughness value. In comparison to metals which have a fracture toughness value of about 50, ceramics have a very low fracture toughness value of about 1. This signifies that ceramics are about 50 times susceptible to brittle failure than metals.

1.4.2 For subjecting ceramics to high performance applications, it is essential to minimise their propensity to brittle failure. Fracture toughness can be improved by creating ceramic materials that do not contain voids, agglomerations or chemical impurities. These defects are the places from which cracks originate and if they can be eliminated or reduced, the fracture toughness can be improved significantly. To achieve this, it is necessary to improve quality of starting material i.e. ceramic powder.

The necessary steps for improving fracture toughness of ceramic materials at powder preparation stage are:

1. Production of powder of high chemical purity.
2. Production of powder particles as fine as possible (1μm φ), so that they be packed tightly together.

1.4.3 The significant improvements in fracture toughness can be achieved by adding special flocculants which prevent agglomeration of particles during sintering.

1.4.4 The required properties can also be achieved by exercising control over the structure of the ceramics at varying levels. At the atomic level, structure is controlled through chemical purity and control of sintering temperature and pressure. Through control of particle size and control over phenomena that takes place on the surface of particles (by adding flocculants), product quality at dimensions of about 100 atoms are controlled. At the macroscale (typically about one thousandth of millimetre), control over grain size and proper packing of the powder gives the required properties.

1.4.5 The other technical approach adopted to make ceramics tougher or more fracture resistant is to arrest the cracks and prevent their growth. One method of doing this is called transformation toughening. This method uses a transformation of the crystal structure of ceramic material, that is induced by stresses, at the crack tip.

1.4.6 The toughness of ceramic can also be improved by interlacing fine ceramic fibres within the ceramic matrix. These fibres bridge the gap between the two sides of a growing crack and prevent them from widening and growing further by taking on some of the stresses.
2.1.0 INTRODUCTION

2.1.1 Hi-Tech Ceramics, though a new area in the field of Advanced materials, has witnessed a significant growth in the recent times. Hi-Tech Ceramic products are finding application in newer and newer areas. They are used as dual in line packages of integrated circuits, as capacitors in electronics, hard and soft ferrites are used for magnetic applications. Piezo-electric ceramics are used for ignition in gas heaters, cooking stoves and cigarette lighters. Other applications are, as optoelectronic materials for conversion of electron to light and vice versa and many more fields. As a result, it accounts for approximately 61% of the total market for advanced materials.

2.2.0 WORLD INDUSTRY STATUS

2.2.1 The world market of Advanced Ceramic products is virtually dominated by advanced countries like Japan, USA and Western European countries. There are many manufacturers engaged in this area. However, major share of market is cornered by few manufacturers in each application areas.

2.2.2 Wide range of companies from different industrial sectors have entered or planning to enter this field. The main motives behind their interest to enter this particular arena are:

* Forward integration by materials manufacturers towards higher value added products.
* Upgradation of Technology by traditional ceramic manufacturer.
* Backward integration by user industries, which are led by necessity to develop new materials on their own.

2.2.3 Variation in Industry structure is observed among different regions. For instance, most US Companies active in ceramics are fragmented into segments, like companies producing ceramic powders and companies producing specific components. Contrary to this, Japanese companies are highly vertically integrated. Japanese companies like Kyocera, Murata make ceramic powders as well as many products. A list of major manufacturers of ceramic powders and Hi-Tech Ceramic products is given as Annexure 2.1.

2.2.4 At International level, competition is quite fierce. The investments made by Japan, US and Western Europe are so large and hence they are striving vigorously to defend their markets. The vast number of institutions, universities and industrial organisations involved in ceramics research around the world, indicate the massive efforts and resources being poured into this area.

2.2.5 Several new technologies are emerging because of these intensive efforts. Three important emerging ceramic technologies are:

* High Performance Ceramic Coatings
* Sol-gel Technology
* Ceramic matrix composites (CMCs)

**High Performance Ceramic Coatings**

The current major applications of ceramic coatings are in Aircraft engines/Aerospace applications, cutting tools and engine (Auto, Diesel, Turbines) applications. Aircraft engines/Aerospace and cutting tool applications account for more than 85% of the ceramic coating market.
• Ultra high-resolution auger electron spectroscopy.
• Secondary-ion mass spectrometry.
• Imaging X-ray Photoelectron spectroscopy.
• High Resolution transmission electron microscopy.

3.2.6 Major R & D centres world wide in this area and their scope of research work are listed in the Annexure 3.1.

3.2.7 Specific Government sponsored programmes in the area of structural ceramics have been undertaken in the developed nations. Such major programmes currently under progress are listed in Annexure 3.2.

3.2.8 Industrial organisations, especially in the advanced countries are constantly trying to develop new applications for structural ceramics. Several structural ceramic products which are currently under development are listed in Annexure 3.3.

3.3.0 DOMESTIC R & D SCENARIO

3.3.1 The domestic R & D efforts in the field of advanced ceramics are quite minuscule as compared to the efforts devoted in the advanced countries like Japan, US and European countries. Even if we compare the quality of research in this area, there is an enormous difference.

3.3.2 The domestic research efforts are concentrated mainly on powder preparation/synthesis while research in the advanced countries are towards new applications development, apart from development of new processing techniques so as to overcome existing technical barriers.

3.3.3 With regard to basic research on powder preparation/synthesis, there is a lot of work going on in India. Premier institutes like Central Glass and Ceramic Research Institute(CGCRI), Defence Metallurgical REsearch Laboratory (DMRL), Indian Institute of Technology(IIT), Bhabha Atomic Research Centre (BARC), Ceramic Technological Institute(CTI) are actively involved in the research in this field. They have developed high purity powders of Alumina, Zirconia, Silicon Carbide, Boron Carbide etc. using various techniques including Sol-Gel Processing and Plasma Synthesis. However, little attempt has been to upscale these laboratory scale technologies to pilot plant scale and further to commercial scale. The main drawback plaguing our research institutes the lack of ‘commercial approach’.

3.3.4 Except for a few isolated cases, applied research to develop novel applications is found to be missing.

3.3.5 Few Indian public and private sector companies such as Carborundum Universal, Grindwell Norton, ACC, IVP, Widia, BHREL, BEL are quite seriously doing R & D work, but they are confined by the non-availability of high quality raw materials, which needs to be imported. Besides, their focus is on short term commercial gains rather than long term technology and market development. Their R & D works primarily relate to - Refractories, Material handling liners, grinding media etc. - comparatively low technology area in the field of advanced ceramics.

A list of various Indian Organisations actively doing R & D work in the field of advanced ceramics is given in Annexure 3.4.

3.3.6 A brief profile on few major R & D centres working in this area is given in the following section.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Area/Product</th>
<th>Present Manufacturers</th>
<th>Likely New Entrants</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. 1.</td>
<td>Electro-Ceramics</td>
<td>GM Chip Components, Dalmia Cement has recently started manufacture of MLCS.</td>
<td>GIIC-Poly AVX ICICON Projects are under implementation.</td>
<td>Barium titantium powder—the raw material is not available indigenously.</td>
</tr>
<tr>
<td>2.</td>
<td>Substrates for IC chips and Hybrid circuits</td>
<td>NIL</td>
<td>NIL</td>
<td>IC chips &amp; hybrid circuit manufacturers import their requirement of ceramic substrates.</td>
</tr>
<tr>
<td>3.</td>
<td>Ferrites (Hard and Soft)</td>
<td>Many projects already exist</td>
<td></td>
<td>Enough indigenous capability exists in this area. The raw material (ferric oxide easily available).</td>
</tr>
<tr>
<td>4.</td>
<td>Piezoelectrics</td>
<td>Several manufacturers for single crystal piezoelectrics and few for polycrystalline piezoelectrics.</td>
<td></td>
<td>Indigenous technical know-how available.</td>
</tr>
<tr>
<td>5.</td>
<td>Thermistor (PTC/NTC)</td>
<td>Several manufacturers. However, large quantity is imported.</td>
<td></td>
<td>Technology available indigenously. Ceramic compound required is not available indigenously.</td>
</tr>
<tr>
<td>6.</td>
<td>Varistors</td>
<td>ELPRO, Pune</td>
<td>NIL</td>
<td>Requirement is entirely imported.</td>
</tr>
<tr>
<td>7.</td>
<td>Sensors</td>
<td>-</td>
<td></td>
<td>Requirement is entirely imported.</td>
</tr>
<tr>
<td>B.</td>
<td>Structural Ceramics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Spark Plug Cores (Ceramic body)</td>
<td>MICO has facility to manufacture ceramic body (Alumina compound is imported).</td>
<td>Modi Champion</td>
<td>Modi Champion import preformed ceramic blanks. Grade of alumina powder required for spark plug body not easily available.</td>
</tr>
</tbody>
</table>

Table 2.
High Tech Ceramics Products Current Status - India
Central Glass And Ceramic Research Institute (CGCRI)

The Central Glass and Ceramic Research Institute (CGCRI), Calcutta, a National Laboratory under the Council of Scientific and Industrial Research (CSIR), was established in 1950.

Objective of the Institute has been to carry out scientific and industrial/applied research in the field of glass, ceramics, refractories, vitreous enamels, composites and allied materials in consonance with the national needs and priorities as identified in the technology plans and missions. Activities of the institute include:

- R & D directed towards evaluation and gainful utilisation of the country’s resources of the related raw materials, including agro and industrial wastes.
- Development of technologies for import substitution in the field of special materials and adaptation and updating of imported technologies in the related areas.
- Undertaking projects sponsored by the industries in the public and private sectors.
- Development of appropriate technologies relating process innovation and product diversification for the industry in the small scale and tiny sectors.
- Carrying out basis research in the related fields.
- Technical assistance to the industry for improvement in quality, productivity, performance of furnaces etc.

Major achievements and thrust areas in the current programme of work of the institute broadly relate to optical Materials, Electronic Materials, Engineering and High Temperature Materials, Conservation of Energy etc.

Brief outline of various developments made at the Institute in the field of ceramics is given below:

A. Electronics Ceramics

1. Thick Film Printing Ink/Paste for the Electronic Industry

Thick film printing is one of the advanced technologies in the field of micro-electronics. In the integrated circuits, resistor and conductor patterns are formed by screen printing of thick film pasted into ceramic substrates. The institute developed screen printable resistive and conductive pastes confirming to international standards. The pastes are suitable for use in potentiometric trimmers, printing hybrid circuits and ceramic to metal seals especially for power electronics.

2. Ceramic Components for Advanced Electronics

The institute has initiated a major programme on the development of indigenous technology for the manufacture of a number of ceramic micro-electronic components, viz. multilayer capacitors based on both Barium Titanate dielectrics and newer lead based relaxor ferro electrics, tape cast alumina substrates for hybrid circuits, ceramic packaging for LST and VLST devices and multilayer piezoelectric devices based on PZT and PLZT ceramics.

3. Ceramic Superconductors

The institute has launched a major research programme on high temperature ceramic superconductors and development of suitable techniques for fabricating superconducting wires, tapes and thin films with sufficient current density.
2.3.7 From the above, it can be seen that the presence of Indian companies in the advanced ceramics market is quite marginal. Large amount of the supply for most products (except refractories and material handling liners) are imported.

2.3.8 In many cases, these products are imported as integral parts or accessories. In other case, companies having collaborations source parts from their principals abroad.

Major factors hindering indigenous development of these products are described below:

* Raw Materials of ceramic grade need to be imported. Large manufacturers may be able to source supplies more easily, but smaller companies face a lot of problems. In addition, delays in import, high inventory of raw materials, further increase overheads.

* Various additives used in processing, such as binders, plasticizers, flocculants, defoamer are not easily available and hence they are imported.

* With regard to Plant and Machinery, High Temperature Kilns, Hot Isostatic Presses, moulds for isostatic press, linings and grinding media are the equipments that are not available indigenously. Most of the manufacturers, use hydraulic presses for forming and then go for sintering.

* Ceramic product manufacturers do not invest in market development and hence most potential users are quite unaware of the advantages of using ceramics.

* Workforce engaged in the manufacture of Hi-Tech Ceramic products lacks in skills required by this industry.

* The apparent lack of demand has deferred several prospective investors in this area.

The future outlook of Hi-Tech Ceramic Industry in India seems quite prospective. Demand for Hi-Tech Ceramics is likely to increase substantially. Many existing ceramic companies are trying to broader and improve its products range.
Various processes developed/under development at CGCRI are listed below:

**Processes Released to Industries**

1. Alumina Ceramics for electrical and other engineering uses.
2. Ceramic colours
3. Cordierite based saggars
4. Glass Ceramic Tiles
5. Low cost glazed wall tiles
6. Insulating bricks
7. High Alumina bricks
8. High density dolomite sinters
9. Low thermal mass kiln
10. Synthetic high alumina aggregate
11. Low moisture castable

**Process Completed and Awaiting Release**

1. Reaction Bonded Silicon Nitride (RBSN)
2. High Alumina Cement
3. Crystal Glass
4. High performance kiln car deck slab for pottery industry
5. Thick film printing ink/paste for electronic industry.

**Processes in Advanced stage of Completion**

1. Metallisation of Ceramics

**Bhabha Atomic Research Centre (BARC), Bombay**

BARC's Metallurgy Division is quite actively involved with the research and development activities in the area of advanced ceramics. Their prime work relates to basic research on powder preparation/synthesis. They have produced high purity powder of Alumina, Zirconia using various techniques including sol-gel processing and plasma synthesis. They have developed Lab-scale technology for the synthesis of high purity powders. BARC is trying to sell technology for the production of PSZ on a non exclusive basis.

Following developments have been made at BARC, in the field of ceramics.

1. Development of machinable ceramics for use as insulators in UHV systems natural and synthetic mica based compositions.
2. Development of recrystallised Alumina ware - fabrication of small boats and crucibles.
3. Development of High Temperature oxide super conductors (Y - Ba - Cu-O and Bi-Sr. Ca-Cu-O system) - synthesis and fabrication - Bulk production of powders.
4. Metallisation of Ceramics for seals and feed throughs.
3.1.0 INTRODUCTION

3.1.1 Since, past few years, considerable efforts have been devoted in the field of advanced ceramics, as it has immense potential to bring revolutionary changes in the field of materials science and fabrication technology. Despite of these efforts, the commercialisation of advanced ceramics has not been as rapid as anticipated. The main reason for this is the difficulty in overcoming inherent technical barriers associated with the production and fabrication of advanced ceramics.

3.1.2 Ceramics are very sensitive to small flows that are introduced during processing or in service. Flows, physical or chemical can occur in any of the stages (i.e. powder synthesis, conditioning, shaping and densification) of the fabrication process. These flows once introduced can not be rectified in subsequent stages.

3.1.3 The major technical barrier to commercialisation is the multiplicity of flows occurring during processing of ceramics. These flows are the source of the unreliability of structural components made from ceramic materials.

3.2.0 INTERNATIONAL R&D SCENARIO

3.2.1 Vast number of institutions, universities and industrial organisations are involved in ceramics research around the world massive efforts and resources are being poured into this area. As it is not possible to enlist all these efforts in this report. However, an attempt has been made to indicate various directions of current research in this area.

3.2.2 Ongoing Research is directed at the following broad areas:
- Characterisation of Ceramic Materials
- Synthesis of powders with high chemical purity and controlled particle size.
- Technology developments towards the production of reliable, reproducible and cost effective products.

3.2.3 In order to attain above objectives, several novel processing techniques for production of ceramics and ceramic composites are being researched. These include:
- Solution chemistry processing (Sol-gel, Organo-metallic Techniques, solution precipitation)
- Tape Casting of composites
- Self-propagating high temperature synthesis(SHS)
- Microwave-assisted sintering
- Multiple - step processing
- Laser surface modification and welding
- Robotic manipulation for testing

3.2.4 Considerable R & D efforts are going on to develop ceramic-matrix composites (CMCs).

3.2.5 Research interests are also in the area of non-destruction testing based on various wave-field techniques for process monitoring, characterisation and inspection. Several new testing techniques have been developed to detect formation of possible flows so as to prevent their occurrence. Some of the new and improved techniques developed due to these efforts are:
Ceramic Technological Institute (CTI)

The Ceramic Technological Institute (CTI) is being set up by Bharat Heavy Electricals Limited (BHEL) with United Nations Development Programme (UNDP) assistance.

The main objective of the institute is to support the Indian Ceramic Industry in modernizing its technology and to develop new products and processes in the emerging technology of Advanced Ceramics.

The main objectives of CTI are:
* To conduct applied research on various aspects of ceramic materials.
* To upgrade technology from laboratory to pilot scale prior to commercial production.
* To provide consultancy and engineering services.
* To establish facilities for characterisation and testing of ceramic materials.
* To impart training and testing of ceramic materials.
* To disseminate knowledge and experience among Indian Industries.

The main areas of activities of CTI are in:
* Beneficiation of Raw Materials
* Material Testing
* Refractories
* Ceramic Coatings
* Energy Savings Systems
* Electronic Ceramics
* Wear Resistant Materials
* Technical Ceramics

Major facilities available with CTI are:
* High temperature furnace
* Hydraulic Press
* Injection Moulding Equipment
* Viscometer
* X-Ray Diffractometer
* Optical Microscope
* Particle Size Analyser
* Spray Drier
* Ball Mill
* Filter Press

CTI offers services for characterisation and Testing of Ceramic raw materials and products, equipment selection etc. CTI also has pilot plant facility.
4.2.2 Sectorwise breakup of this advanced ceramics market is presented below:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Market (US $ Billion)</th>
<th>Share Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics</td>
<td>10.00</td>
<td>70</td>
</tr>
<tr>
<td>Structural</td>
<td>2.50</td>
<td>18</td>
</tr>
<tr>
<td>Coatings</td>
<td>1.70</td>
<td>12</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>14.20</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Report on Advanced Ceramics by Kline and Co., USA.

4.2.3 Regionwise break up of advanced ceramics market is as shown below:

- Japan - 57%
- USA - 31%
- Rest of the world - 12%

4.2.4 Electronics is the single largest market for ceramic products. The use of ceramics in electronics is well established and represents a technologically mature market. The applicationwise break-up of Electronic ceramics market is depicted in the following table 4.2.

<table>
<thead>
<tr>
<th>Application</th>
<th>Market (US $ Billion)</th>
<th>Share Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip carriers</td>
<td>2.50</td>
<td>25</td>
</tr>
<tr>
<td>Capacitors</td>
<td>2.50</td>
<td>25</td>
</tr>
<tr>
<td>Ferrites</td>
<td>2.00</td>
<td>20</td>
</tr>
<tr>
<td>Piezoelectrics</td>
<td>1.25</td>
<td>13</td>
</tr>
<tr>
<td>Resistors</td>
<td>1.00</td>
<td>10</td>
</tr>
<tr>
<td>Others</td>
<td>0.75</td>
<td>8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>10.00</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Report on Advanced Ceramics by Kline and Co., USA.

21
B. Engineering And High Temperature Ceramics

1. Alumina Ceramics

Alumina ceramics find a number of applications in the fields of engineering and electronics because of high mechanical strength, refractoriness, chemical resistance and excellent electrical properties. The institute has developed four compositions of alumina ceramics to cover the entire range of applications, in engineering and electronics industries as well as in nuclear technology.

2. Partially stabilized Zirconia(PSZ) and Transformation Toughened Alumina(TTA)

A major time targeted programme has been taken up at the institute to produce PSZ and TTA and Plasma coating of the oxides on metal substrates to achieve dense microstructure at relatively low sintering temperatures. The programme aims at development of an internationally competitive technology package with adequate engineering back-up.

3. Glass Ceramic Coatings on Metal Substrates

The institute has made a significant contribution in the area of engineering materials by developing glass-ceramic coatings on metal substrates such as nimonic alloys, stainless steel, mild steel, etc. Such coatings possess much superior properties as compared to conventional vitreous enamels. They are being produced at the institute for application on aeroengine parts for protection against excessive heat and chemical corrosion. Glass-ceramic coated mild steel components can be used as textile thread guides, heat exchangers, engine exhausts and various other engineering and domestic products where high resistance to abrasion, chemical corrosion and thermal shock is required.

4. Non-Oxide Ceramics

Non-oxide ceramics like reaction bonded silicon nitride and nitride bonded silicon carbide are used as refractory materials in non-ferrous and ferrous metallurgy as well as for producing various items for engineering applications. The Institute Developed Reaction Bonded Silicon Nitride(RBSN) for use in non-ferrous metallurgy and also for producing various engineering items like welding nozzles, pump seals etc.

5. Synthetic High Alumina Aggregates

Synthetic high alumina aggregates in various shapes are used in iron and steel, cement, glass and other industries and the present requirement of the country is met through import. The institute has developed a new technique to produce such aggregates and the related products. The process has been transferred to the industry.

6. Low-moisture Castables

Low-moisture castable refractories have a number of advantages over the conventional castables in respect of high temperature pergormance, loss of strength at intermediate temperature and application in critical areas. The institute has developed an innovative process for manufacturing low-moisture castable containing 45-50% alumina. The castables are suitable for use in blast furnace trough, re-heating furnace, blow pipes, laddles, burners etc. of iron and steel industry. The process has been transferred to the industry.

7. High density Dolomite Sinters

Tar/pitch bonded dolomite sinters are used at the wearling in LD converters. The institute has developed an innovative technology for production of dolomite sinters having densities (3.35gm/cc) which could not be achieved earlier commercially. The process has been released to the industry.
4.2.8 These future demand projections for advanced ceramics are based on the current pattern of its use in various applications. It does not take into account the probable impact of certain likely futuristic applications, which many researchers and scientists are trying to develop. If they succeed in surmounting the technical barriers, it will open up new avenues for advanced ceramics, especially in structural application areas.

4.3.0 INDIAN SCENARIO

4.3.1 The market for advanced ceramic products in India is quite marginal in comparison to the extent to which it has grown in the advanced countries. There are several factors which have hindered the growth of this market in India. Among these factors, most important ones are:

* Indigenous non-availability of such Hi-Tech ceramic products.
* User’s non-awareness about benefits of Hi-Tech ceramics.
* Higher cost of Hi-Tech ceramics.

4.3.2 Even in the sectors, where advanced ceramics have entered, the penetration is very little. Producers manufacture very small quantities since demand is low. This leads to very high cost of manufacture. The user’s on the other hand, do not change over to the new materials since costs are high and availability is not assured.

4.3.3 In India, at present, the use of advanced ceramics is mainly in the electronics sector. Though, the demand for ceramic components required by this sector is quite large, indigenous manufacturers have not taken up manufacture of these items. As a result, these items are imported in large quantities.

4.3.4 The prospects of Hi-Tech ceramics in structural applications seem quite promising. At present, very few Companies in India, are engaged in the manufacture of Hi-Tech ceramics for structural applications.

4.3.5 The current requirements and future demand estimates for various Hi-Tech ceramic products have been estimated as given in the Table 4.5.
5. Boron Carbide powders, Boral composites: Polyboron sheets for use in neutron shielding applications and abrasive material.

**Other Research Institutes**

Several other institutes which are actively conducting R & D work in this area and their major contributions are listed herebelow:

<table>
<thead>
<tr>
<th></th>
<th>Institute Name</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Defence Metallurgical Research Lab., Hyderabad</td>
<td>Hexagonal Boron Nitride, Zirconia &amp; Zirconia based ceramics to meet defence requirements.</td>
</tr>
<tr>
<td>3.</td>
<td>Indian Rare Earth Ltd, Kerala</td>
<td>Lab Scale technology for PSZ manufacture.</td>
</tr>
<tr>
<td>4.</td>
<td>IIT, Bombay</td>
<td>Lab Scale synthesis of Zirconia by Sol-gel technology.</td>
</tr>
</tbody>
</table>

**3.4.0 CONCLUSION**

3.4.1 Penetration by structural ceramics is going to revolutionize almost all sectors of the economy. Increases in productivity and performance will ensure that those who do not adopt these technologies will cease to be competitive. In order to ensure that India is not left behind in this race, certain steps need to be taken. The efforts must be aimed to attain following broad objectives:

- Build research capabilities oriented towards commericialization of R & D efforts.
- Enhance interaction between industry and R & D institutes so as to absorb and commercialize new technologies quickly and competitively.
<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Varistors (Ref. Profile No.4)</td>
<td>6.87 Mln.</td>
<td>3.44 Cr.</td>
<td>9.17 Mln.</td>
<td>4.59 Cr.</td>
<td>14.88 Mln.</td>
<td>7.44 Cr.</td>
</tr>
<tr>
<td>7.</td>
<td>Sensors</td>
<td>Small</td>
<td>Small</td>
<td>Small</td>
<td>Small</td>
<td>Small</td>
<td>Small</td>
</tr>
<tr>
<td><strong>B. Structural Ceramics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Ceramic Engine Components</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
</tr>
<tr>
<td>2.</td>
<td>Spark Plug Cores</td>
<td>12.6 Mln.</td>
<td>10.00 Cr.</td>
<td>17.0 Mln.</td>
<td>13.60 Cr.</td>
<td>22.50 Mln.</td>
<td>18.00 Cr.</td>
</tr>
<tr>
<td>3.</td>
<td>Catalytic Converter (Honeycomb Type)</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
</tr>
<tr>
<td>4.</td>
<td>Ceramic Cutting tool inserts</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td></td>
<td>5.00 Cr.</td>
</tr>
<tr>
<td>5.</td>
<td>Super Abrasives</td>
<td>1300 Tons</td>
<td>10.0 Cr.</td>
<td>1800 Tons</td>
<td>14.0 Cr.</td>
<td>2600 Tons</td>
<td>20.00 Cr.</td>
</tr>
<tr>
<td>6.</td>
<td>Mechanical Seal faces (Ref. Profile No.7)</td>
<td></td>
<td>5.0 Cr.</td>
<td></td>
<td>8.00 Cr.</td>
<td></td>
<td>15.00 Cr.</td>
</tr>
</tbody>
</table>
4.1.0 INTRODUCTION

4.1.1 Many industries have realised the need to develop Hi-Tech Ceramic products for several applications. Some of the applications have huge market potential and considerable success has been achieved in tapping these markets, especially in advanced countries like USA and Japan. Many novel applications of HiTech Ceramics particularly in structural applications have been thought of by researchers and scientists working in this field. In case of its successful materialisation, it will surely bring revolutionary changes in the field of material science and engineering, enhancing its capabilities further. However, in order to realise this dream, many technical barriers need to be surmounted. Also, it is very difficult to conjecture when these barriers are likely to be surmounted. Hence, a reliable long term demand potential is quite difficult to envisage.

4.1.2 Apart from technical barriers, economic limitations also prohibit penetration of HiTech Ceramics in structural applications. Market penetration depends on the relative merits of competing materials, especially cost. In most cases ceramics will compete with existing metals, and hence, market penetration will depend on the trade-off between performance and cost, which will be different for each industry.

4.1.3 In the advanced countries like USA, Japan and West European Countries, ceramic materials are being used for wide range of structural applications. The market for advanced structural ceramics is growing at tremendous pace in these countries.

4.1.4 Demand for advanced ceramic structural products in India is quite marginal in comparison to demand in advanced countries. Even the most common applications of advanced structural ceramics in these countries are yet to enter the Indian market. The market for such Hi-Tech Ceramic products is still in infant stage of development. The reasons that can be attributed for this situation are:

* Lack of awareness
* High cost of development
* Non-availability of relevant technologies, indigenously.

All these factors have stunted the market growth. However, recently, an interest has been generated in the country. Many industrial units, which were traditionally manufacturing abrasives, grinding wheels, refractories and other engineering components have made plans to diversify in this area thinking it to be a logical extension to their existing business.

4.1.5 An attempt has been made here to estimate the potential demand for various HiTech Ceramic products. However, these demand estimates (for most of the products) are just indicative as it is difficult to get correct market information as most of products covered under this study are in the developmental stage.

4.2.0 INTERNATIONAL SCENARIO

4.2.1 Among the markets for advanced Materials, Advanced Ceramics constitute the most important segment. Kline and Company, has estimated the world advanced materials market to be US $23 billion in 1989. Of this, advanced ceramics form US $14 billion or approximately 61% of the market for advanced materials.
Table 4.6
Demand Estimates: Hi-Tech Ceramic Powder

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Volume</td>
<td>Value</td>
<td>Volume</td>
<td>Value</td>
</tr>
<tr>
<td>1.</td>
<td>Alumina</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Electro-ceramic</td>
<td>17.0 Tons</td>
<td>0.65 Cr.</td>
<td>59.0 Tons</td>
<td>4.3 Cr.</td>
</tr>
<tr>
<td></td>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Spark Plug Grade</td>
<td>630 Tons</td>
<td>3.80 Cr.</td>
<td>850 Tons</td>
<td>5.10 Cr.</td>
</tr>
<tr>
<td></td>
<td>- Structural Grade</td>
<td>2800 Tons</td>
<td>16.80 Cr.</td>
<td>4565 Tons</td>
<td>27.40 Cr.</td>
</tr>
<tr>
<td>2.</td>
<td>Barium Titanate</td>
<td>60 Tons</td>
<td>1.2 Cr.</td>
<td>400 Tons</td>
<td>8.00 Cr.</td>
</tr>
<tr>
<td>3.</td>
<td>Silicon Carbide</td>
<td>2000 Tons</td>
<td>30.0 Cr.</td>
<td>4000 Tons</td>
<td>60.0 Cr.</td>
</tr>
<tr>
<td>(Structural applications)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Silicon Nitride</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

4.3.6 Demand Summary

The market for various application area would be as under:

<table>
<thead>
<tr>
<th>Product Group</th>
<th>Current</th>
<th>Year (Value in Rs. Crores) 1994-95</th>
<th>1999-2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electro-Ceramics</td>
<td>169 (59%)</td>
<td>424 (60%)</td>
<td>1358 (78%)</td>
</tr>
<tr>
<td>Structural Ceramics</td>
<td>118 (41%)</td>
<td>191 (31%)</td>
<td>378 (22%)</td>
</tr>
<tr>
<td>Total</td>
<td>287 (100%)</td>
<td>615 (100%)</td>
<td>1736 (100%)</td>
</tr>
</tbody>
</table>
4.2.5 The use of ceramics in structural applications is quite limited because they are still at a fairly nascent stage of development. However, this sector holds promising future for advanced ceramic materials. To realise this, several technical barriers need to be surmounted.

*Table 4.*

**World Market For Structural Ceramics (1989)**

<table>
<thead>
<tr>
<th>Application Area</th>
<th>Market US $ Billion</th>
<th>Share Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>1500</td>
<td>60</td>
</tr>
<tr>
<td>Industrial</td>
<td>625</td>
<td>25</td>
</tr>
<tr>
<td>Aerospace</td>
<td>250</td>
<td>10</td>
</tr>
<tr>
<td>Others</td>
<td>125</td>
<td>5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2500</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Report on Advanced Ceramics by Kline and Co., USA.

4.2.6 The world market for coatings is divided as depicted in Table 4.4.

*Table 4.*

**World Market For Ceramics Coatings (1989)**

<table>
<thead>
<tr>
<th>Types</th>
<th>Market US $ Billion</th>
<th>Share Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxides</td>
<td>870</td>
<td>51</td>
</tr>
<tr>
<td>Carbides</td>
<td>320</td>
<td>19</td>
</tr>
<tr>
<td>Nitrides</td>
<td>119</td>
<td>7</td>
</tr>
<tr>
<td>Others</td>
<td>390</td>
<td>23</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1700</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Report on Advanced Ceramics by Kline and Co., USA.

The probability of ceramic coatings penetrating the market is quite high compared to parts made out of monolithic structural ceramics. Physical and Chemical vapour deposition, sol-gel coatings, plasma coatings and laser coatings are all likely to be important, though chemical vapour deposition is the most common technique in use today.

4.2.7 The world market for Advanced Ceramics is likely to go up to US $30 billion by 2000 A.D. of which, the market for structural ceramics and coating will be US $3.8 billion respectively.
* Bayer process
* Thermal decomposition of ammonium alum
* Treatment of aluminium flakes by electric powder discharge in water.

5.2.3 Bauxite is the chief source of alumina. The Bayer process is the most widely used for production of alumina from bauxite.

5.2.4 Manufacture of Alumina

Description of the Process:
The ore bauxite is refined by Bayer process to obtain Alumina.
The reactions involved are:
\[ \text{Al(OH)}_3 + \text{NaOH} \rightarrow \text{NaAlO}_2 + 2\text{H}_2\text{O} \]
\[ \text{AlO(OH)} + \text{NaOH} \rightarrow \text{NaAlO}_2 + \text{H}_2\text{O} \]
Following are the operations that are performed.
* Dissolution of the alumina at high temperature.
* Separation and washing of the insoluble impurities of bauxite (red muds) to recover the soluble alumina and caustic soda.
* Partial hydrolysis of sodium aluminate at a lower temperature to precipitate aluminium trihydroxide.
* Regeneration of the solutions for recycle to step (1) by evaporation of the water introduced by washing.
* Transformation of the trihydroxide to anhydrous alumina by calcination at 1450 K.

Dissolution of Alumina by Digestion with Caustic Soda

Gibbsite, \( \text{Al(OH)}_3 \) (hydrargillite; alumina trihydrate) is the most economical to process due to its high solubility in Bayer process liquor at a moderate temperature and pressure. Liquor containing 120-135 g/L \( \text{Na}_2\text{O} \) is used at about 140°C. Bochmite (\( \text{AlO(OH)} \)) and diasporic (\( \text{AlO(OH)} \)) are the principal minerals in monohydrate bauxite while other commonly associated minerals are also found like haematite, goethite, siderite, ilmenite, brookite, etc. The highest extraction conditions are set like for example Bochmitic bauxite requires 200 to 250°C and pressure of 34 atm.

Digestions are performed in steel autoclaves or in tubular reactors. Heat exchangers recover much of the heat content of liquor leaving the reactor to heat liquor entering it.

Separation, Washing and Disposition of the Residues

The insoluble residues that are left out after digestion are known as red mud. The muds may have a very fine particle size (sometimes less than 1 μm). Hence, they are difficult to separate and wash. These operations are performed by continuous counter current decantation, the dilute wash liquors being combined with the more concentrated pregnant liquors.

The washed red mud is then disposed by lagooning. Approximately one square km of lagoon area is required for a plant processing 3.3 Mt. of bauxite per year.

Precipitation of Aluminium Trihydroxide

After a final filtration to remove the last traces of insoluble mud, the liquors have a \( \text{Na}_2\text{O}:\text{Al}_2\text{O}_3 \) molar ratio between 1.5 and 1.8.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Volume (Nos.)</td>
<td>Value (Rs.Crore)</td>
<td>Volume (Nos.)</td>
</tr>
<tr>
<td>1.</td>
<td>Electro Ceramics</td>
<td>3.</td>
<td>4.</td>
<td>5.</td>
</tr>
<tr>
<td>1.</td>
<td>Ceramic Capacitors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Disc type</td>
<td>530 Million</td>
<td>53.0 Crore</td>
<td>900 Million</td>
</tr>
<tr>
<td></td>
<td>* Multilayer type (MLC)</td>
<td>120 Million</td>
<td>18.0 Crore</td>
<td>800 Million</td>
</tr>
<tr>
<td></td>
<td>(Ref.Profile No.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Substrates for IC Chip Carriers and Hybrid Circuits (Ref. Profile No.2)</td>
<td>16.88 Mln.</td>
<td>17.00 Cr.</td>
<td>59.00 Mln.</td>
</tr>
<tr>
<td>3.</td>
<td>Ferrites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Hard Ferrites</td>
<td>3825 Tons</td>
<td>19.10 Cr.</td>
<td>6200 Tons</td>
</tr>
<tr>
<td></td>
<td>* Soft Ferrites</td>
<td>3250 Tons</td>
<td>32.5 Cr.</td>
<td>5400 Tons</td>
</tr>
<tr>
<td></td>
<td>(Ref. Profile No.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Piezo-Electrics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Single Crystal</td>
<td>15.00 Mln.</td>
<td>9.90 Cr.</td>
<td>26.0 Mln.</td>
</tr>
<tr>
<td></td>
<td>* Polycrystalline</td>
<td>13.00 Mln.</td>
<td>8.30 Cr.</td>
<td>20.0 Mln.</td>
</tr>
<tr>
<td>5.</td>
<td>Thermisters (PTC/NTC)</td>
<td>4.58 Mln.</td>
<td>2.29 Cr.</td>
<td>6.53 Mln.</td>
</tr>
<tr>
<td></td>
<td>(Ref. Profile No.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Currently usage of MLC is quite limited due to its non-availability. It is envisaged that it will largely replace ceramic disc capacitors as it offers ultimate convenience for surface mounted technology & automatic assembly process. It is expected that it will attain 50% and 75% penetration in the total ceramic capacitors market by 1994-95 & 1999-2000 respectively. Substantial demand-supply gap is envisaged.

40% share of ceramic carriers have been envisaged in various types of carriers used for IC packaging. Substantial demand-supply gap is envisaged.

Consistently growing market for both Hard and Soft Ferrites. Substantial demand-supply gap is envisaged for soft ferrites.

Consistently growing market for both Single Crystal and Polycrystalline Piezo-Electrics. Substantial demand-supply gaps exist for single crystal devices for wrist watches and PZT ceramic filters & delay lines.

Market is growing consistently. However, future demand-supply gap is envisaged to be very marginal.
FLOW SHEET OF THE BAYER PROCESS

Bauxite

NaOH or Na₂CO₃
Lime (if used)

Grinding

Mixing

Preheating

Solution of Alumina by attack under pressure

Evaporation

Heat Exchange

Precipitation of Al(OH)₃

Al(OH)₃ Seeding

Recovered steam

Expansion

Dilution

Separation of Red muds

Final filtering

Washing of Red muds

Wash Water

Calcination

Wash water

Calcined chemical alumina

Red muds to waste

NaOH solution Return

Gas or fuel
<table>
<thead>
<tr>
<th></th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
<th>8.</th>
<th>9.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Domestic Tap Cartridges (Ref. Profile No.7)</td>
<td>35,000 Nos.</td>
<td>3.15 Cr.</td>
<td>60,480 Nos.</td>
<td>3.0 Cr.</td>
<td>150,500 Nos.</td>
<td>7.50 Cr.</td>
<td>The growth including substitution of dual knob taps is estimated to be 20%. The impact of price reduction (if manufactured locally) on market penetration is likely to be significant.</td>
</tr>
<tr>
<td>8</td>
<td>Ceramic Bearings</td>
<td>NIL</td>
<td>NIL</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Ceramic bearings are unlikely to find application even by 2010 AD. Use is likely to be limited to defence or aerospace.</td>
</tr>
<tr>
<td>9</td>
<td>Textile Thread Guides (Ref. Profile No.6)</td>
<td>100 Tons</td>
<td>10.0 Cr.</td>
<td>200 Tons</td>
<td>20.0 Cr.</td>
<td>400 Tons</td>
<td>40.00 Cr.</td>
<td>Good replacement market. Market is expected to grow consistently because of good prospects for textile machinery and increased penetration of ceramics.</td>
</tr>
<tr>
<td>10</td>
<td>Ceramic Nozzles (Ref. Profile No.5)</td>
<td>-</td>
<td>1.40 Cr.</td>
<td>-</td>
<td>3.0 Cr.</td>
<td>-</td>
<td>7.40 Cr.</td>
<td>Ceramic nozzles have started penetrating tungsten carbide nozzle market used for and shot blasting equipment and welding equipments. 65% penetration is envisaged by 2000 AD.</td>
</tr>
<tr>
<td>11</td>
<td>Grinding Media (Ref. Profile No.5)</td>
<td>150 Tons</td>
<td>1.50 Cr.</td>
<td>260 Tons</td>
<td>2.60 Cr.</td>
<td>650 Tons</td>
<td>6.50 Cr.</td>
<td>Market for white cement is creating a good market for ceramic grinding media. Substantial demand-supply gap is envisaged in future.</td>
</tr>
<tr>
<td>12</td>
<td>Material handling ceramic liners (Ref. Profile No.9)</td>
<td>1000 Tons</td>
<td>10.0 Cr.</td>
<td>2100 Tons</td>
<td>21.0 Cr.</td>
<td>3900 Tons</td>
<td>39.00 Cr.</td>
<td>Potential demand for material handling liners is in power, steel, cement and coal sector. Ceramic liners will become more popular in the coming years.</td>
</tr>
<tr>
<td>13</td>
<td>Special Refractories (made from synthetic ceramic powders) (Ref. Profile No.9)</td>
<td>9000 Tons</td>
<td>59.0 Cr.</td>
<td>14,000 Tons</td>
<td>92.0 Cr.</td>
<td>30,000 Tons</td>
<td>195.00 Cr.</td>
<td>The growth of this sector is likely to be high as: * Existing steel plants are modernising their plants * Growth of private sector * Mini-steel plants.</td>
</tr>
<tr>
<td>14</td>
<td>Coatings</td>
<td>-</td>
<td>8.0 Cr.</td>
<td>-</td>
<td>14.0 Cr.</td>
<td>-</td>
<td>25.00 Cr.</td>
<td>Increased penetration envisaged in certain applications like gas turbines, aerospace and textile machinery.</td>
</tr>
</tbody>
</table>

**SUB-TOTAL (B)**

<p>| | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>118.00 Cr.</td>
<td>191.00 Cr.</td>
<td>378.00 Cr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL (A + B)**

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>287.00 Cr.</td>
<td>615.00 Cr.</td>
<td>1736.00 Cr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
VARIOUS GRADES OF ALUMINA POWDERS FROM BAXRITE

Abrasive Calcined Grade Bauxite

Refractory Grade

Calcined $\text{Al}_2\text{O}_3$ metal grade

Aluminium Hydroxide Chemicals

$\text{Al}_2\text{O}_3$ gel

$\alpha$-Trihydrate

$\beta$-Trihydrate

$\alpha$-Monohydrate

Bayer Process

Calcined $\text{Al}_2\text{O}_3$ Specials

Calcined $\text{B-Al}_2\text{O}_3$

Calcined $\text{X-Al}_2\text{O}_3$

Sintered Tabular $\text{Al}_2\text{O}_3$

Fused $\text{Al}_2\text{O}_3$

Activated Aluminas
$\text{Al}_2\text{O}_3$ gels Amorphous Transition Aluminas

$\text{r}$

$\text{n}$

$\text{x}$

$\text{f}$

Normal $\text{Na}_2\text{O}$ 0.3-0.6%

Int. $\text{Na}_2\text{O}$ 0.15-0.25%

Low $\text{Na}_2\text{O}$ <0.01% $\text{Na}_2\text{O}$

Extra high purity <0.01% $\text{Na}_2\text{O}$

Reactive

$\text{Al}_2\text{O}_3$
5.1.0 CERAMIC MATERIALS FOR HIGH PERFORMANCE APPLICATIONS

5.1.1 Major ceramic materials used in high performance applications are based on:
- Alumina
- Zirconia
- Beryllia
- Ferrites
- Titanates
- Mixed Oxides
- Silicon Carbide
- Silicon Nitride and Sialons

5.1.2 The properties of several important advanced ceramic materials are depicted in Table 5.1.

Table 5.1

Properties of Several Advanced Structural Ceramic Materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>Melting Point (°C)</th>
<th>Density (gm/CM^3)</th>
<th>Modulus of Elasticity (MPa)</th>
<th>Fracture Toughness (MPa m 1/2)</th>
<th>Bond strength (MPa)</th>
<th>Vickers Hardness (GPa)</th>
<th>Co-efficient of Thermal Expansion (1/k x 106)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumina</td>
<td>2050</td>
<td>3.95</td>
<td>300-370</td>
<td>3-4.5</td>
<td>350-580</td>
<td>16-17</td>
<td>8.1</td>
</tr>
<tr>
<td>Zirconia (TZP)</td>
<td>2500-2600</td>
<td>5.90</td>
<td>200</td>
<td>6-15</td>
<td>900-1000</td>
<td>12</td>
<td>10.5</td>
</tr>
<tr>
<td>Zirconia (PSZ)</td>
<td>2500-2600</td>
<td>6.05</td>
<td>200</td>
<td>6-12</td>
<td>900-1000</td>
<td>11</td>
<td>10.5</td>
</tr>
<tr>
<td>Cordierite</td>
<td>1.5-2.0</td>
<td>130</td>
<td>1.5-2.5</td>
<td>100-200</td>
<td>8</td>
<td></td>
<td>0.8-1.2</td>
</tr>
<tr>
<td>(Porous)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiC*</td>
<td>2300-2500</td>
<td>3.17</td>
<td>420</td>
<td>4</td>
<td>450-520</td>
<td>20</td>
<td>4.3</td>
</tr>
<tr>
<td>RBSN*</td>
<td>1750-1900</td>
<td>2.60</td>
<td>150</td>
<td>2.5-3.5</td>
<td>200-300</td>
<td>5-7</td>
<td>3.0</td>
</tr>
<tr>
<td>Si3N4(Dense)*</td>
<td>1750-1900</td>
<td>3.20</td>
<td>230</td>
<td>6</td>
<td>500-600</td>
<td>15</td>
<td>3.3</td>
</tr>
<tr>
<td>Aluminium Titanate*</td>
<td>1860</td>
<td>3.20</td>
<td>20</td>
<td>40</td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
</tbody>
</table>

* Decomposition Temperature

5.2.0 ALUMINA

5.2.1 Alumina is one of most widely used ceramic material. Many different aluminas are used in a myriad of applications. Apart from the its use in structural applications such as cutting tools, nozzles and mechanical seals, it is widely used in electronics as chip carriers for housing ICs and in hybrid microcircuit mother boards. Spark plugs are another major items consuming alumina. Translucent aluminas are used for cover glasses for gas discharge lamps. Alumina is also used in prosthesis devices. Various grades of alumina powders are available and their prices differ, depending upon the purity and the applications they are subjected to.

5.2.2 The alumina powder for advanced ceramic applications is manufactured using one of the following four process:
These requirements are standardized and practised by end-users (especially ceramic parts manufacturers).

5.2.5 In India, commercially available alumina is manufactured by calcination of aluminium trihydrate obtained in the Bayer process. This contains impurities of Silica, ferric oxide, sodium oxide etc. The maximum purity achieved is 99.5%.

Indian Aluminium Company (INDAL), makes two grades of alumina powder ~ SRM 30 (Particle Size between 3-5 μm) and C-grade (particle size ~ 43 μm). These grades are mainly used by refractory and abrasive manufacturers. INDAL also makes reactive grade alumina for structural applications. However, they do not meet all the requirements structural applications.

National aluminium company has recently announced intended production of alumina for spark plugs, electronics etc.

M/s. Thermo Chemical Industry, Junagadh has developed laboratory scale technology to produce High Purity Calcined Alumina by Sol-Gel method. They have achieved purity above 99.97+% with controlled particle size. (For details, refer Appendix-4).

5.2.6 Bayer alumina is bought by abrasives manufacturers in the country and further processed for use in the abrasives industry. The companies involved in the production of abrasive grade alumina are:

<table>
<thead>
<tr>
<th></th>
<th>Capacity (TPA)</th>
<th>Production (TPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orient Abrasives</td>
<td>18,000</td>
<td>14,000</td>
</tr>
<tr>
<td>Carborandum Universal</td>
<td>8,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Cut Fast Abrasives</td>
<td>1,500</td>
<td>1,200</td>
</tr>
<tr>
<td>Grindwell Norton</td>
<td>5,000</td>
<td>3,000</td>
</tr>
</tbody>
</table>

5.2.7 Tubular alumina is imported mainly from Alcoa. The current import of tabular alumina is about 1000 TPA.

5.2.8 M/s. Reynolds Metal Corp., M/s. Kaiser Chemicals, M/s. Alcoa, La Roche Chemical Inc., Fusion Ceramics Inc., in the US, and Toshiba Corp in Japan are some of the major producers of tabular alumina.

5.2.9 The prevailing prices of various grades of alumina are follows:

<table>
<thead>
<tr>
<th>Grades</th>
<th>Prices (Rs./Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallurgical</td>
<td>8,000</td>
</tr>
<tr>
<td>Refractory</td>
<td>15,000-20,000</td>
</tr>
<tr>
<td>Tabular</td>
<td>US $ 1750</td>
</tr>
<tr>
<td></td>
<td>(Rs. 52,500 without duty)</td>
</tr>
<tr>
<td></td>
<td>(Rs. 1,23,500 with 135% duty)</td>
</tr>
</tbody>
</table>
The filtered liquors are cooled to between 47 and 62°C preparatory to precipitation of 50% of their alumina content. Precipitation requires hydrolysis of ions AlO₂⁻ to yield aluminium trihydroxide.

\[ \text{AlO}_2^- + 2\text{H}_2\text{O} \rightarrow \text{Al(OH)}_3 + \text{OH}^- \]

To carry out precipitation on an industrial scale, aluminate liquor is seeded with the fines elutriated from previously precipitated crystals (up to 4 times the amount in solution) and the mixture is agitated. The seed grows to crystal agglomerates that are easy to separate and wash. This precipitation requires 20-80h retention in large steel agitating tanks.

**Evaporation**

The circulating aluminate solution, diluted by the water used to wash the muds prior to precipitation is reconcentrated to its initial concentration in large multi-stage evaporation equipment.

**Calcination**

The aluminium trihydroxide from precipitation is filtered and washed in rotary filters. These filters feed large rotary kilns or fluid-bed calciners where the alumina is heated to 1100-1200°C. During heating, the trihydroxide undergoes a series of changes in composition and crystalline structure with essentially no change in particle shape. The product is a white powder consisting of aggregates whose size ranges from 20 to 200 μm.

The properties like loss on ignition, moisture, particle size distribution, surface area are variable and depend on reduction plant operating techniques, handling equipment, etc.

The particle size of the unground calcined Bayer aluminas is primarily controlled during precipitation because very little particle shrinkage occurs even though water is lost from the gibbsite structure. The resulting unground porous agglomerates of alumina crystals are nominally 100-325 mesh. Although calcined alumina grades may appear to be very similar macroscopically, the scanning electron microscope differentiates the surfaces of the unground Bayer agglomerates which can have ultimate crystals controlled to a median diameter as fine as 0.5 μm and as large as 15 μm.

Special Bayer calcined aluminas can be broadly categorized according to sodium content in addition to crystal size. Besides the normal soda products, special grades are made at the intermediate (0.15 - 0.25% Na₂O) and low (<0.1% Na₂O) soda levels. Extra-high purity 0.5 μm calcined, typically 99.95% Al₂O₃ with less than 0.01%Na₂O, are also available.

The large production of metal grade alumina enables economic production of special ceramic grade and other aluminas from the Bayer process.

**Ground Calcined Aluminas**

Most ceramic grade aluminas are supplied dry ground to about 95% - 325 mesh, using 85-90% Al₂O₃ ceramic ball, cibratory, or fluid energy milling. The +44 μm particles can be removed by air classification to produce 99+-%-325 mesh product. Severe mill packing problems may occur when dry ball milling aluminas having submicron crystals finer than 325 mesh. Mill packing may be avoided by wet grinding, however, contamination of the ground product becomes excessive when using 85% Al₂O₃ grinding ball because the wear rate runs about twenty times higher than in dry grinding. Commercialisation of 99.8% Al₂O₃ grinding media permits ball wear contamination to be minimized, but mill linings have yet to be upgraded to compensate for the increased wear associated with the use of these higher density +99.8% Al₂O₃ media.
These requirements are standardized and practised by end-users (especially ceramic parts manufacturers).

5.2.5 In India, commercially available alumina is manufactured by calcination of aluminium trihydrate obtained in the Bayer process. This contains impurities of Silica, ferric oxide, sodium oxide etc. The maximum purity achieved is 99.5%.

Indian Aluminium Company (INDAL), makes two grades of alumina powder — SRM 30 (Particle Size between 3-5 μm) and C-grade (particle size — 43 μm). These grades are mainly used by refractory and abrasive manufacturers. INDAL also makes reactive grade alumina for structural applications. However, they do not meet all the requirements structural applications.

National aluminium company has recently announced intended production of alumina for spark plugs, electronics etc.

M/s. Thermo Chemical Industry, Junagadh has developed laboratory scale technology to produce High Purity Calcined Alumina by Sol-Gel method. They have achieved purity above 99.97% with controlled particle size. (For details, refer Appendix-4).

5.2.6 Bayer alumina is bought by abrasives manufacturers in the country and further processed for use in the abrasives industry. The companies involved in the production of abrasive grade alumina are:

<table>
<thead>
<tr>
<th></th>
<th>Capacity (TPA)</th>
<th>Production (TPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orient Abrasives</td>
<td>18,000</td>
<td>14,000</td>
</tr>
<tr>
<td>Carborandum Universal</td>
<td>8,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Cut Fast Abrasives</td>
<td>1,500</td>
<td>1,200</td>
</tr>
<tr>
<td>Grindwell Norton</td>
<td>5,000</td>
<td>3,000</td>
</tr>
</tbody>
</table>

5.2.7 Tubular alumina is imported mainly from Alcoa. The current import of tabular alumina is about 1000 TPA.

5.2.8 M/s. Reynolds Metal Corp., M/s. Kaiser Chemicals, M/s. Alcoa, La Roche Chemical Inc., Fusion Ceramics Inc., in the US, and Toshiba Corp in Japan are some of the major producers of tabular alumina.

5.2.9 The prevailing prices of various grades of alumina are follows:

<table>
<thead>
<tr>
<th>Grades</th>
<th>Prices (Rs./Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallurgical</td>
<td>8,000</td>
</tr>
<tr>
<td>Refractory</td>
<td>15,000-20,000</td>
</tr>
<tr>
<td>Tabular</td>
<td>US $ 1750</td>
</tr>
<tr>
<td></td>
<td>(Rs.52,500 without duty)</td>
</tr>
<tr>
<td></td>
<td>(Rs.1,23,500 with 135% duty)</td>
</tr>
</tbody>
</table>
Reactive Aluminas

Thermally reactive aluminas were developed when dry grinding aids permitted products containing submicron crystals to be dry ball milled to their ultimate crystals or superground. The grinding aids sorb on the surface of the alumina, prevent mill packing and reduce the energy required to separate the individual crystals from the Bayer agglomerates mill packing tendencies decrease with increasing mill size and ball to charge ratio.

Reactive aluminas enabled 85,90 and 95% Al₂O₃ ceramics to be upgraded to the higher alumina content with improved mechanical, thermal and electronic properties because they could be sintered without fluxes in the temperature range of about 1450-1750°C, rather than 1800-1850°C. Advances in microminiaturization of components for the electronic computer and aerospace industries have been directly related to the development of low soda and reactive aluminas.

Sintered Alumina (Tabular Alumina)

Sintered Alumina (Tabular Alumina) contains large, typically 50-300 µm, tablet like crystals of α-Al₂O₃. Processing is quite similar to that required for making sintered Al₂O₃ ceramics. Ground calcined alumina is shaped by agglomeration, extrusion, or pressing, sometimes with the aid of organic binders. The pieces are compacted and recrystallized upon sintering at 1600-1850°C. The 3.40-3.60t/m³ bulk specific gravity product (99.5% Al₂O₃) exhibits closed spherical porosity typical of a fully sintered ceramic with secondary recrystallisation. Typical impurities include about 0.05% SiO₂, 0.05% Fe₂O₃, and less than 0.1-0.25% Na₂O.

Tabular aluminas are available in ball sizes to about 2 cm diameter and in crushed and graded sizes from a top size of about 1.3 cm to -325 mesh. Extensive magnetic separation is required to remove iron from the crushed grains to minimize discoloring in ceramic and refractory products.

Fused Alumina

Fused alumina comes in two varieties: the large tonnage, brown alumina, is made by fusing calcined abrasive grade bauxite; fusing calcined Bayer hydrate give a higher quality white alumina. Considerable energy is required to fuse alumina: 2750-4400KWH/Ton of brown Al₂O₃ and 1350-1900 KWH/Ton for white product. Besides white, pink, red and ruby fused alumina abrasive grains, calcined alumina is used in the production of alumina-silica fibres and hollow Al₂O₃ spheres made by pouring white fused Al₂O₃ into a jet stream of air or steam, white fused mullite for refractory grain and fused cast refractories, Crushed brown and white fused alumina are also used as refractory grains.

Abrasive - grade calcined alumina (less than 1 µm) having a slight water sorptive capacity of about 1% gives excellent fusion characteristics when melting in large electric-arc resistance furnaces using graphite electrodes. The furnace comprises a cylindrical steel shell cooled by water so that a peripheral layer of unmelted alumina is maintained to serve as refractory lining. New ore is charged as the melt grows and serves as an insulating cover to reduce radiation losses. Charging, melting and cooling takes several tens of hours to produce ingots as large as 10 t. A 1.5-2 ton steel ball is dropped on the cooled ingot to reduce the pig to small pieces which can be handled initially by jaw and gyratory crushers. Roll, gyratory and/or other types of crushers are used to produce grain of desired grit sizes.

Grey discoloration of the white fused ingot increases with harder burned/low sorptive capacity aluminas. Furnaces operation with softer burned aluminas becomes erratic with excessive dusting because of agitation caused by volatilization of the sorbed water. Controlled water and fluoride additions are claimed to improve whiteness.
5.3.6 The current prices of Zircon sand in the international market is about 400$ per ton.

5.3.7 IREL and Bhalla Chemical Works are the two producers of Zirconia. The current production of Zirconia by these two parties is about 25 TPA, which is used for production of high value pottery and sanitary ware. Zirconia of high purity (99.8% pure) is also produced by Nuclear Fuels Complex in small quantities for the production of Zirconium tubes. Also, small quantities of 99.8% pure Zirconia are produced for electronic applications. Partially Stabilised Zirconia is entirely imported. The import of PSZ is about 25-30 TPA. Total import of Zirconia used in ceramics and refractories would be about 60-70 TPA. The current international prices of PSZ ranges between $ 22-25 per kg. (Rs.1550-1760/kg including 135% Duty).

5.3.8 BARC, IREL has developed lab scale technology for the production of PSZ.

5.3.9 Inadequate pilot plant facilities and very low demand have been stated to be the major hindrances in scaling up the technology available indigenously.

5.4.0 BERRYLLIA

5.4.1 Beryllia is an unique ceramic material having high electrical resistivity, thermal conductivity and high heat stress resistance. It is transparent to microwave radiation and immune to nuclear radiation. Its uses are many, such as: Electron tubes, resistor cores, transistor mountings, high temperature reactor systems, additives to glass, ceramics and plastics, etc.

5.5.0 FERITES

5.5.1 Certain classes of ceramic materials normally termed ferrites, exhibit unusual magnetic properties due to particular nature of their crystal structure. All ferrites have Iron Oxide(Fe₂O₃), as a major constituent. They are combined with oxides of divalent metals like zinc, manganese, nickel, barium, strontium, etc., to produce crystal structures which have magnetic properties. Depending on the nature of their behaviour, magnetic materials are termed hard or soft. Hard ferrites retain their magnetism once they are magnetised (it is hard to demagnetise them). Soft ferrites are easily magnetised and demagnetised. Barium ferrites and strontium ferrites are hard, while manganese zinc ferrites and nickel zinc ferrites are soft.

5.5.2 Soft ferrites have lower eddy current losses and higher resistances as compared to more traditional soft magnetic materials, such as transformer steels. This makes them useful in applications where magnetic fields have to be switched on and off very fast.

5.5.3 Hard ferrites though having inferior properties to traditional permanent magnetic materials like ALNICO and Cobalt Samarium magnets are much cheaper and are therefore widely used.

5.5.4 Inconsistency in quality of indigenous raw material especially mined ferric oxide is a major problem even for comparatively low grade requirement of hard ferrites. In respect of raw materials for soft ferrites requiring better grades of raw materials, higher percentage of impurities like silica and alumina is causing serious concern. Concentrated efforts are being undertaken at ACRE, IIT and manufacturing units for total development of ferric oxide for existing product range and higher grade applications.

5.6.0 BARIUM TITANATE (BaTiO₃)

5.6.1 Barium Tinate is known for its high dielectric constant, piezoelectric and ferro electric properties. Barium Titanate exists in many crystalline forms each of which is stable over a particular range of temperatures. The tetragonal form which exhibits spontaneous electrical polarisation is piezoelectric. Above 130°C, barium titanate has cubic structure and paraelectric.
White fused grains normally exceeds 99% Al₂O₃. The crushed and ground grits are not only magnetically separated, but are often acidwashed. A typical composition is 99.53% 0.33% Na₂O, 0.10% Fe₂O₃, and 0.03% C. The 0.03-0.05% Na₂O in Bayer alumina primarily forms β-Al₂O₃, concentrated in the centre of large ingots by zone refining of the Na₂O during slow cooling, is segregated from the product after crushing. Some soda is lost to volatilisation. Minute continuous pores formed by vapours as the molten mass solidifies aids friability of the grain and coolness of cut by the abrasive when machining tempered alloys. However, grain without these continuous open pores are preferred for refractory aggregate application requiring good grain strength and low sorption.

The hardness of white fused grain is increased by addition of 0.05-0.03% Cr₂O₃ to form pink and red fused Al₂O₃ abrasives. Brown fused aluminas containing 94-98% Al₂O₃ are produced in the largest tonnages.

Fused-cast refractories production requires a hard burned Bayer alumina calcined to a lower sorptive capacity (less than 0.2% ignition loss) to minimize porosity caused by gases entrapped in the cast fused blocks.

Several other processes has been developed for the production of different grades and qualities of alumina powder. For example very purity, ultra fine powders are produced by Aluminium Isopropoxice route(solution precipitation process). In this process, Aluminium metal is mixed with alcohol(C₃H₇OH). The resultant mix is hydrolysed in a alcohol-water solution to produce suspension of fine oxide particles. The alumina gel is separated by centrifugation. Alumina gel is then calcined to give dried powder. Alumina powder obtained from this process has particle size between 0.3 to 0.6 μm and very high a-alumina content with Na₂O levels well below 0.01 wt%.

The other processes for producing high quality alumina powders having low Na₂O content are Alum process and Itawani process.

The required quality of calcined alumina powder for various applications is described in the following table:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Speciality Application</th>
<th>Particle Size (in μm)</th>
<th>Na₂O content (% wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Electronic Ceramic</td>
<td>0.5 - 5.0</td>
<td>0.02 - 0.10</td>
</tr>
<tr>
<td>2.</td>
<td>Sodium Vapour LamO</td>
<td>&lt; 0.5</td>
<td>0.02 - 0.10</td>
</tr>
<tr>
<td>3.</td>
<td>Mechanical/Structural</td>
<td>0.5 - 5.0</td>
<td>0.02 - 0.40</td>
</tr>
<tr>
<td>4.</td>
<td>Polishing</td>
<td>0.5 - 5.0</td>
<td>0.02 - 0.40</td>
</tr>
<tr>
<td>5.</td>
<td>Fused Abrasives</td>
<td>0.5 - 1.0</td>
<td>0.20 - 0.40</td>
</tr>
<tr>
<td>6.</td>
<td>Ceramic Fibres</td>
<td>0.5 - 1.0</td>
<td>0.20 - 0.40</td>
</tr>
<tr>
<td>7.</td>
<td>Hi-Tech Refractories</td>
<td>0.5 - 3.0</td>
<td>0.1 - 0.25</td>
</tr>
<tr>
<td>8.</td>
<td>Spark Plug Cores</td>
<td>2.5 - 75.0</td>
<td>0.02 - 0.20</td>
</tr>
<tr>
<td>9.</td>
<td>Chinaware</td>
<td>0.5 - 3.0</td>
<td>4.00</td>
</tr>
<tr>
<td>10.</td>
<td>Glass</td>
<td>0.5 - 3.00</td>
<td>4.00</td>
</tr>
<tr>
<td>11.</td>
<td>Refractories</td>
<td>0.5 - 5.00</td>
<td>0.2 - 4.00</td>
</tr>
<tr>
<td>12.</td>
<td>Fused cast Refractories</td>
<td>2.0 - 50.0</td>
<td>&gt; 4.00</td>
</tr>
<tr>
<td>13.</td>
<td>Porcelain Insulators</td>
<td>2.0 - 5.0</td>
<td>0.20 - 4.0</td>
</tr>
</tbody>
</table>
5.7.6 In India, there are two major manufacturers of silicon carbide powder, viz. Carborundum Universal Grindwell Norton, besides couple of other smaller manufacturers. The current installed capacity and production of silicon carbide powder is given below:

<table>
<thead>
<tr>
<th>Company</th>
<th>Installed Capacity (TPA)</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carborundum</td>
<td>5,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Grindwell Norton</td>
<td>10,000</td>
<td>3,500</td>
</tr>
<tr>
<td>Others</td>
<td>NA</td>
<td>1,00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>6,500</strong></td>
</tr>
</tbody>
</table>

5.7.7 Indigenous silicon carbide powder is of 96-98% purity and available in two grades i.e. black and green. Black silicon powders are used for refractories and abrasives for non-ferrous application, while green silicon powders are used for grinding tungsten carbide products.

5.7.8 The current prices of silicon carbide powders are as given below:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Price per Tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black SiC</td>
<td>Rs.40,000-45,000</td>
</tr>
<tr>
<td>Green SiC</td>
<td>Rs.60,000</td>
</tr>
</tbody>
</table>

5.7.9 In India, silicon carbide powders are mainly used for abrasives and refractories. Silicon carbide powder required for other structural applications is generally imported as finer particle sized powders are not available indigenously. Additional milling to achieve fine grain size of silicon carbide for structural application pushes up the cost of powder substantially.

5.7.10 With regard to the production of silicon carbide, India has a raw material advantage in terms of silica as silicon minerals are abundantly available. However, the petroleum coke required for silicon carbide production is not available freely in the country.

5.8.0 SILICON NITRIDES

5.8.1 Silicon nitride is one of the most important among newly emerging ceramic materials. Its importance arises from the fact that it is the strongest contender for automobile applications. Silicon nitride has several unique properties such as good mechanical strength at high temperatures, good wear resistance, good thermal shock properties, low thermal expansion and low heat capacity, high temperature stability and oxidation resistance, resistance to attack by most chemicals.

5.8.2 Silicon nitride components for structural applications are normally made through following three prime routes:

1. Reaction Bonded Silicon Nitride(RBSN), where the starting material is silicon powder. Silicon is converted to silicon nitride after formation into the required shape.
White fused grains normally exceeds 99% Al₂O₃. The crushed and ground grits are not only magnetically separated, but are often acidwashed. A typical composition is 99.53% 0.33% Na₂O, 0.10% Fe₂O₃, and 0.03% C. The 0.03-0.05% Na₂O in Bayer alumina primarily forms β-Al₂O₃, concentrated in the centre of large ingots by zone refining of the Na₂O during slow cooling, is segregated from the product after crushing. Some soda is lost to volatilisation. Minute continuous porosities formed by vapours as the molten mass solidifies aids friability of the grain and coolness of cut by the abrasive when machining tempered alloys. However, grain without these continuous open porosities are preferred for refractory aggregate applications requiring good grain strength and low sorption.

The hardness of white fused grain is increased by addition of 0.05-0.03% Cr₂O₃ to form pink and red fused Al₂O₃ abrasives. Brown fused aluminas containing 94-98% Al₂O₃ are produced in the largest tonnages.

Fused-cast refractories production requires a hard burned Bayer alumina calcined to a lower sorptive capacity (less than 0.2% ignition loss) to minimize porosity caused by gases entrapped in the refractory blocks.

Several other processes has been developed for the production of different grades and qualities of alumina powder. For example, very purity, ultra fine powders are produced by Aluminium Isopropoxide route(solution precipitation process). In this process, Aluminium metal is mixed with alcohol(C₃H₇OH). The resultant mix is hydrolysed in a alcohol-water solution to produce suspension of fine oxide particles. The alumina gel is separated by centrifugation. Alumina gel is then calcined to give dried powder. Alumina powder obtained from this process has particle size between 0.3 to 0.6 μm and very high a-alumina content with Na₂O levels well below 0.01 wt%.

The other processes for producing high quality alumina powders having low Na₂O content are Alum process and Itaguni process.

The required quality of calcined alumina powder for various applications is described in the following table:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Speciality Application</th>
<th>Particle Size (in μm)</th>
<th>Na₂O content (% wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Electronic Ceramic</td>
<td>0.5 - 5.0</td>
<td>0.02 - 0.10</td>
</tr>
<tr>
<td>2.</td>
<td>Sodium Vapour LamO</td>
<td>&lt; 0.5</td>
<td>0.02 - 0.10</td>
</tr>
<tr>
<td>3.</td>
<td>Mechanical/Structural</td>
<td>0.5 - 5.0</td>
<td>0.02 - 0.40</td>
</tr>
<tr>
<td>4.</td>
<td>Polishing</td>
<td>0.5 - 5.0</td>
<td>0.02 - 0.40</td>
</tr>
<tr>
<td>5.</td>
<td>Fused Abrasives</td>
<td>0.5 - 1.0</td>
<td>0.20 - 0.40</td>
</tr>
<tr>
<td>6.</td>
<td>Ceramic Fibres</td>
<td>0.5 - 1.0</td>
<td>0.20 - 0.40</td>
</tr>
<tr>
<td>7.</td>
<td>Hi-Tech Refractories</td>
<td>0.5 - 3.0</td>
<td>0.1 - 0.25</td>
</tr>
<tr>
<td>8.</td>
<td>Spark Plug Cores</td>
<td>2.5 - 75.0</td>
<td>0.02 - 0.20</td>
</tr>
<tr>
<td>9.</td>
<td>Chinaware</td>
<td>0.5 - 3.0</td>
<td>4.00</td>
</tr>
<tr>
<td>10.</td>
<td>Glass</td>
<td>0.5 - 3.00</td>
<td>4.00</td>
</tr>
<tr>
<td>11.</td>
<td>Refractories</td>
<td>0.5 - 5.00</td>
<td>0.2 - 4.00</td>
</tr>
<tr>
<td>12.</td>
<td>Fused cast Refractories</td>
<td>2.0 - 50.0</td>
<td>&gt; 4.00</td>
</tr>
<tr>
<td>13.</td>
<td>Porcelain Insulators</td>
<td>2.0 - 5.0</td>
<td>0.20 - 4.0</td>
</tr>
</tbody>
</table>
5.8.5 The sintered reaction bonded silicon nitride, combines the advantages of both routes - green machining, reduced porosity and superior strength. It also starts with lower cost silicon powders.

5.8.6 The silicon nitride products made by these alternative processes differ in properties. The best mechanical properties are obtained with hot isostatic pressed sintered silicon nitride, though they may be costlier than reaction bonded silicon nitride.

5.8.7 Silicon nitride in the form of strong, hard and tough components with low density and low friction are being used as cutting tools, welding nozzles, extrusion and tube drawing dies, and plugs, precision jigs and fixtures, as components for handling molten metals and corrosive chemicals, ball and roller bearings, turbo charger rotors and engine wear parts, composites and coatings.

5.8.8 Silicon nitride powder is not manufactured in India. Some of the manufacturers of silicon nitride powders in the world are Coors Ceramic Co., Hoechst Ceramtec, Kyocera, Norton, Toyo Soda, etc.

5.8.9 Non availability of the processing equipments and non-destructive characterisation techniques have adversely affected usage of silicon nitride in India.

5.9.0 **SIALONS**

5.9.1 ‘Sialon’ is an acronym derived from Silicon, Aluminium, Oxygen and Nitrogen. The pressureless sintering capability of Sialon makes it possible to produce complex shapes which could after sintering, give products with densities close to their theoretical densities.

5.9.2 Sialons are important group of ceramics and were first synthesized in 1970. These are materials in which part of Si in Si3N4 is replaced by Al and at the same time N is replaced by O. They are represented by phases Si-Al-O-N and M-Si-Al-O-N, where M is lithium beryllium, yttrium, scandium, magnesium, etc. Only beta sialons having structure similar to beta silicon nitride have been developed as engineering ceramics. Two of the sialons which are yttrium beta sialons are being sold under the trade names of ‘sialon’ and ‘Kyon2000’. These are outstanding cutting tools for machining metals. Other potential applications of Sialons are for extrusion and drawing dies, seals and bearings, prosthesis devices, refractories, rock and coal cutting, turbine blades, aerospace, etc.

5.9.3 M/s. Lucas Cookson Sylon Ltd., UK are the pioneers in manufacture of Sialons. They have licensed this technology in Japan and USA. The manufacturers include Hitachi, Mitsubishi and NGK of Japan and Carborundum of USA besides Lucas. In India, sialons are not produced.

5.10.0 **AVAILABILITY OF CERAMIC MATERIALS IN GUJARAT.**

5.10.1 Ceramic minerals are abundantly available in the Kachchh and Saurashtra region of Gujarat. Estimated reserves & production of various ceramic minerals are indicated below:

<table>
<thead>
<tr>
<th>Ceramic Mineral</th>
<th>Estimated Reserves (Million Tonnes)</th>
<th>Production(1988) (Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball Clay</td>
<td>Not assessed</td>
<td>-</td>
</tr>
<tr>
<td>Bauxite</td>
<td>87.42</td>
<td>4140</td>
</tr>
<tr>
<td>Bentonite</td>
<td>82.56</td>
<td>3382</td>
</tr>
<tr>
<td>Chromite</td>
<td>Nil</td>
<td>Nil</td>
</tr>
</tbody>
</table>
5.3.0 ZIRCONIA

5.3.1 Processing of Zirconia

Zircon is the original existing mineral. By Thermal dissociation, zirconia can be produced.

Thermal Dissociation

At the temperature of 1650°C or higher when zircon is passed through the intense heat of plasma and immediately thereafter quenched, the molten droplets result in the formation of dissociated zircon particles of generally spheroid configuration. The spheroids consist of a fused, amorphous silica mass in which radiating crystallites of monoclinic zirconia are dispersed.

This dissociated zircon is amenable to hot aqueous caustic leaching to remove the silica in the form of soluble sodium silicate. The remaining skeletal structure of zirconia is readily washed to remove residual caustic. Purity of this zirconia is directly related to the purity of the starting zircon since only silica, phosphate, and trace alkalies and alaline earth are removed during the leach. The zirconia, and the untreated dissociated zircon are both proposed for use in ceramic color glazes.

5.3.2 Zirconia ceramics exhibit excellent fracture toughness, an important prerequisite for all mechanical applications. There are three types of Zirconia in common use:

* Oartuakkt stabilized Zirconia(PSZ)
* Cubic Stabilized Zirconia(CSZ)
* High toughness Zirconia(HTZ)

5.3.3 Each group of Zirconia is further classified depending on the system used to stabilise Zirconia, Magnesia, Yttria are typical stabilisers. However, magnesia is more popular because of its lower cost.

5.3.4 Zirconia continues to acquire new uses - as high performance refractories, abrasives and cutting tools and for an increasing number of mechanical applications. Zirconia coating realised through plasma spray and other techniques, also have many potential applications.

5.3.5 The two important minerals for Zirconia are Zircon sand and baddeleyite. Zircon is the most common and widely distributed. Zircon sand contains about 65-66% Zirconia, 33% silica and 1-2% impurities. Kerala's sea beach sand is rich in Zircon content. The proven reserves of Zircon sand in India are about 12 to 13 lac tonnes and the current total production of Zircon sand is placed at 18-19000 YPA. Indian Rare Earths Ltd(IREL) is the main producer alongwith Kerala Minerals and Metals Ltd(KMML). The current production of Zircon sand is as follows:

<table>
<thead>
<tr>
<th>Company</th>
<th>Production(TPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IREL</td>
<td>18000</td>
</tr>
<tr>
<td>KMML</td>
<td>~1000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>19000</strong></td>
</tr>
</tbody>
</table>

36
Major districts of Gujarat, where Bauxite is available are Jamnagar, Junagadh, Kachchh, Kheda and Sabar Kantha. The Bauxite available in Gujarat has higher alumina content (above 45% Al₂O₃). This indicates good prospects for Alumina based ceramic units. However, it is very essential to set up plant to manufacture required grades of alumina powder for Bauxite available in the region.

5.11.0 CONCLUSIONS

5.11.1 Ceramic powders for advanced ceramic applications are not available indigenously and hence they are imported in large quantities. This is one of the most important factor hindering the growth of this sector in India.

5.11.2 India has large mineral deposits of Zircon, Silica and Bauxite. India can export value added high quality ceramic grade powders rather than export ore and import powders and products.
5.6.2 Barium Titanate is conventionally manufactured by intimate mechanical mixing of barium carbonate and titanium oxide and calcining the solid mixture so obtained at a temperature of about 300°C in the presence of additives. It is very difficult to obtain the exact stoichiometric proportion in the fired product. When the TiO₂ is high, the material is suitable for capacitors, but if low, may be used for transducers. More recently reported method which gives comparatively purer product but at a higher cost is co precipitation and freeze drying.

5.6.3 Barium Titanate is not manufactured in the country. M/s. Atlantic Equipment Engineers, Cerac Inc, and Tam Ceramic Inc; are the major US manufacturers of Barium Titanate.

5.6.4 Barium Titanate powder is not available indigenously. Titanium dioxide, which required for Barium Titanate manufacture is not available indigenously. The cost of Barium Titanat powder required for MLC manufacture is about 2.5-3.0 $ per kg. (Rs.185-220/kg including 145% duty) for this application, a high purity material is desired, as over 2% SiO₂ and Al₂O₃ drastically deteriorates the required properties.

5.6.5 M/s. Thermo Chemical Industry, Junagadh has laboratory scale technology to produce high purity electronic grade BaTiO₃ powders by Sol-Gel method. (For details Refer Appendix-4 at the end of the report).

5.7.0 SILICON CARBIDE (SIC)

5.7.1 Silicon carbide is an important structural ceramic material of interest. For high performance applications two types of pure silicon carbide materials are used. These are:

* Reaction bonded silicon carbide
* Sintered silicon carbide

Sintered silicon carbide is a material which is a material which is densified without pressure by using sintering aids, hence it is also known as ‘self bonded silicon carbide’.

5.7.2 Reaction bonded silicon carbide is produced from a mixture of silicon carbide powder and carbon in the presence of liquid or gaseous silicon, by the reaction of three components. If silicon is supplied in quantities that are just sufficient to convert all the carbon into silicon carbide, porous reaction bonded silicon carbide is produced. If an excessive amount of silicon is present, the pores will fill and dense reaction bonded silicon carbide is formed.

5.7.3 Silicon carbide powders are made into high wear, high strength, high heat and corrosion resistant mechanical seals, sliding bearings, cutting tools, lining and other wear resistant products, rocket nozzles, engine components, heat exchangers and other high temperature products. Silicon carbide is also used for electronic substrates, solar cells, light emitting diodes and various semi-conductor devices and for nuclear applications, as electrical insulators and as armour protection.

5.7.4 The use of silicon carbide particulates, fibres and whiskers for the reinforcement particularly of metals but also of ceramics, glasses and other materials has accelerated. The composites sector is firmly expected to be a major growth area. Similar expectations do apply to coatings also.

5.7.5 Pure silicon carbide has been imported in the country. During 1990-91 about 1130 tons of pure silicon carbide was imported valued at about Rs.2.5 crores. M/s. Shin-En-Shu Chemical Co.Ltd., Japan; Ibideu Co. Ltd., Japan; Cerac Inc, USA; Carborundum Co, USA and Lonza Inc, USA are some of the major producers of silicon carbide.

5.8.4 Sintered Silicon Nitride (SSN) can be thought of as a high strength alternative to reaction bonded silicon nitride, since its porosity is less. Here the starting material is silicon nitride powder. However, after pressureless sintering, these components shrink by as much of
### Table 6.1
Comparative Evaluation (Electro Ceramics)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameters</th>
<th>Multilayer Ceramic Capacitors</th>
<th>Substrates for IC Chips and Hybrid Circuits</th>
<th>Ferries (Hard and Soft)</th>
<th>Piezoelectrics</th>
<th>Thermistors (NTC/PTC)</th>
<th>Variours</th>
<th>Ceramic Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Market Potential</td>
<td>Currently use of MLC is limited (about 120 mln. Nos) mainly because of its non-availability. Demand is likely to go up to 800 mln. Nos. in 1994-95 and 3000 mln. Nos. in 1999-2000.</td>
<td>The current market for ceramic substrates is quite large (about 17.0 mln. Nos). Demand for ceramic substrates is likely to go up by 59.0 mln. Nos by 1994-95 &amp; 185 mln. Nos. by 2000 AD.</td>
<td>The current market for hard &amp; soft ferrites is quite large, demand is growing consistently at 10-12%. Usage of ferrites well established in the country. Good domestic demand. However, gap is not substantial especially for high ferrites.</td>
<td>Substantial demand exists for single crystal devices required for wrist watches, polycrystalline piezoelectric devices for ceramic filters, delay lines for consumer and electronics applications.</td>
<td>Substantial demand (about 5 mln. Nos) exist in the domestic market. Demand is likely to go up to 10 mln. Nos by 1994-95 &amp; 10 mln. Nos by 2000 AD.</td>
<td>Substantial demand (5.5 mln. Nos) exist in the domestic market which is likely to go up to 34 mln. Nos. by 2000 AD.</td>
<td>The current market for ceramic base sensors are very limited. Future market is also not very encouraging.</td>
</tr>
<tr>
<td>2.</td>
<td>Supply Scenario</td>
<td>Present installed capacity is about 320 million pieces (GM Chip Components &amp; Dalmia Cement Ltd).</td>
<td>Currently, entire requirement is imported.</td>
<td>Enough indigenous capacity exists for hard ferrite manufacture. For soft ferrites, indigenous capacity is not sufficient to cater to its demand.</td>
<td>Several mfrs. of Quartz crystal for clocks, crystal based oscilloscopes including crystals, PZT piezoelectric element. Single crystal devices required for wrist watches are imported from Japan.</td>
<td>Several mfrs. of NTC/PTC resistors in the country. However, capacity is not enough to meet domestic demand.</td>
<td>Several manufacturers. However, installed capacity is not enough to meet domestic demand.</td>
<td>No indigenous manufacture.</td>
</tr>
<tr>
<td>3.</td>
<td>Raw Material (Compound) Availability.</td>
<td>Barium titanate powder not available indigenously. Even technology to produce high grade BaTiO3 at commercial scale is not available.</td>
<td>The compound i.e. electronic grade alumina (purity above 99.9%) is not available indigenously. However, alumina is amply available in the country. Technology to produce very high purity alumina compound at commercial scale is not available indigenously.</td>
<td>Compounds (ferrite oxide) are manufactured in the country by Ferrite mfrs. Technology for powder preparation has been indigenised. Large reserves of ferrite oxide in the country. However, inconsistent quality of ferric oxide is the major problem.</td>
<td>No indigenous supplier of compounds (i.e. lithium niobate, PZT and PLZT).</td>
<td>No indigenous supplier of compounds (barium titanate with sironium or lead titanate, complex spinel structure of nickel manganese, cobalt and copper oxide). Lack of technology to produce high grade TiO2 powder.</td>
<td>Semiconductor compounds like (BaTiO3, SiC, ZaO-bizO) and other transition metal oxides. These compounds are not available freely.</td>
<td>Alumina and Zirconia compounds. Required grades are not freely available.</td>
</tr>
</tbody>
</table>

45
2. Sintered Silicon Nitride (SSN), which uses silicon nitride powders as the starting material and which can be sintered (because of additives) or hot isostatically pressed to form the required component.

3. Sintered Reaction Bonded Silicon Nitride (SRBSN), which also uses silicon powder as the starting material. This combines advantages of both processes.

**SILICON NITRIDE PROCESSES**

<table>
<thead>
<tr>
<th>REACTION BONDED SILICON NITRIDE (RBBSN)</th>
<th>SINTERED SILICON NITRIDE (SSN)</th>
<th>SINTERED REACTION BONDED SILICON NITRIDE (SRBSN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon Powder</td>
<td>Silicon Nitride Powder</td>
<td>Silicon Powder</td>
</tr>
<tr>
<td>Binder Additives</td>
<td>Mixing/Milling</td>
<td>Mixing/Milling</td>
</tr>
<tr>
<td>Spray Drying</td>
<td>Forming</td>
<td>Forming</td>
</tr>
<tr>
<td>Forming</td>
<td>Sintering</td>
<td>Presomter</td>
</tr>
<tr>
<td>Nitriding</td>
<td>Diamond Grinding</td>
<td>Green Machining</td>
</tr>
<tr>
<td>Inspection</td>
<td>Inspection</td>
<td>Sintering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diamond Grinding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inspection</td>
</tr>
</tbody>
</table>

5.8.3 The reaction bonded silicon nitride process uses dry pressing or injection moulding off forming the required shape in the case of high volume production. For low to medium volume production, wet bag isostatic pressing is used, especially when components are to be green machines from an iso-pressed billet. The green machining route enables manufacture of complex shapes, which may not be produced by other routes. The finished component is then heated in a nitrogen gas environment close to the melting point of silicon, when nitriding takes place. The resulting product has 10-15% porosity. This results in relatively poor mechanical properties. However, complex final shapes can be formed without much difficulty.

5.8.4 Sintered Silicon Nitride (SSN) can be thought of as a high strength alternative to reaction bonded silicon nitride, since its porosity is less. Here, the starting material is silicon nitride powder. However, after pressureless sintering, these components shrink by as much of 20%. Hence, unless the product is shaped to dimensions close to those in which it is used, the final product is diamond ground from a solid block of the material, in order to form the final shape. This makes this process expensive, though its mechanical properties are superior.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameters</th>
<th>Spark Plug Body</th>
<th>Catalytic Converter</th>
<th>Grinding Media</th>
<th>Thread Guides</th>
<th>Cutting Tool Inserts</th>
<th>Mechanical Seal faces &amp; Domestic Tap cartridges</th>
<th>Nozzles for Welding and Sand blasting equipments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Market Potential</td>
<td>Currently market for spark plug in India is about 12.6 mln. Nos. per annum, which is likely to go up to 22.5 mln. Nos. by 2000 AD.</td>
<td>Large potential market (about 400 crores by 2000 AD). But there are certain constraints to growth. Use of ceramic converter possible only if MTBE used as octane enhancer and Govt. would make its use mandatory. However, this seems to be a distant reality.</td>
<td>The current market of 150 tons is likely to go up to 400 tons by 2000 AD.</td>
<td>The current market size of 10 crores is likely to go up to 40 crores by 2000 AD. Consistent growth envisaged because of good prospects of textile machinery and increasing penetration of ceramics in this sector.</td>
<td>The market for complete cutting tool inserts is very negligible. Future potential is also envisaged to be limited.</td>
<td>The current market of 8 crores is likely to go up to 30 crores by 2000 AD. Penetration is likely to increase if available from indigenous source.</td>
<td>The current market is very small. However, good future demand has been envisaged.</td>
</tr>
<tr>
<td>2</td>
<td>Supply Scenario</td>
<td>Enough capacity exists for spark plug manufacturer (MICO, Moth Champion and IVP are the major players). However, they do not have facility to manufacture ceramic bodies required for plug. They import the green blank and after firing it is assembled.</td>
<td>No indigenous manufacturers at present.</td>
<td>Few indigenous suppliers of ceramic grinding media.</td>
<td>Major part of the current requirement is imported. Henslo Jyoti, NTB International are major domestic manufacturers.</td>
<td>Complete ceramic inserts are not available. Indigenously. However, WIDIA and Sandvik supplies coated ceramic cutting tools.</td>
<td>Major part of the requirement is imported. M/s IVP and WIDIA are the only domestic suppliers.</td>
<td>IVP supplies ceramic nozzles for welding. A large amount is imported.</td>
</tr>
<tr>
<td>3</td>
<td>Raw Material (Compound Availability)</td>
<td>Alumina powder is mix (90% Al₂O₃ with additions of silica, calcium oxide and magnesium) is not easily available indigenously. However, alumina-the main raw material is available in the country.</td>
<td>Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is available in the country.</td>
<td>Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is available in the country.</td>
<td>Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is available in the country.</td>
<td>Silicon carbide. Silicon carbide is not manufactured indigenously.</td>
<td>Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is available in the country.</td>
<td>Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is available in the country.</td>
</tr>
<tr>
<td>Ceramic Mineral</td>
<td>Estimated Reserves (Million Tonnes)</td>
<td>Production (1988) (Tonnes)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------------------------------</td>
<td>---------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diaspore</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dolomite</td>
<td>696.33</td>
<td>232652</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limestone</td>
<td>8109.56</td>
<td>5546000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feldspar</td>
<td>Not assessed</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nepheline Synite</td>
<td>14.00</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire Clay</td>
<td>134.52</td>
<td>146503</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphite</td>
<td>11.60</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gypsum</td>
<td>0.022</td>
<td>237</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesite</td>
<td>10.32</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mica</td>
<td>Nil</td>
<td>Nil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrophillite</td>
<td>Nil</td>
<td>Nil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz &amp; Quartzite</td>
<td>28.76</td>
<td>8081</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaolin</td>
<td>3.78</td>
<td>34687</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andalusite</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kyanite</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silimanite</td>
<td>Nil</td>
<td>Nil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talc (Steatite)</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wollastonite</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zircon</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zirconia (Baddelyite)</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China Clay</td>
<td>63.00</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Indian Minerals Yearbook, 1990

5.10.2 Alumina is the most important material for many Hi-Tech Ceramics. Bauxite, an important source for alumina is abundantly available in Gujarat. The estimated reserves of Bauxite in the state is about 87.4 million tonnes. Grade wise distribution of Bauxite Reserves is as given below:

<table>
<thead>
<tr>
<th>Bauxite Grade</th>
<th>Estimated Reserve ('000 Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Grade</td>
<td>3929</td>
</tr>
<tr>
<td>Refractory/Abrasive Grade</td>
<td>3986</td>
</tr>
<tr>
<td>Chemical Mixed with others</td>
<td>24303</td>
</tr>
<tr>
<td>Metallurgical Grade I</td>
<td>5061</td>
</tr>
<tr>
<td>Metallurgical Grade II</td>
<td>226</td>
</tr>
<tr>
<td>Metallurgical Grade III</td>
<td>617</td>
</tr>
<tr>
<td>Metallurgical, Mixed</td>
<td>4141</td>
</tr>
<tr>
<td>Low Grade</td>
<td>4186</td>
</tr>
<tr>
<td>Mixed Grade</td>
<td>35865</td>
</tr>
<tr>
<td>Others</td>
<td>568</td>
</tr>
<tr>
<td>Not-known</td>
<td>4541</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>87423</td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Parameters</td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Market Potential</td>
</tr>
<tr>
<td>2</td>
<td>Supply Scenario</td>
</tr>
<tr>
<td>3</td>
<td>Raw Material (Compound)</td>
</tr>
<tr>
<td>4</td>
<td>Acquisition of Technology</td>
</tr>
<tr>
<td>5</td>
<td>Export Potential</td>
</tr>
<tr>
<td>7</td>
<td>Opportunities</td>
</tr>
</tbody>
</table>
6.1.0 INTRODUCTION

6.1.1 A comparative evaluation based on various techno-market considerations for various Hi-Tech ceramic products is essential in order to identify relevant products. An attempt has been made here to identify suitable projects based on comparative evaluation.

6.1.2 Various factors that have been taken into consideration for this evaluation are:

- Market prospects
- Anticipated competition (i.e., future supply scenario)
- Raw materials (compound) availability
- Access to technology
- Export potential
- Risk factors

6.2.0 COMPARATIVE EVALUATION

6.2.1 A comparative evaluation based on above described parameters is depicted in Table 6.1 and Table 6.2
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameters</th>
<th>Multilayer Ceramic Capacitors</th>
<th>Substrates for IC Chips and Hybrid Circuits</th>
<th>Ferrites (Hard and Soft)</th>
<th>Piezo-Electrics</th>
<th>Thermistors (NTC/PTC)</th>
<th>Varistors</th>
<th>Ceramic Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Acquisition of Technology</td>
<td>Easy acquisitions many foreign companies are willing to offer technology.</td>
<td>Technology acquisition is not very easy as most of the technology suppliers have their own stake in the manufacture and supply of this item.</td>
<td>Good technical know-how is available fairly easily and at low cost.</td>
<td>Technology can be acquired easily, indigenous know-how available.</td>
<td>Technology can be acquired easily, indigenous.</td>
<td>Technology can be acquired easily.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Export Potential</td>
<td>Limited as international market is already mandated. However, it is possible if buy-back arrangements are made with technology supplier.</td>
<td>Possibility of export is bleak as severe competition from international giants. However, it is possible if a buy-back arrangement is made with technology suppliers.</td>
<td>Good scope for India to enter world market in both hard &amp; soft ferrites. Possibility also exists for export of ferrite powders.</td>
<td>Possibility of export is bleak as severe competition from international giants.</td>
<td>Limited as there are many competitive manufacturers worldwide.</td>
<td>Limited as there are many competitive manufacturers worldwide.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Opportunities</td>
<td>Good opportunities for MLC manufacture and barium titanate powder manufacture.</td>
<td>Good opportunity for substrate as well as electronic grade alumina powder.</td>
<td>Production of hard &amp; soft ferrite powders based on Indian Ferrite Oxide - a worthwhile opinion.</td>
<td>Opportunity exist in import of quartz ingot/poly crystalline powders and processing them into the required piezoelectric elements.</td>
<td>Ceramic bases thermistors manufacture represents good business opportunity since most requirements are currently met by imports.</td>
<td>Ceramic bases varistors manufacture represents good business opportunity.</td>
<td>Less opportunity in the near future.</td>
</tr>
</tbody>
</table>
In the essence, prospects for Hi-tech ceramics industry in Gujarat seems quite bright.

Based on various criteria like availability of raw material, power situation, water availability etc., an attempt has been made for Hi-tech ceramic items in the State.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Product</th>
<th>Preferred</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Alumina Powder</td>
<td>Jamnagar/ Junagadh</td>
<td>Raw material bauxite is available abundantly in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kachchh Dist.</td>
<td>these regions.</td>
</tr>
<tr>
<td>2.</td>
<td>Abrasive Grains</td>
<td>Jamnagar/ Junagadh</td>
<td>Raw material bauxite is available abundantly in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dist.</td>
<td>these regions.</td>
</tr>
<tr>
<td>3.</td>
<td>High Alumina Bricks</td>
<td>Jamnagar/ Junagadh</td>
<td>Raw material bauxite is available abundantly in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dist.</td>
<td>these regions.</td>
</tr>
<tr>
<td>4.</td>
<td>Alumina Castables &amp; Kiln Furniture</td>
<td>Jamnagar/ Junagadh</td>
<td>Raw material bauxite is available abundantly in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dist.</td>
<td>these regions.</td>
</tr>
<tr>
<td>5.</td>
<td>Barium Titanate Power</td>
<td>Gandhinagar</td>
<td>Special incentives for electronics industry are</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dist.</td>
<td>available in this region.</td>
</tr>
<tr>
<td>6.</td>
<td>Multilayer Ceramic Capacitors</td>
<td>Gandhinagar</td>
<td>Special incentives for electronics industry are</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dist.</td>
<td>available in this region.</td>
</tr>
<tr>
<td>7.</td>
<td>Ceramic Substrates for IC Chips and Hybrid</td>
<td>Gandhinagar</td>
<td>Special incentives for electronics industry are</td>
</tr>
<tr>
<td></td>
<td>Circuits</td>
<td>Dist.</td>
<td>available in this region.</td>
</tr>
<tr>
<td>8.</td>
<td>Grinding Media</td>
<td>Any industrially developed</td>
<td>Location.</td>
</tr>
<tr>
<td>9.</td>
<td>Welding Nozzles</td>
<td>Any industrially developed</td>
<td>Location.</td>
</tr>
<tr>
<td>10.</td>
<td>Ceramic Seal Faces</td>
<td>Any industrially developed</td>
<td>Location.</td>
</tr>
<tr>
<td>11.</td>
<td>Thread Guides</td>
<td>Ahmedabad, Surat</td>
<td>Good market prospects due to well developed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dist.</td>
<td>textile sector.</td>
</tr>
<tr>
<td>12.</td>
<td>Material Handling Liners</td>
<td>Jamnagar, Junagadh</td>
<td>Raw material bauxite is amply available in the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kachchh Dist.</td>
<td>region.</td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Parameters</td>
<td>Spark Plug Body</td>
<td>Catalytic Converter</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------</td>
<td>----------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>4.</td>
<td>Acquisition of Technology</td>
<td>Technology to manufacture ceramic body for spark plug can be available easily.</td>
<td>Relatively easy to acquire technology.</td>
</tr>
<tr>
<td>5.</td>
<td>Export Potential</td>
<td>Not existing as the market is captured by major spark plug manufacturers like Bosch, AC Champion and NGK.</td>
<td>Difficult as there are many already established manufacturers in the world.</td>
</tr>
<tr>
<td>6.</td>
<td>Risk Factors</td>
<td>Existing spark plug manufacturers easy undertake manufacture of ceramic bodies also. In that case, the investment may turn out to be redundant.</td>
<td>MTBE may not be used as Gasoline octane enhancer. Govt. may not allow use of catalytic converter mandatory.</td>
</tr>
<tr>
<td>7.</td>
<td>Opportunities</td>
<td>Good opportunities for ceramic spark plug body manufacture and for aluminas compound required for spark plug.</td>
<td>Good opportunities to manufacture ceramic catalytic converter if above mentioned constraints are removed.</td>
</tr>
</tbody>
</table>
The Central Government has granted exemptions in the import duties for the import of ceramic materials and components used to manufacture electronic goods. (Ref. Noti. No:94, dt. 1-3-92, Cus. Tariff 1991-93). Effective duties for such materials and components are given in the following table:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Basic</th>
<th>Auxiliary</th>
<th>C.V.D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Barium Titanate based ceramic compositions</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
<tr>
<td>2.</td>
<td>Ferric Oxide (above 99% purity)</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
<tr>
<td>3.</td>
<td>Manganese Oxide (above 99% purity)</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
<tr>
<td>4.</td>
<td>Manganese Dioxide (above 99% purity)</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
<tr>
<td>5.</td>
<td>Manganese Carbonate (above 99% purity)</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
<tr>
<td>6.</td>
<td>Nickel Oxide</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
<tr>
<td>7.</td>
<td>Strontium Carbonate</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
<tr>
<td>8.</td>
<td>Ceramic/Alumina Substrates</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
<tr>
<td>9.</td>
<td>Alumina Powder of purity 99.9% and above</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
<tr>
<td>10.</td>
<td>Reactive Alumina (Super Ground)</td>
<td>35</td>
<td>5</td>
<td>15+2.25</td>
<td>64.15</td>
</tr>
</tbody>
</table>
6.3.0 SELECTION OF RELEVANT PROJECTS

6.3.1 Based on above analysis, following projects have been indentified as prospective projects:

A. Electro-Ceramics

1. Multilayer ceramic capacitors
2. Substrates for IC chip carriers and hybrid circuits
3. Hard and soft ferrites
4. Ceramic sensors

B. Structural Ceramics

1. Grinding media
2. Nozzles for welding
3. Thread guides
4. Ceramic seal faces
5. Continuous cast refractories
6. Material handling liners

C. Ceramic Powders

1. Alumina powder for various application
2. Barium titanate powders
3. Ferrite powders

6.3.2 While selecting above projects, major emphasis is given to such projects, which have clear potential and are implementable in the immediate period. Emphasis is also given to alumina based projects, as Gujarat (and India also) has large bauxite reserves.
Electro Ceramics
- AVX
- Corning
- Ceramtec
- Amperex
- Honeywell Inc.

Cutting Tools & Wear Parts
- Kennametal
- TRW/Wendt
- Astro Met
- Norton
- ESK Corp.

Heat Engines & Parts
- Ford Motor
- Garret Corp.
- International Harvester
- Pratt and Whitney

Composites
- DuPont

C. U.K.

Ceramic Powders
- Magnesium Elektron
- Lucas Cookson

Cutting Tools & Wear Parts
- Doulton Industries
- Morgan
- Smiths
- Magnesium Elektron
- ICI

Automotive Engines & Parts
- Leyland Diesel
- Ford UK
- Perkins Engine

D. Germany

Ceramic Powders
- Bayer
- Hermann Stark

Electro Ceramics
- Asternetics
- Siemens

- Vitramon
- Adolf Melter
- Champion Spark Plug DM Steward

- Coors Porcelain
- Armeco
- Carborundum
- Lambertsville
- Art Inc.

- General Motors
- General Electric
- Caterpillar

- Celanese

- Lucas Cookson
- Royal Worcester
- Alcan International
- AED

- BL Technology
- Rolls Royce
- AE Turbine Components

- Hoechst
- Harshaw Chemie

- Hoechst
7.1.0 The ceramics is an energy intensive industry. The irregular power/coal availability affects this industry drastically. The state of Gujarat is fortunate to have better power situation compared to other states in India. Besides, natural gas from the large deposits in the districts of Baroda, Bharuch, Kheda and Ahmedabad can be used as an alternative fuel. The discovery of new natural gas fields in Gandhar and Tapti Basin has opened up possibility of using natural gas as an alternative energy source on a large scale. The Government has decided to allocate gas according to the need and priorities of the industries. Natural gas for large projects can be tapped from the available gas resources of Gandhar and gas passing through HBJ pipelines. In addition, large lignite resources available in the state (in Jagadia and Kachchh) could also cater the ceramic industry’s need for fuel to some extent.

7.2.0 Ceramic minerals are abundantly available in Gujarat in the Kachchh and Saurashtra region. Bauxite, Bentonite, Fire-clay are available in good quantity. Alumina powder is the most important ceramic material for many Hi-Tech structural ceramics applications. Bauxite, and important source for alumina, is amply available in Gujarat. This indicates good prospects for Alumina based Hi-Tech Ceramic projects in Gujarat, if a plant to manufacture Alumina powder from Bauxite is set up in Gujarat.

7.3.0 Gujarat has fairly well developed industrial estate. Good infrastructure facilities are available with these industrial estate.

7.4.0 There is no dearth of technical man-power required for such HiTech ceramic projects, because of well-developed conventional ceramic industry in the state. Besides, an extension centre of central glass and Ceramic Research Institute in the state can provide necessary guidance to entrepreneurs for the development of desired projects in the field of Hi-Tech Ceramics.

7.5.0 The new industrial policy of the state Government is quite favourable for such projects. Various incentive schemes, which have been devised to attract entrepreneurs are:

* Capital Investment Subsidy Scheme
* Sales Tax incentives scheme
* Incentives scheme for employment oriented industries
* Pioneer unit incentive Scheme
* Prestigious units incentive scheme
* Incentive scheme for 100% export Oriented Unit
* Special incentive scheme for electronics industry.

7.6.0 Besides these, GIIC Ltd (Gujarat Industrial Investment Corporation Ltd) renders financial assistance to small and medium industries in Gujarat through various schemes like:

* Concessions in backward areas
* Foreign exchange loan
* Term loan for modernisation
* Quick finance for acquisition of capital goods/equipment
* Seed capital assistance
## COMMERCIALY AVAILABLE STRUCTURAL CERAMIC PRODUCTS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Product</th>
<th>Material</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Automobile water pump seal ring</td>
<td>&quot;Hexoloy SA&quot; Sintered SiC</td>
<td>Carborundum Co.</td>
</tr>
<tr>
<td>2.</td>
<td>Armour Protection for gunship aircraft</td>
<td>&quot;Hexology SA&quot; Sintered SiC</td>
<td>Carborundum Co.</td>
</tr>
<tr>
<td>3.</td>
<td>Oil Field Components, abrasive cleaning nozzles, bearings and guides</td>
<td>SiC/TiB₂ particulate composite</td>
<td>Standard Oil Engineered Materials Co.</td>
</tr>
<tr>
<td>4.</td>
<td>Ceramic bearings, hybrid ceramic bearings for aerospace, defence machine tools, biotechnology and automotive</td>
<td></td>
<td>Joint venture between Torrington Co. and Norton Co.</td>
</tr>
<tr>
<td>5.</td>
<td>Bearing components (balls, roller raceway blanks), water plates</td>
<td>Si₂N₄</td>
<td>Norton Co.</td>
</tr>
<tr>
<td>6.</td>
<td>Wear plates for industrial components, sand blast nozzles, acid pump seals and bushings, broachable glue nozzles, critical electrochemical machining fixtures, spray nozzles and extrusion dies.</td>
<td>&quot;AmAlox 68&quot; High density ceramic</td>
<td>Astro Met Associates, Cincinnati, Ohio USA</td>
</tr>
<tr>
<td>7.</td>
<td>Parts upto 2 m long for large rollers pump seals, conveyor rollers, non-lubricated bearings for severe service conditions and a variety of structural &amp; aerospace applications.</td>
<td>Si₃N₄</td>
<td>Enprotech Corporation, USA</td>
</tr>
<tr>
<td>8.</td>
<td>Precision fabricated nuts &amp; bolts, other threaded components for applications such as high voltage insulators, electrode holders, gas stream deflectors for heat shield assemblies.</td>
<td>Various ceramics</td>
<td>Aremco Products Inc., USA</td>
</tr>
<tr>
<td>9.</td>
<td>Tool bits</td>
<td>Si₃N₄, SiC Whisker reinforced composites</td>
<td>Greenleaf Corpn. and several other manufacturers</td>
</tr>
<tr>
<td>10.</td>
<td>Liquid metal filters, precombustion chambers, exhaust manifold liners, ceramic rocker arm bearings.</td>
<td>Zirconia-Mullite</td>
<td>Ceramique et Composite, France</td>
</tr>
<tr>
<td>11.</td>
<td>Pump Cylinder liners and pistons, valve seals, mill lining blocks, grinding media, wear tile, computer tape guides, die plates.</td>
<td>Alumina</td>
<td>Diamonite Products, USA</td>
</tr>
<tr>
<td>12.</td>
<td>Diesel engine glow plugs, prechamber cups, turbocharger rotors.</td>
<td>Si₃N₄</td>
<td>Turbocharger with ceramic rotor installed in the GM automobile &quot;Regal Grand National&quot;.</td>
</tr>
</tbody>
</table>
8.1.0 LICENSING FOR THE PROJECT

8.1.1 According to latest industrial policy, industrial license is required only for 18 industry groups, which relate to security and strategic concerns, social reasons, hazardous chemicals and environmental reasons. This list excludes ceramic industry, hence no industrial license is required.

8.2.0 IMPORT OF CAPITAL GOODS

8.2.1 As per the revised trade policy announced recently, import of capital goods for new units is allowed without any clearance from the Government and foreign equity participation is no longer essential. In view of this, it is expected that the import of capital goods for the project under consideration could be undertaken by arrangement of their own foreign exchange.

8.3.0 MINIMUM ECONOMIC SIZE

8.3.1 Minimum economic capacities have not been laid down for the projects under consideration.

8.4.0 CUSTOMS TARIFF

8.4.1 The customs duty on the imported ceramic powders required for Hi-tech ceramics industry, as described in the Customs Tariff Act (1992-93) are as follows:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Customs Duty (%)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Basic</td>
<td>Auxiliary</td>
</tr>
<tr>
<td>1.</td>
<td>Calcined Alumina (99% pure &amp; above)</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Tabular Alumina (99% pure &amp; above)</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Zirconia Bubbles (99% pure &amp; above)</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>4.</td>
<td>Silicon Carbide (other than used for Grinding Wheels and Abrasive products)</td>
<td>65</td>
<td>45</td>
</tr>
<tr>
<td>5.</td>
<td>Silicon Carbide (for Grinding Wheels and Abrasive products)</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Silicon Carbide (for the manufacture of Crucibles)</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Barium Titanates</td>
<td>65</td>
<td>45</td>
</tr>
<tr>
<td>8.</td>
<td>Silicon Nitride</td>
<td>65</td>
<td>45</td>
</tr>
</tbody>
</table>
### Terms of Various Foreign Collaborations

#### A. Multilayer Chip Capacitors

**Gujarat Poly-AVX Ltd., Gandhinagar**

Collaborator: AVX Corp., USA  
Year of Collaboration: 1989  
Foreign Equity: 25%  
Royalty: 4% for 5 years  
Lumpsum: $0.5 Million  
Duration: 5 years

**ICICON Pvt Ltd., Baroda**

Collaborator: Iskara, Slovenia  
Year of Collaboration: 1988  
Foreign Equity: 40%  
Royalty: 3% for 5 years  
Lumpsum: $0.3 Million  
Duration: 5 years

**Dalmia Cement (Bharat) Ltd., New Delhi**

Collaborator: Palomar Systems & Machines Inc., USA  
Year of Collaboration: 1987  
Foreign Equity: -  
Royalty: -  
Lumpsum: US $0. Million  
Duration: 2 years

#### B. Soft Ferrites

**Suchitra Electronics Pvt Ltd., Hyderabad**

Collaborator: LCC, France  
Year of Collaboration: 1987  
Foreign Equity: -  
Royalty: -  
Lumpsum: FF 8.0 Million  
Duration: 7 years
LIST OF COMPANIES ACTIVE IN COMMERCIALISATION OF ADVANCED CERAMICS

A. Japan

Ceramic Powders
- Showa Denko
- Sumitomo Chemical
- Nippon Soda
- Fuji Titanium
- Nippon Steel
- Kyocera

Mitsubishi Chemical
Ube Industries
Mitsubishi Mining and Cement
Toray
Nippon Carbon

Electro Ceramics
- Kyocera International
- Narumi China
- Taiyo Yoden
- Toshiba Ceramics
- Unizion
- Nippon Denso
- Sumitomo Electric

Nippon Tokushu Togyo
Nippon Gaishi
TDK Corp.
Murata Manufacturing
Matsushita Electricals
Fuji Denki
Toray Industries

Cutting Tools & Wear Parts
- Kyocera Corp
- Fujikin
- NGK Spark Plug
- Mitsubishi Metal
- Hitachi Chemical

Kyoto Ceramics
Token Industries
Sumitomo Electric
Nippon Gaishi

Automotive Engines & Parts
- Kyocera International
- Nippon Denso
- Nippon Shobubla

Nippon Tokushu Togyo
Nippon Gaishi
Toyota Machine Works

Composites
- Nippon Carbon

B. U.S.A.

Ceramic Powders
- Alcoa
- Reynolds
- TAM
- GTE Electrical
- Ferro Corp.
- DM Steward Co.

Kaiser Aluminium
Union Carbide
Elkem
Corning Glass
Ferrites Inc.
### D. INDUSTRIAL CERAMICS

**NTB International Pvt. Ltd., Pune**

<table>
<thead>
<tr>
<th>Collaborator</th>
<th>Lamertville Ceramics and Mfg. Co., USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Collaboration</td>
<td>1987</td>
</tr>
<tr>
<td>Foreign Equity</td>
<td>-</td>
</tr>
<tr>
<td>Royalty</td>
<td>-</td>
</tr>
<tr>
<td>Lumpsum</td>
<td>US $ 0.1 Million</td>
</tr>
<tr>
<td>Duration</td>
<td>10 years</td>
</tr>
</tbody>
</table>

**IVP Ltd., Bombay**

<table>
<thead>
<tr>
<th>Collaborator</th>
<th>Feldmuhle KG, Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Collaboration</td>
<td>1986</td>
</tr>
<tr>
<td>Foreign Equity</td>
<td>DM 0.375 Million</td>
</tr>
<tr>
<td>Royalty</td>
<td>3% for 5 years</td>
</tr>
<tr>
<td>Lumpsum</td>
<td>-</td>
</tr>
<tr>
<td>Duration</td>
<td>5 years</td>
</tr>
</tbody>
</table>

**Indoswe Engineers Ltd., Pune**

<table>
<thead>
<tr>
<th>Collaborator</th>
<th>Stettner &amp; Co., Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Collaboration</td>
<td>1986</td>
</tr>
<tr>
<td>Foreign Equity</td>
<td>DM 0.8 Million</td>
</tr>
<tr>
<td>Royalty</td>
<td>5% for 5 years</td>
</tr>
<tr>
<td>Lumpsum</td>
<td>-</td>
</tr>
<tr>
<td>Duration</td>
<td>5 years</td>
</tr>
</tbody>
</table>

### E. REFRACTORIES

**Orissa Industries Ltd., Cuttack**

<table>
<thead>
<tr>
<th>Collaborator</th>
<th>Taiko Refractories Co., Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Collaboration</td>
<td>1985</td>
</tr>
<tr>
<td>Foreign Equity</td>
<td>-</td>
</tr>
<tr>
<td>Royalty</td>
<td>2% for 2 years</td>
</tr>
<tr>
<td>Lumpsum</td>
<td>Japanese Yen 300 lakhs</td>
</tr>
<tr>
<td>Duration</td>
<td>-</td>
</tr>
</tbody>
</table>
Cutting Tools & Wear Parts

- Krupp Widia
- Paul Rauschert
- Stall. Porzellan
- Feldmühle
- Friedrichsfeld
- Heinz Welte

Heat Engines & Parts

- Annawaerk-Degussa
- Feldmühle
- HC Stark
- Diemler Benz
- ESK
- Sigri
- Rosenthal
- Volkswagen

57
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>R &amp; D Centre</th>
<th>Main Areas of Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>Industrial Materials Research Institute, Canada</td>
<td>Plasma coatings, non-destructive testing, wear resistant materials, semi-conductor coatings, PZT coatings and sensors.</td>
</tr>
<tr>
<td>12.</td>
<td>Ontario Research Foundation, Canada</td>
<td>Sol-Gel Technology, Engines, non-destructive testing.</td>
</tr>
<tr>
<td>13.</td>
<td>Max Planck Institute, Germany</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>14.</td>
<td>T.V. Berlin, Germany</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>15.</td>
<td>T.V. Clansthal-Zellerfield, Germany</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>16.</td>
<td>IZEP Saarbrucken, Germany</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>17.</td>
<td>T.V. Karlsruhe, Germany</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>18.</td>
<td>Universitat Erlangen, Germany</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>19.</td>
<td>DFVLR Koln, Germany</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>20.</td>
<td>NIRIM, USA</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>21.</td>
<td>DARPA, USA</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>22.</td>
<td>NASA, USA</td>
<td>High performance ceramics</td>
</tr>
<tr>
<td>23.</td>
<td>Pennsylvania University, USA</td>
<td>Dielectrics</td>
</tr>
</tbody>
</table>

64
# ANNEXURE - 2.3

## LIST OF EXISTING COLLABORATIONS IN THE FIELD OF ADVANCED CERAMICS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Product</th>
<th>Indian Company</th>
<th>Collaborator</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Electro-Ceramics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Multilayer Ceramic Capacitors</td>
<td>GM Chip Components</td>
<td>Novacap, USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dalmia Cement</td>
<td>Novacap, USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gujarat Poly-AVX</td>
<td>AVX Corp., USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ICICON</td>
<td>Iskara Commerce, Slovenia</td>
</tr>
<tr>
<td>2.</td>
<td>Hard Ferrites</td>
<td>Morris Electronics</td>
<td>Hitachi Metal, Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GP Electronics Ltd</td>
<td>Tokyo Kikai Sanyo, Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bihar State Electronics Corp.</td>
<td>Iskara Commerce, Slovenia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KSIDC</td>
<td>Iskara Commerce, Slovenia</td>
</tr>
<tr>
<td>3.</td>
<td>Soft Ferrites</td>
<td>Morris Electronics</td>
<td>Nippon Ferrites, Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Permanent Magnets</td>
<td>Sumitomo Special Metals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suchitra Electronics</td>
<td>DEG, Germany</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Webel Electro Ceramics Ltd</td>
<td>Unitra Polfer, Poland</td>
</tr>
<tr>
<td>5.</td>
<td>Ceramic tubes</td>
<td>BEL</td>
<td>NEC Corp., Japan</td>
</tr>
<tr>
<td>6.</td>
<td>Piezo Electronic Ceramic devices</td>
<td>MK Vijayshankar</td>
<td>Interquip Ltd., Hongkong</td>
</tr>
<tr>
<td>B.</td>
<td>Structural Ceramics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Advance (Tech.) Ceramics</td>
<td>NTB International P.Ltd</td>
<td>Lambertville Ceramics, USA</td>
</tr>
<tr>
<td>2.</td>
<td>Ceramic Thread Guides</td>
<td>NTB International P.Ltd</td>
<td>Lambertville Ceramics, USA</td>
</tr>
<tr>
<td>4.</td>
<td>Industrial Ceramics using</td>
<td>IVP Ltd</td>
<td>Feldmuehle KG, Germany</td>
</tr>
<tr>
<td></td>
<td>Injection Moulding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Industrial/Technical Ceramics</td>
<td>Carborundum Universal Ltd Widia (India) Ltd</td>
<td>Coors Ceramic Co., USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Krupp Widia, Germany</td>
</tr>
<tr>
<td>C.</td>
<td>Refractories</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Alumina &amp; other refractories</td>
<td>Orissa Industries Ltd</td>
<td>Harbison Walker, USA</td>
</tr>
<tr>
<td>2.</td>
<td>Continuous casting refractories</td>
<td>IFGL Rectractors Ltd</td>
<td>Harima Ceramic, Japan</td>
</tr>
<tr>
<td>3.</td>
<td>Refractories (Monolithics)</td>
<td>Grindwell Norton Ltd</td>
<td>Norton Co., USA</td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Product</td>
<td>Material</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>1.</td>
<td>Engine components-cum spring cap, fulcrum, roller followers, valve, valve guide.</td>
<td>Si₃N₄</td>
<td>Norton/TRW Ceramics Northboro, Ma, USA</td>
</tr>
<tr>
<td>2.</td>
<td>Prechamber for fuel injection in diesel engines.</td>
<td>Reaction bonded Si₂N₄</td>
<td>Daimler Benz, Germany</td>
</tr>
<tr>
<td>3.</td>
<td>Ceramic reinforced pistons for Mack tractors.</td>
<td>(80% Al₂O₃ + 20% SiO₂) fibre preform+squeeze cast aluminium</td>
<td>Wickes Manufacturing USA</td>
</tr>
<tr>
<td>4.</td>
<td>Valves for marine diesel engines.</td>
<td>SiC or Si₂N₄ bonded to Nimonic 80</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Gas turbine hot section components blades, vanes, rotors, combustor, liners, flame holders, struts.</td>
<td>Si₃N₄</td>
<td>Norton/TRW Ceramics Northboro, Ma, USA</td>
</tr>
<tr>
<td>6.</td>
<td>All ceramic bearings for aircraft engines.</td>
<td></td>
<td>Japanese companies</td>
</tr>
<tr>
<td>7.</td>
<td>Components for piston driven IC engines.</td>
<td></td>
<td>GTE and Eaton jointly USA</td>
</tr>
<tr>
<td>8.</td>
<td>Parts of compressor turbines for 150 HP two shaft engine.</td>
<td></td>
<td>Toyota, Japan</td>
</tr>
<tr>
<td>10.</td>
<td>Components for high temperature ballistic application.</td>
<td></td>
<td>DuPont and Landixxe jointly, USA</td>
</tr>
<tr>
<td>11.</td>
<td>Rollers for cold rolling of steel, aluminium sheets.</td>
<td>Sialon</td>
<td></td>
</tr>
</tbody>
</table>
## WORLD-WIDE RESEARCH CENTRES IN HI-TECH CERAMICS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>R &amp; D Centre</th>
<th>Main Areas of Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Centre National de la Recherche Scientifique (CNRS), France</td>
<td>Ceramic composites, sintering and properties of zirconia, ceramic-metal interfaces, plasma spraying, etc.</td>
</tr>
<tr>
<td>2.</td>
<td>Commissariat e l' Energie Atomique (CEA), France</td>
<td>Ceramics for nuclear applications, powders, hot isostatic pressing, plasma spraying.</td>
</tr>
<tr>
<td>3.</td>
<td>Office National d Etude et de Recherches Aerospatiales (ONERA), France</td>
<td>Ceramic composites, CVD coatings, gas turbine design and component testing.</td>
</tr>
<tr>
<td>4.</td>
<td>Rutgers University, USA</td>
<td>Glass formation from multicomponent alkoxide solutions; hydroxylated surfaces in sol-gel glasses and their use in ultrafiltration; sol-gel derived sealing materials for micro-electric packaging, thin film coatings using sol-gel processes, toughening of composite materials, atomic diffusion of glass surfaces.</td>
</tr>
<tr>
<td>5.</td>
<td>UK Atomic Energy Authority, UK</td>
<td>Plasma-coating Technology.</td>
</tr>
<tr>
<td>6.</td>
<td>Atomic Energy Research Establishment, Canada</td>
<td>Nuclear waste</td>
</tr>
<tr>
<td>7.</td>
<td>Atomic Energy of Canada, Canada</td>
<td>Ceramic processing</td>
</tr>
<tr>
<td>8.</td>
<td>Department of Defence, Canada - Defence Research Establishments</td>
<td>Ceramics for engines, fire safety, non-destructive testing, ceramics for transducers.</td>
</tr>
<tr>
<td></td>
<td>- Nova Scotia</td>
<td>Piezoelectric ceramics</td>
</tr>
<tr>
<td>9.</td>
<td>Dept. of Energy, Mines and Resources, Canada (Ceramics Section)</td>
<td>Dielectric ceramics, ceramics for energy conversion, thermal properties, ceramic processing.</td>
</tr>
<tr>
<td>10.</td>
<td>National Aeronautical Establishment, Canada</td>
<td>Hot-isostatic pressing, non-destructive testing, composites.</td>
</tr>
</tbody>
</table>
## MAJOR STRUCTURAL CERAMICS PROGRAMMES CURRENTLY UNDER PROGRESS

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Name</th>
<th>Organisation</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>AGT 100 and AGT 101 Projects</td>
<td>US Dept. of Energy</td>
<td>First phase lasting 5 years concluded without testing at designed operating temperature of 1350°C, projects being continued.</td>
</tr>
</tbody>
</table>
C. SILICON CARBIDE POWDER

U.S.A.

1. Norton Company
   1, New Bond Street, PB 15008
   Worcester, MA-01608
   USA
   Tlx: 920-428, 508-795-5741

Japan

1. Showa Denko
   13-9, Shiva Daimon 1-Chome
   Minato-Ku, Tokyo - 105
   Japan
   Tel: 03-432-5111

3. Fujimi Abrasive Co Ltd
   Nishibiwajima Cho
   Nishi Kasugai Gun, Aichi Pref 452
   Japan
   Tel: 052-501-6271

Germany

1. Hermann C. Stark
   Elisabeth Str 25/33
   Postfach 1560 -D-4520, Melle 1
   Germany
   Tel: 05422/1070

D. SILICON NITRIDE POWDER

U.S.A.

1. Elkem Metals
   PO Box 266
   Pittsburgh, PA - 15230
   USA
   Tlx: 866365, Fax: 412-787-1346

Japan

   Speciality Products Division
   1-7-7 Akasaka, Minata Ku, Tokyo
   Japan
   Tel: 03-585-3311

3. Denka
   Sanshi Building, 4-1 Yaraku Cho-1-Chome
   Chiyoda Ku, Tokyo 100
   Japan

Germany

1. Hermann C. Stark
   Elisabeth Str 25/33
   Postfach 1560 -D-4520, Melle 1
   Germany
   Tel: 05422/1070

2. Sohio Engineered Materials Co.
   PO Box 187
   Keasbey, NJ 08832
   USA
   Tel: 201-738-4600

2. Ilbiden Co.
   1, Kandamachi 2-Chome
   Ohaki City, Gifu 503
   Japan
   Tlx: 473920

2. GTE Products Corp.
   Chemical & Metallurgical Division
   Hawes Street, Towanda
   PA - 18848, USA
   Tlx: 834610, Fax: 717-265-1410

2. UBE Industries
   7-2 Kasumigaseki 3-Chome
   Chiyoda ku, Tokyo 100
   Japan
   Tlx: 2224645, Fax: (03) 505-9234
# INDIAN ORGANISATIONS ACTIVE IN R & D

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Name of Organisation</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Associated Cement Company (ACC)</td>
<td>Bombay</td>
</tr>
<tr>
<td>2.</td>
<td>Basic Technology Pvt Ltd.</td>
<td>Calcutta</td>
</tr>
<tr>
<td>3.</td>
<td>Bhabha Atomic Research Centre, Metallurgy Dept.</td>
<td>Bombay</td>
</tr>
<tr>
<td>4.</td>
<td>Bharat Heavy Electricals Ltd., Electro Porcelain Dvn.</td>
<td>Hyderabad</td>
</tr>
<tr>
<td>5.</td>
<td>Bharat Heavy Electricals Ltd., MHD Dvn.</td>
<td>Tiruchirapalli</td>
</tr>
<tr>
<td>6.</td>
<td>Carborundum Universal Ltd</td>
<td>Madras</td>
</tr>
<tr>
<td>7.</td>
<td>Central Glass &amp; Ceramic Research Institute (CGCRI)</td>
<td>Calcutta</td>
</tr>
<tr>
<td>8.</td>
<td>Ceramic Technological Institute (CTI)</td>
<td>Bangalore</td>
</tr>
<tr>
<td>9.</td>
<td>College of Ceramic Technology</td>
<td>Calcutta</td>
</tr>
<tr>
<td>10.</td>
<td>Dalmia Inst. of Scientific &amp; Industrial Research</td>
<td>Rajganagpur</td>
</tr>
<tr>
<td>11.</td>
<td>Defence Metallurgical Research Laboratory (DMRL)</td>
<td>Hyderabad</td>
</tr>
<tr>
<td>12.</td>
<td>Dept. of Ceramic Engg., BHV Inst. of Technology</td>
<td>Varanasi</td>
</tr>
<tr>
<td>13.</td>
<td>Grindwell Norton Ltd</td>
<td>Bangalore</td>
</tr>
<tr>
<td>14.</td>
<td>Indian Aluminium Ltd (INDAL)</td>
<td>Calcutta</td>
</tr>
<tr>
<td>15.</td>
<td>Indian Inst. of Technology, Materials Science Centre</td>
<td>Bombay</td>
</tr>
<tr>
<td>16.</td>
<td>IVP Limited</td>
<td>Bangalore</td>
</tr>
<tr>
<td>17.</td>
<td>Materials Technology Division, CPRI</td>
<td>Bangalore</td>
</tr>
<tr>
<td>18.</td>
<td>MSRIT</td>
<td>Bangalore</td>
</tr>
<tr>
<td>19.</td>
<td>NCML</td>
<td>Bombay</td>
</tr>
<tr>
<td>20.</td>
<td>Nalco, R &amp; D Lab</td>
<td>Orissa</td>
</tr>
<tr>
<td>21.</td>
<td>RDCIS, SAIL</td>
<td>Ranchi</td>
</tr>
<tr>
<td>22.</td>
<td>RRL</td>
<td>Trivandrum</td>
</tr>
<tr>
<td>23.</td>
<td>RVCE</td>
<td>Bangalore</td>
</tr>
<tr>
<td>24.</td>
<td>Tata Steel</td>
<td>Jamshedpur</td>
</tr>
<tr>
<td>25.</td>
<td>Widia (India) Ltd</td>
<td>Bangalore</td>
</tr>
</tbody>
</table>

67
3. Nippon Ceramic Ltd
   15-2 Nanei Cho
   Totton Shi
   Totton 689-11
   Japan
   Tel: 0857-53-3600

5. Sumitomo Special Metals
   5-22, Kitahama 5-Chome
   Higashi Ku
   Osaka 541
   Japan
   Fax: (06) 411-0974

4. Dowa Mining Co Ltd
   26 Orwake Nishi
   Tenno Cho, Minamiakita Gun
   Akita 010-01
   Japan
   Tlx: J 26298

6. Shin Etsu Chemical Co
   6-1 Ohke Machi 2-Chome
   Chiyoda Ku
   Tokyo-100
   Japan
A. ALUMINA POWDER

U. S. A.

1. Aluminium Co. of America (ALCOA)
   PO Box 300
   Bauxite
   AR - 72001
   USA
   Tlx: 536447, Fax: 501-776-4685

2. Kaiser Aluminium & Chemical Corp.
   3000, Lakeside Drive
   Oakland, CA-94643
   USA
   Tel: 415-271-3300

3. Reynolds Metal Company
   Raw Materials Division
   Aluminium Division Technology
   PO Box 9911, Corpus Christi
   USA
   Tlx: 78469-9911, Fax: 512-777-2218

4. Sumitomo Chemical America
   345, Park Avenue
   New York
   NY 10054
   USA
   Tel: 212-207-0603

5. Union Carbide Corporation
   Industrial Chemicals Division
   750, South 32nd Street
   Washougal, WA-98671, USA
   Tel: 206-835-8566

Japan

   10-14, Inage Higashi 2-Chome
   Chiba-281
   Japan
   Tel: 0472-43-7321

2. Mitsubishi Kasei Corp.
   5-2, Marunouchi Chi-2, Chome
   Chiyoda ku, Tokyo - 100
   Japan
   Tlx: (03) 283-6274

   26-10, 2 Chomo Tenjin
   Naganokyo Shi, Kyoto-617
   Japan
   Tlx: J 64270

5. Otsuka Ceramics Inc.
   30, Nagalsuka
   Shimosuma Shi, Ibaraki 304
   Japan
   Tel: (0296) 44-3165

B. ZIRCONIA POWDER

U.S.A.

1. TAM Ceramics
   4511, Hyde Park Boulevard
   Bridge Station, Box-C
   Niagara Falls, NY 14305
   USA
   Tlx: 710-524-1659

Germany

1. Harshaw Chemie GmbH
   Viktoria Str 5, D-5632, Wermels Kirchen-1
   Germany
   Tel: 02196/3097

2. Kyocera Corporation
   5022, Kitainoue-Chou
   Higashino, Yamachinaku
   Kyoto-607, Japan
   Tlx: 5422-479 KCIPAN J
   Fax: 075-502-3696

3. Tokyo Cathode Laboratory
   10-14, Itabashi 1-Chome
   Itabashi, Ku, Tokyo-173
   Japan
   Tel: (03) 962-8311

U.K.

1. Magnesium Elektron Inc.
   Regal House, London Road
   Twickenham
   TW 1-30A
   UK
   Tel: 01-892-4488

Japan

   Speciality Products Div., 1-7-7 Akasaka
   Minata-Ku, Tokyo, Japan
   Tel: 03-585-3311
B. CERAMIC SUBSTRATES

U.S.A.

1. Adolf Meller
   PO x 6001 T
   Providence, Rhode Island 02940
   USA
   Tel: (401) 331-3717

2. Ceramtec Inc.
   2455, 900 West
   Salt Lake City, UT 84119
   USA
   Tel: 801-972-9455

3. Champion Spark Plug Co.
   2000, Conner Avenue
   Detroit, MI 48234
   USA
   Tel: 318-891-4040

4. Hidensity
   455, Queens Lane
   San Jose, CA-95134
   USA
   Tel: 408-262-5354

5. Hybrid Tek
   Route:516, Millstone Road
   Clarksburg, NJ 08510
   USA
   Tel: 201-922-4020

6. Interamics
   11353, Sorrento Valley Road
   San Diego, CA-921121
   USA
   Tel: 619-359-7928

7. August Inc.
   33, Perry Avenue
   Attleboro, MA-02763
   USA
   Tlx: 650-398-4109, Fax: 508-699-9106

8. Diamon Inc.
   4812, Kearny Mesa Road
   San Diego, CA-92111
   USA
   Tel: 619-279-6992

9. Du Pont Electronics
   Barley Mill Plaza
   Wilmington, DE-19898
   USA

10. General Ceramics Inc.
    Greenwood Avenue, Haskell
    NJ 07420, USA
    Fax: 201-839-5716

11. Hoechst Ceramtech
    171, Forbes Bldg.
    Mansfield, MA-02048
    USA

12. Paktek Incorporated
    7025, Brethare Drive, San Jose
    CA 95120, USA
    Tlx: 650-131-9707

Japan

1. Kyoto Ceramic
   52-11, Inoeucho, Higashino
   Yamamachinaku, Kyoto-607
   Japan
   Tel: 075-592-3851

2. Kyocera Corporation
   5-22, Kitainoue Cho, Higashino
   Yamamachinaku, Kyoto-607
   Japan
   Tlx: 5422-479, Fax: 075-502-3696

   26-10, 2 Chomo Tenjin
   Nagaokyo Shi, Kyoto-617
   Japan
   Tlx: J 64270

4. NGK Spark Plug
   14-18, Takatsuji Cho, Mizohu-Ku
   Nagoya 467-91
   Japan
   Tlx: 159592, Fax: (0568) 76-1297

5. Toshiba Ceramics
   8, Shin Sugita Cho, Isogo Ku
   Yokohama, Kanagawa-235
   Japan
   Tel: 045-774-111

6. Narumi China Corp.
   3, Denji Yama, Narumi-Chu
   Midori-Ku, Nayoga Shi, Aichi-458
   Japan
   Fax: (08375) 3-1209
E. SIALON POWDER

U.K.

1. Vesuvius Zyalons
   Tonyrefail Porth, Mid Glamorgan
   CF 39 8 YW, Wales
   UK
   Tel: 44-443-670666

2. Lucas Cookson Sayalon Ltd
   Cranmore Boulevard, Shirley Solihull
   West Midlands B 90 4 LL
   UK
   Tlx: 338526

F. BARIUM TITANATE POWDER

U.S.A.

1. TAM Ceramics
   4511, Hyde Park Boulevard
   Bridge Station, Box-C
   Niagara Falls, NY 14305
   USA
   Tlx: 710-524-1659

2. AVX
   PO Box 867, Myrtle Beach
   South Carolina
   SC 29577
   USA
   Tlx: 810-661-2252

3. Corning Glass International
   Houghton Park, HP-AB-02
   Corning, NY-14831
   USA
   Tlx: 932-499

4. Union Carbide Corp.
   Route 276
   South East Greenvillia, SC 29606
   USA

5. Ferro Corporation
   Transcelo Division
   Penn Yann, NY-14527
   USA
   Tel: 315-536-3357

Japan

1. Kyoto Ceramic
   52-11, Inoue Cho, Higashino
   Yamashina Ku, Kyoto 607
   Japan
   Tel: 075-592-3851

   26-10-2, Chomo Tenjin
   Jagaokyo Shi, Kyoto 617
   Japan
   Tlx: J 64270

3. Taiyo Yuden
   16-20 Ueno-6-Chome
   Taitaku, Tokyo-110
   Japan
   Tlx: 265-5169, Fax: (03) 835-4754

G. FERRITE POWDER

U.S.A.

1. Ferrites Inc.
   52, North Main Street
   Fairport, NY 14450
   USA
   Tel: 716-223-1010

Japan

1. Hitachi Metal
   1-2 Marunouchi-2-Chome
   Chiyoda Ku, Tokyo 100
   Japan
   Tlx: J 24494

2. DM Steward Company
   PO Box No.510
   Chatanooga, TN - 37401
   USA
   Fax: 615-867-4102

   4926-10, 2 Chmo Tenjin
   Nagaokoya Shi, Kyoto-617
   Japan
   Tlx: J 64270
5. Vemitron Corporation
Piezo-Electric Division
232, Forbs Road
Bedford, OH 44146
USA
Tel: 216-232-8600

Japan

1. Asahi Glass Co.
102, Marunouchi 2-Chome
Chiyoda Ku, Tokyo 100
Japan
Tel: (03) 218-5555

3. Fuji Electro Chemical
Hamagomu Building
36-11 Shinbashi 5-Chome
Minato Ku, Tokyo 105
Japan
Tlx: 242-2174

5. Kyocera Corporation
5-22, Kitainoue-Cho, Higashino
Yamachinaku, Kyoto 607
Japan
Tlx: 5422-479, Fax: 075-502-3696

7. NGK Spark Plug
14-18, Takatsuki Cho
Mizohu-Ku, Nagoya 476-91
Japan
Tlx: J 59592, Fax (0568) 76-1297

9. Nippon Ceramic
15-2, Nanei Chu, Totton Shi
Totton 689-11
Japan
Tel: (0857) 53-3600

11. Tokyo Ceramics Co.
8-10, Toranomon 1-Chome
Minato Ku, Tokyo 105
Japan
Tel: (03) 591-8408

E. CERAMIC SENSORS

1. Dale Electronics Inc.
2064, 12th Avenue
Columbus, WE 68601
USA
Tel: 401-564-3131

Refractories Division
PO Box 187
Keasbey, NJ 68832
USA
Tel: 201-738-4600

2. Fuji Ceramics
2320-11, Yamamiya, FujinomuJa Shi
Shizuoka 418-01
Japan
Tel: (0544) 58-4651

4. Hitachi Metals
1-2 Marunouchi-2 Chome
Chiyoda Ku
Tokyo 100
Japan
Tlx: J 24494

4926-10, 2 Chomo Tenjin
Nagaokakyo Shi, Kyoto 617
Japan
Tlx: J 64270

8. Ni-Cera Corporation
7-1 Chiyoda 5-Chome
Sakado Shi, Saitama 350-02
Japan
Tel: (0492) 81-8111

10. Sumitomo Special Metals
5-22 Kitahama 5-Chome
Higashi Ku, Osaka 541
Japan
Fax: (06) 411-0974

2. Leach Corporation
6900, Orangethorpe Avenue
Buena Park, CA 90620
USA
Tel: 817-325-7871

4. Betatherm Corporation
910, Turnpike Road
Route:9, Shrewsbury
MA 01545
USA
Tlx: 508-842-0748
ELECTRO-CERAMICS MANUFACTURERS

A. MULTILATER CAPACITORS

U.S.A.

1. AVX Corp.
   PO Box 867, Myrtle Beach
   South Carolina, SC-29577
   USA
   Tel: 810-661-2252

2. Corning Glass International
   Houghton Park, HP-AB-02
   Corning, NY 14386
   USA
   Tlx: 932-499

3. Johanson Dielectric Inc.
   2720, Screenland Drive
   Burbank, California-91505
   USA
   Tel: 818-848-4465

4. Sprague Electric Co
   149 Marshall Str.
   MA-01247
   USA
   Tlx: 926415, Fax: 710-369-1360

5. Thin Film Technology Inc.
   153, Industrial Way
   Buellton, California 93427
   USA

6. Unitrode Corporation
   11494, Sovertno Valley Road
   San Diego, CA 92121
   USA
   Tel: 619-453-8020

Japan

1. Kyoto Ceramic
   52-11, Inoeu Cho, Higashino
   Yamashina Ku, Kyoto 607
   Japan
   Tel: 075-592-3851

   26-10-2, Chomo Tenjin
   Jagaokyo Shi, Kyoto 617
   Japan
   Tlx: J 64270

3. Taiyo Yuden
   16-20 Ueno-6-Chome
   Tsitaku, Tokyo-110
   Japan
   Tlx: 265-5169, Fax: (03) 835-4754

4. Tokin Corp.
   Hazama Bldg., 5-8 Kita Aayoma
   2-Chome, Minato Ku, Tokyo 107
   Japan
   Tlx: 02422694, Fax: (03) 497-9756

5. TDK Electronics Co. Ltd
   1301, Nihon Bash 1-Chome
   Chuo Ku, Tokyo
   Japan
   Tlx: J 26937

6. Hitachi Condenser Co Ltd
   31-1, Nishi Gotanda-1-Chome
   Singagawa Ku, Tokyo 141
   Japan
   Tlx: J 22447

7. NEC Corporation
   33-1, Shiba 5 Chome
   Minata Ku, Tokyo 108
   Japan
   Tlx: J 22686

Germany

1. Asternetech GmbH
   Linden regis 3, DD-8028
   Tajkinchen
   Germany

2. MSK Corporation
   Tokan No.2 Castle, Room:1011
   5-12 Nishi Shinjuku 3-Chome
   Shinjuku Ku, Tokyo 108, Japan
   Tlx: 0232-4988, Fax: (03) 342-6534
STRUCTURAL CERAMICS MANUFACTURERS

A. CERAMIC CUTTING TOOLS

U.S.A.

1. Coors Ceramic Co.
   600, Ninth Street
   Golden, CO-80401
   USA
   Tlx: 45-593

2. Babcock and Wilcox
   Nucormet, PO Box 687
   Hendersonville, NC 28893
   USA
   Tel: 800-438-0233

3. Carboloy Systems Department
   General Electric Co.
   Box 237, GPO
   Detroit, MI 48232
   USA
   Tel: 313-536-9100

4. Carment Materials Division
   1100 E, Mandoline
   Madison Heights, MI-48232
   USA
   Tel: 313-566-3190

5. Greenleaf Corp.
   Greenleaf Dr.
   Saegertown, PA 16433
   USA
   Fax: 814-763-4137

6. GTE Electrical Products Corp.
   Precision Materials Group
   100, Endicott Street
   Danvers, MA 01923
   USA
   Tel: 617-777-1900

7. Kennametal Inc.
   PO Box 346
   Latrobe, PA 15650
   USA
   Tlx: 866-674, Fax: 412-539-5079

8. Kyocera International Inc.
   Cutting Tool Division
   8611, Balboa Avenue
   San Diego, CA 92123
   USA
   Tlx: 697-929

   1, New Bond Street
   PB 15008
   USA
   Tlx: 920-428, Fax: 508-795-5000

10. NTK Cutting Tools Division
    NGK Spark Plugs (USA) Inc.
    10551, Allen Road, Allen Park
    MT-48101, USA
    Tel: 313-381-1793

11. Sumitomo Electric Industries
    Sumiden Carbide America Inc.
    5627, Howard St., Niles
    ILL-60648, USA
    Tel: 312-647-8293

12. TRW Carube Tools Div.
    205 N 13 Str.
    Rogers, Arkansas 72755
    USA
    Tel: 501-636-1515

    Valeron Corp.
    31100, Stephenson Highway
    Madison Heights, MI-48071
    USA
    Tel: 313-548-7055

14. VR/Wesson Division
    Fransteel
    800, Market St., Waukegan
    ILL-60085, USA
    Tel: 312-689-5000

Japan

1. Kyocera Corporation
   5-22 Kitainoue Cho, Higashino
   Yamuchinaku, Kyoto 607
   Japan
   Tlx: 5422-479, Fax: 075-502-3696

2. Mitsubishi Metals
   S-2, Otemachi 1-Chome
   Chiyoda Ku, Tokyo 100
   Japan
   Tel: (03) 270-8451
C. FERRITES

U.S.A.

1. Ampex Electronics Corp.
   Ferrox Cube Division
   5083, Kings Highway, Sangerties
   New York 12477
   USA
   Tel: 914-246-2811

2. DM Steward Company
   PO Box 510
   Chattanooga, TN 37401
   USA
   Fax: 615-867-4102

3. Ferrites Inc.
   52, North Main Street
   Fairport, NY 14450
   USA
   Tel: 716-223-1010

Japan

1. Fuji Electro Chemical Co.
   Hamagomu Building
   36-11, Shinbashii 5-Chome
   Minata Ku, Tokyo 105
   Japan
   Tlx: 242-2174

2. Hitachi Metal
   1-2 Marunouchi 2-Chome
   Chiyoda Ku
   Tokyo 100
   Japan
   Tlx: J 24494

   46 26 10 , 2 Chomo Tenjin
   Nagaokokyoshi, Kyoto 617
   Japan
   Tlx: J 64270

4. Nippon Ferrites
   1-25, 1 Hyakunin Cho
   Shinjuku Ku, Tokyo 160
   Japan
   Tel: (03) 363-7571

5. Sumitomo Special Metals
   5-22, Kitahama 5-Chome
   Higashi Ku, Osaka 541
   Japan
   Fax: (06) 411-0974

6. TDK Corporation
   13-1, Nihonbashi 1-Chome
   Chu Ku, Tokyo
   Japan
   Tlx: J 26937

7. Taiyo Yuden
   16-20, Ueno-6-Chome
   Taitaku, Tokyo 10
   Japan
   Tlx: 265-5169, Fax: (03) 835-4754

8. Dowa Mining Co Ltd
   8-2 Marunouchi 2-Chome
   Chiyoda Ku, Tokyo 100
   Japan
   Tlx: J 26298

9. Nippon Ceramic Ltd
   15-2 Nanei Cho
   Totton-Shi, Totton 689-11
   Japan
   Tel: (0857) 53-3600

D. PIEZO-ELECTRICS

U.S.A.

1. American Piezo Ceramics
   Duck Run Road, PO Box 180
   Mackeyville, PA-17750
   USA
   Tel: 717-726-6961

2. EDO Corporation (Western Division)
   2465, South 300th West
   Salt Lake City, UT 84115
   USA
   Tlx: 388-315, Fax: 801-486-3846

3. Honeywell Incorporated
   Undersea Systems Division
   Hopkins, MN 55343
   USA
   Tel: 612-931-6333

   645, W. 11th Str.
   Erie, PA 16512
   USA
   Tlx: 91-4437, Fax: 814-452-4050
11. Carborundum Co.
   345, 3rd Street
   PO Box 156, Niagara Falls
   NY 14302, USA
   Fax: 716-278-2900

12. Duramic Products Inc
    428, Commercial Avenue
    Palisades Park
    NJ 07650, USA
    Tlx: 710-991-9632

13. DFC Ceramics Inc
    PO Box 110-7
    Canton City, Colorado 81212
    USA
    Tlx: 296-440, Fax: 719-275-2051

14. Hoover Universal
    1390, Industrial Park Drive
    Sault Ste., Marie
    MI 49783, USA

15. Champion Spark Plug Co
    (Ceramic Division)
    20000-T, Conner, Detroit
    MI 48234, USA
    Tel: 313-891-4040

16. Howell Ceramic Mfg. Co
    Dept C, 430, Railroad Avenue
    Brevard, NC 28712
    USA
    Tel: 704-883-2310

17. Maryland Ceramic Steatite Co. Inc.
    PO Box 527-T, Bel Air
    Maryland 21014
    USA
    Tlx: 301-838-4114

18. Armeco Products Inc.
    21, Snowden Avenue
    Ossining, NY 10562
    USA
    Tlx: 137441

19. Astromet Associates Inc.
    9974, Springfield Pike
    Cincinnati, OH 45215
    USA
    Tel: (513) 772-1242

20. Ferro Corporation
    1000 Lakeside Avenue
    Cleveland, OH 44114
    USA
    Tlx: 980-165, Fax: 216-696-6958

Japan

1. Kyocera Corporation
   5-22, Kitainoue Cho, Higashino
   Yamachinaku, Kyoto 607
   Japan
   Tlx: 5422-479, Fax: 075-502-3696

2. Fujikin International Inc.
   1-4-8 Shibata, Kita Ku
   Osaka 530
   Japan
   Tlx: 5234204

3. Centuri Koeki Ltd
   2-5-8 Minami Semba
   Minami Ku, Osaka 542
   Japan
   Tlx: J 64972

4. Nagase and Co. Ltd
   5-1 Nihombashi Kobunacho
   Chuo Ku, Tokyo 103
   Japan
   Tlx: J 24737

5. Toshiba Denko Co. Ltd
   8-3-7, Ginza, Chuo Ku
   Tokyo 104
   Japan
   Tlx: J 27652

6. Toto Kiki K.K.
   2-1-1 Nakashima, Kokura-Kita-Ku
   Kitakyushu 802
   Japan
   Tlx: 712835

7. Token Industries Co. Ltd
   3-30, Kawabato Cho, Seto City
   Aichi-489
   Japan
   Tlx: 04496-024

8. Denki Kagaku Kogyo
   Sanshin Building
   4-1 Yuraku Cho 1-Chome
   Chiyoda Ku, Tokyo 100
   Japan
   Tlx: J 22647

9. Hitachi Ltd
   5-1 Marunouchi 1-Chome
   Chiyoda Ku
   Tokyo 100
   Japan
   Fax: 03-287-1793

10. Kurosaki Refractories Ltd
    14-20, Ginza 6-Chome
    Arakawa Ku
    Tokyo 116
    Japan
5. Corning Glass Works
(Ceramics Dept)
MP-WX-02-02
Corning, NY 14831
USA
Tel: 932-499

600, Penn State Boulevard
PO Box 426, Pittsburgh
PA 15235, USA
Tel: 812-453, Fax: 412-967-3451

Japan

1. Hitachi Metal
1-2 Marunouchi 2-Chome
Chiyoda Ku, Tokyo 100
Japan
Tel: J 24494

3. Mitsubishi Mining & Cement Co.
5-1, Marunouchi 1-Chome
Chiyoda Ku, Tokyo 100
Japan
Fax: (03) 5396-0008

4926-10, 2 Chomo Tenjin
Nagakyo Shi, Kyoto 617
Japan
Tel: J 64270

7. Sanyo Electric Co.
18, Keihan Hondom 2-Chome
Monguchi Shi, Osaka 570
Japan
Tel: (06) 991-1181

9. TDK Corporation
13-1, Nihon Bashu 1-Chome
Chuo Ku, Tokyo, Japan
Tel: J 26937

11. TOEI Electronics Co Ltd
Kanda Cent Building
2-4 Yushima 1-Chome
Bunkyo Ku, Tokyo 113
Japan
Tel: J 32699

5-4 Mitsuya Naka 2-Chome
Yodogawa Ku
Osaka 532
Japan
Tel: (06) 308-2111

6. General Monitors
3037, Enterprise St.
Costa Mesa, CA 92626
USA
Tel: 714-540-4895

8. Rexnord
207, East Java Drive
Sunnyvale, CA 94086
USA
Tel: 408-734-1221

2. Hokunku Electric Industry
3158 Shimo Okubo, Osawanomachi
Kami Nikawa Gun, Toyama 939-22
Japan
Tel: (0764) 67-1111

4. MSK Corporation
Tokan No.2 Castle, Room:1011
5-12 Nishi Shinjuku 3-Chome
Shinjuu Ku, Tokyo 160
Japan
Tel: 0232-4488, Fax: (03) 342-6534

6. Nichicon Corporation
Machara Building
Olkodon, Kataoma, Higashi Ku
Nakagyo Ku, Kyoto 604
Japan
Tel: (075) 231-8461

8. Taiyo Yuden
16-20, Ueno 6-Chome
Taitaku, Tokyo 10, Japan
Tel: 265-5169, Fax: (03) 835-4754

10. Technical Seven
3-10 Kamoi 1-Chome, Midon Ku
Yokohama Shi, Kanagawa 226
Japan
Tel: (045) 931-3321

12. Tokyo Cathode Laboratories
10-14 Itabashi 1-Chome
Itabashi Ku
Tokyo 173
Japan
Tel: (03) 962-8311

14. Toshiba Ceramics
8, Shin Sugita Cho
Isogo Ku, Yokohama
Kanagawa 235
Japan
Tel: (045) 774-1111
Germany

1. Paul Rauschert GmbH and Co. KG
   Bahnhofstrasse-1
   Postfach 1120
   D-8644, Pressig
   Germany
   Tlx: 642626

2. Feldmühle KG
   Feldmühle Aktiengesellschaft
   Postfach 3029
   D-4000
   Dusseldorf-1
   Germany

3. Krupp Widia GmbH
   Münchner Str.
   90, Postfach 102161
   D-4300, Essen 1
   Germany
   Tlx: 0857180

4. Friedrichsfeld GmbH
   Steinzeugtrope 50
   Postfach 7
   D-6800 Mannheim 71
   Germany
   Tlx: 0463103

5. Staatsliche Porzellan
   WegelysBe-1
   D-1000, Berlin
   Germany
   Tlx: 181356

   Max Planck Str.7
   Postfach 3222
   D-5030 Hurth-Hermulheim
   Germany
   Tlx: 8882843
3. NGK Spark Plug
14-18 Takatsuji Cho, Mizohu Ku
Nagoya 476-91
Japan
Tlx: J59592, Fax: (0568) 76-1297

5. Sumitomo Electric Industries Ltd
15, Kitahama 5-Chome
Higashi Ku, Osaka 541
Japan
Tel: (06) 220-4141

4. Nippon Tungsten
460 Sanno, Shiobaru, Minami Kui
Fukuoka, Fukuoka Prefecture 815
Japan
Tlx: 722557

6. Toshiba Tungaloy
1-7, Tsukagoshi, Saiwai Ku
Kawasaki, Kanagawa Pref. 210
Japan
Tlx: 3842-334

1. Feldmuhle
Feldmuhle Aktiengesellschaft
Postfach 3029, D-4000
Dusseldorf-1
Germany
Tel: 0211-581-1

2. Krupp Widia GmbH
Munchener Str.
90, Postfach 102161, D-4399
Essen-1
Germany
Tlx: 0463-103

1. Lucas Cookson Syalons Ltd
Cranmore Boulevard
Shirley Solihull
West Midlands B90 4LL
U.K.

B. CERAMIC WARE PARTS

U.S.A.

1. Coors Porcelain Co.
600, Nineth Street
Golden, CO-80401
USA
Tlx: 45-593

2. Ceramtec Inc.
2455, 900 West
Salt Lake City
UT 84119, USA
Tel: 801-972-9455

3. Dylon Ceramic Technologies Corp.
5201 Dension Avenue
Cleveland, OH 44112
USA
Fax: 216-651-1777

4. Hi Tech Ceramics
PO Box 1105
Alfred, NY 14546
USA
Tel: 607-587-9146

5. Kyocera Feldmuhle
PO Box 678
Mountain Home, NC 28738
USA
Tel: 704-693-0241

245 North Main Street
PO Box 128
Lamberstville, NJ-08530
USA
Tlx: 642-212

1, New Bond Street
Post Box: 15008
Worcester, MA 01608
USA
Tlx: 920-428, Fax: 508-795-5741

8. PAKCO Industrial Ceramics
56 Hillview Avenue
Latrobe, PA 15650
USA
Tel: 412-539-6000

9. Corning Glass Works
(Ceramics Department)
MP-WX 02-02
Corning, NY 14831
USA
Tel: (607) 974-4231

10. NILCRA Ceramics USA
180, West Park Avenue
Elmhurst, IL 60126
USA
Tel: 312-941-0221
11. Toshiba Ceramics Co. Ltd  
   1-26-2, Nishi-Shinjuku  
   Tokyo 163  
   Japan  
   Tlx: 232-4140

12. NGK Spark Plug Co.  
   14-18 Takatsuji Cho, Mizohu Ku  
   Nagoya 47691  
   Japan  
   Tlx: J 59592, Fax: (0568) 76-1297

13. Mitsubishi Metals  
   5-2 Otemachi 1-Chome  
   Chiyoda Ku  
   Tokyo 100  
   Japan

14. Nagaoka Kanaanei Ltd  
   812-4, Hira, Mitara-Cho  
   Minamikawachi Gun  
   Osaka  
   Japan

U.K.

1. Lucas Cookson Syalon Ltd  
   Cranmore Boulevard  
   Shirley Solihull  
   West Midlands B90 4LL  
   U.K.  
   Tlx: 338526

2. Vesuvius Zaylons  
   Tonyrefail Porth  
   Mid Glamorgan  
   CF39 8 YW, Wales  
   U.K.

3. Doulton Insulators Ltd  
   Two Gates, Tamworth  
   Staffs B77 5 AA  
   U.K.  
   Tlx: 341116

4. Northern Mill Thread Guides  
   Mersey Industrial Estate  
   Heaton mersey, Stockport  
   Cheshire SK4 3EF  
   U.K.  
   Tlx: 635091

5. Steatite and Porcelain Products Ltd  
   Bewdley Road  
   Stourport - on - Seven  
   Worcester DY 13 8 QR  
   U.K.

6. Norton Industrial Ceramics Ltd  
   King St., Fenton  
   Stock-on-Trent 3 LY  
   U.K.  
   Tlx: 36179

7. Morgan Refractories Ltd  
   Liverpool Road, Neston  
   Wirrel, Merseyside L64 3 RE  
   U.K.  
   Tlx: 627174

8. Doulton Industrial Products  
   Stone, Staffs, ST 15 O PU  
   U.K.

9. Coors Ceramic UK Ltd  
   35, Cavendish Way  
   Southfield Industrial Estate  
   Glenrothes, Fife KY 7 5 PR  
   U.K.  
   Tlx: 728214

10. Royal Worcester Industrial Ceramics Ltd  
    Gilfach Road  
    Ronyrefail, Porth  
    Mid Glamorgan CF 39, 8 YW  
    U.K.  
    Tlx: 498534

    St. Peters Road  
    Rugby, Warwickshire CV 21 3 QR  
    U.K.
HIGH PURITY POWDERS FROM SOL-GEL METHOD
BY THERMO CHEMICAL INDUSTRY, JUNAGADH

M/s Thermo-Chemical Industry, Junagadh produces High Purity Calcined Alumina and Barium Titanate by Sol-Gel Method. They are preparing both ceramic precursors by this method and have obtained purity above 99.98 +/-% with controlled particle size.

Final products made from such high quality powders are economical and superior in quality.

**FLOW CHART FOR THE MANUFACTURE OF ALUMINA AND BARIUM TITANATE POWDER FROM SOL-GEL METHOD**

<table>
<thead>
<tr>
<th>ALUMINA POWDER</th>
<th>BARIUM TITANATE POWDER</th>
</tr>
</thead>
<tbody>
<tr>
<td>99% Alumina</td>
<td>Organic Solution of Ti(O\textsuperscript{Bu})\textsubscript{4} or Ti(O\textsuperscript{Pr})\textsubscript{4}, or Ti(OEt)\textsubscript{4}</td>
</tr>
<tr>
<td>Al-Metal</td>
<td>Saturated Solution of Ba(OAC)\textsubscript{2} in H\textsubscript{2}O + AcOH added</td>
</tr>
<tr>
<td>High Purity Al-Metal</td>
<td>Complexation Homogenous Solution Prepared</td>
</tr>
<tr>
<td>Organo-Metallic Product</td>
<td>Slow/Fast Hydrolysis Condensation</td>
</tr>
<tr>
<td>Boehmite Precipitation</td>
<td>Alcohol-Acetic Monolithic Gel</td>
</tr>
<tr>
<td>Stable Solution to films or pasten</td>
<td>Drying</td>
</tr>
<tr>
<td>Calcination</td>
<td>Reactive amorphous BaTiO\textsubscript{3} Ceramic Precursors</td>
</tr>
<tr>
<td></td>
<td>Ceramic Capacitors</td>
</tr>
</tbody>
</table>

Product purity above 99.99% with particle size from 25 n-m to 100 \mu m
1.2 INDUSTRY STATUS
Till two years ago, multilayer ceramic capacitors were not manufactured in India. Imports were then the only alternative. There has been since, substantial capacity creation within the country.

Presently, there are two manufacturers of MLCs in the country. They are:

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Company</th>
<th>Capacity per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>GM Chip Components Ltd., Hyderabad</td>
<td>200 million MLCs</td>
</tr>
<tr>
<td>2.</td>
<td>Dalmis Cement (Bharat) Ltd.</td>
<td>120 million MLCs</td>
</tr>
</tbody>
</table>

In addition to these, Gujarat Poly-AVX Electronics and ICICON Electronics are setting up plants to manufacture MLCs. The former is setting up a capacity of 250 million pieces and the later, 100 million pieces. Both projects are expected to commence production by the end of 1992. This will take the domestic installed capacity to 670 million pieces.

The recent trend of increasing penetration of multilayer capacitors into conventional capacitors market indicates good prospects for multilayer ceramic capacitors. Hence, few new projects have been proposed.

1.3 MARKET POTENTIAL
The major user segments for MLCs are:

1. Consumer Electronics : Radio, Tape Recorder, TV, etc.
2. Industrial Electronics : Power Electronics, Process control etc.
3. Commercial Electronics : Computers, Peripherals, Office equipments etc.
4. Telecom and Defence Electronics

There are various types of capacitors available in the Indian Market. The table below shows the Demand Projections made by Electronics Information and Planning Committee.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic film</td>
<td>350</td>
<td>800</td>
<td>2300</td>
</tr>
<tr>
<td>Electrolytic</td>
<td>575</td>
<td>1300</td>
<td>3700</td>
</tr>
<tr>
<td>Tamtalam</td>
<td>5</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>Ceramic</td>
<td>650</td>
<td>1600</td>
<td>4300</td>
</tr>
<tr>
<td>- Disc type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- MLC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gang Condensors</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>1588</td>
<td>3720</td>
<td>10360</td>
</tr>
</tbody>
</table>

Source: Electronics Information and Planning

84
<table>
<thead>
<tr>
<th>SR. NO</th>
<th>NAME OF PROFILE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Multilayer Ceramic Capacitors</td>
<td>83</td>
</tr>
<tr>
<td>02</td>
<td>Ceramic IC Substrates</td>
<td>91</td>
</tr>
<tr>
<td>03</td>
<td>Ferrites - Hard and Soft</td>
<td>98</td>
</tr>
<tr>
<td>04</td>
<td>Ceramic Sensors</td>
<td>108</td>
</tr>
<tr>
<td>05</td>
<td>Grinding Media And Nozzles</td>
<td>116</td>
</tr>
<tr>
<td>06</td>
<td>Thread Guides</td>
<td>123</td>
</tr>
<tr>
<td>07</td>
<td>Mechanical Seal Faces and Tap Seal Discs</td>
<td>129</td>
</tr>
<tr>
<td>08</td>
<td>Material Handling Liners</td>
<td>134</td>
</tr>
<tr>
<td>09</td>
<td>Special Refractories</td>
<td>139</td>
</tr>
<tr>
<td>10</td>
<td>Alumina Powder For Structural Applications</td>
<td>145</td>
</tr>
<tr>
<td></td>
<td><strong>RECOMMENDATIONS</strong></td>
<td>150</td>
</tr>
</tbody>
</table>
**CHART-1**

**PRINCIPAL STEPS IN THREE MLC PROCESSES:**
*WET, DRY AND FUGITIVE - ELECTRODE*

1. **Wet Process**
   - Prepare slip
   - Screen electrodes onto dried dielectric layers
   - Deposit dielectric layers

2. **Tape cast dry process**
   - Cast Tape
   - Stack dielectric sheets into master pads
   - Screen Electrode

3. **Fugitive Electrode process**
   - Dice
   - Binder Burnout
   - Fire
   - Terminate
   - Test
   - Attach Leads
   - Encapsulate
   - Package

- **Preheat**
- **Evacuate**
- **Inject Electrode**
- **Solidify Electrode**
1.1 PRODUCT DESCRIPTION

A capacitor is a component in an electronic/electrical circuit which stores electric charge. It primarily, consists of pair of electrodes which are separated by a non-conductive dielectric material.

The major uses of capacitors in electronic circuits are in:
- Coupling, decoupling, blocking and by passing functions.
- Filtering function.
- Transient voltage suppression function.
- Storing electric charge.

Several types of materials are used for capacitor applications like Ceramics, Tantalum Pentoxide, Aluminium and Polymer films. Tantalum Pentoxide Capacitors are most versatile, covers wide capacitance range. They are very reliable and can be used in almost all applications.

Ceramic capacitors are of two categories.

- Monolithic/Single layer ceramic capacitors (Disc type/Tube type)
- Multilayer Ceramic Capacitors.

Multilayer ceramic capacitors consist of several layers of thin ceramic dielectrics, sandwiched between layers of metal electrodes.

Multilayer Ceramic Capacitors offer higher capacitance values per unit volume than the single layer ceramic capacitors since it has several layers of dielectrics. They can also be made in a chip form, which makes their insertion easy into hybrid and printed circuit boards. Surface mounted technology and automatic assembly processes for printed circuit boards require such multilayer chip capacitors. Since, surface mounted technology (SMT) is gradually replacing conventional methods of integration in integration in electronic circuits, discrete monolithic capacitors will be replaced by multilayer chip type capacitors.

Barium Titanate (BaTiO3) powder is the most widely used ceramic material for capacitor applications. Number of additives are added to Barium Titanate powder to obtain desired properties in the final product.

In India, the usage of MLC is confined mostly to professional electronics sector like defence, aerospace, telecommunication and manufacturers of sophisticated test and measuring equipments, computers. The present applications in India are in the field of hybrid ICs as well as direct mounting on PCB which require special soldering equipment. These designs are based entirely on imported types.

The manufacturing process for MLCs involves very high technology in ceramics and metal deposition. In order to achieve the required high performance of the product, high quality raw materials such as ceramic powder, bonding resins, solvents, high purity metals, metal plates etc. would have to be imported.
1.6 PROJECT SIZE AND PROJECT COST
A minimum installed capacity of 100 million pieces per annum would be necessary to attain economical scale of production.

The estimated investment for the proposed project is about Rs. 13.0 crores.

<table>
<thead>
<tr>
<th></th>
<th>[Rs. in Lacs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land and site development</td>
<td>15.0</td>
</tr>
<tr>
<td>Buildings</td>
<td>60.0</td>
</tr>
<tr>
<td>Plant and machinery</td>
<td>750.0</td>
</tr>
<tr>
<td>Technical know-how, training</td>
<td>115.0</td>
</tr>
<tr>
<td>and consultancy fees etc.</td>
<td></td>
</tr>
<tr>
<td>Misc. fixed assets and</td>
<td>80.0</td>
</tr>
<tr>
<td>contingency</td>
<td></td>
</tr>
<tr>
<td>Preliminary and preoperative</td>
<td>170.0</td>
</tr>
<tr>
<td>expenses</td>
<td></td>
</tr>
<tr>
<td>Margin money</td>
<td>80.0</td>
</tr>
<tr>
<td>Total</td>
<td>1270.0</td>
</tr>
</tbody>
</table>

1.7 ESTIMATED TURNOVER
Rs. 15.0 Crores (at 100% capacity utilisation)

1.8 PLANT AND MACHINERY
For the production of MLC, most of the equipment/machinery may have to be imported. Indicative list of various equipments required for MLC is described below:

List of Equipments for MLC Manufacture
1. Roller Mills
2. Caster
3. Screen Printer
4. Isostatic Press
5. Cutter
6. Chip Setter Loader
7. Bake out oven
8. High temp kiln
9. Side termination machine
10. Tinning System
11. Laser marking system
The current market (1991-92) of MLCs in the country has been estimated to be 120 million pieces, which accounts for about 23% of the total ceramic capacitors market.

It is expected that MLC will largely replace disc ceramic capacitors due to their high capacitance values per unit volume than the single layer disc ceramic capacitors, the easy insertion into hybrid printed circuit boards, convenience for surface mounted technology and automatic assembly processes.

The approximate figures of penetration of the multilayer ceramic capacitor has been estimated as given in the following table.

<table>
<thead>
<tr>
<th></th>
<th>1994-95</th>
<th>1999-2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimistic</td>
<td>50% (800)</td>
<td>75% (3225)</td>
</tr>
<tr>
<td>Pessimistic</td>
<td>40% (600)</td>
<td>60% (2580)</td>
</tr>
</tbody>
</table>

*Figures in bracket shows estimated demand for MLC's in Million Nos.*

The world market size of ceramic capacitors for the year 1989 was 35 to 50 billion nos. 75% of which was of multilayer type. The market is growing at an average rate of 10-15%.

Some of leading manufacturers of MLCs in the world are:
- AVX, USA
- Centra Lab, USA
- Unitrode, USA
- Vitramon, USA
- Kyoto, Japan
- Murata, Japan
- Taiyo Yuden, Japan
- TDK Corp., Japan
- Asernetics GmbH, Germany

The export potential is limited as the international market is already inundated. Export is possible only if there is buy-back arrangement with technology suppliers.

1.4 **MANUFACTURING PROCESS**

Chart-1 highlights the steps involved in the manufacture of MLC.

The basic material required is Barium titanate powder. Two grades of this powder are available of which, the lower purity grade is used. It is made by mixing titanium dioxide (TiO₂) and Barium Carbonate (BaCO₃) and calcining them at high temperature. The obtained powder is then milled in a ball mill to get BaTiO₃ of required particle size.

Disc capacitors are made by pressing the powders along with binders in a disc shaped die and tube capacitors are produced by extrusion. Electrodes are screen printed on these.

MLC can be manufactured by three processes. They are:
- The Wet Process
- The Dry Process
- The fugitive electrode process
• Possibility of market becoming competitive in the presence of multinational giants and new projects if they materialise.

1.12 OPPORTUNITIES IN GUJARAT

• Good OEM Market for the proposed product as several OEMs are situated in the specially developed Electronic estates of the state.
• Gujarat has necessary infrastructure facilities required for such projects
• Special incentives are available to electronic sector projects.

1.13 PREFERRED PRODUCERS

* An existing electronic component manufacturer can take up this project as its a logical extension to his present activity.
* An independent unit by a new entrepreneur can also be set up to manufacture multilayer ceramic capacitor.
* An existing ceramic disc type capacitor manufacturer can also set up this project.

1.14 PROFITABILITY

Good Profits have been envisaged because:

* It is a high value added product.
* Market is growing and supply driven.
The Wet Process

In this process, a suitable additive like polyvinyl alcohol or acrylic resin is added to the powder to make a slip (A slip is material that can flow into a mould into thin layers). Thin layers are formed by screen printing, curtain coating or spraying. The layers are dried and then screen printed on dried dielectric layers. The metals used for electrodes are in the form of precipitated sub-micron powders, which are wetted and mixed with organic screening media to form an ink. Then binder burnout removes the organic binder from the green MLC. The next step is the sintering process carried out at a carefully controlled temperature of between 1200° to 1300° C. A metal paint is then applied to make connection between the conductive coating and all the sandwiched electrodes in the body. This is then fired to about 800° C. Next, the capacitance is measured using simple tests. If necessary, leads are soldered and finally the capacitor is encapsulated in plastic or glass.

Dry Process

This process is carried out by a method called tape casting. The dielectric material is cast with a binder into a thin sheet by doctor blading (Doctor blading involves controlling the thickness of the ceramic layer on the substrate using a very fine blade). The sheets are then rolled on reels. Sheets or tapes of desirable sizes are cut from these reels and screen printed using electrode ink. The dielectric sheets are stacked into master pads and laminated. The next steps from binder burnout onwards are followed as is the case in wet process.

Fugitive Electrode Process

The third process uses the same steps as is in the wet or dry process, except for one major change. In the other processes, the dielectric layer, with printed electrodes are stacked up. But here, instead of gold, silver or palladium electrodes, a fugitive carbon containing electrode ink is used. This ink is driven off during binder burnout and sintering, leaving behind hollow electrode sites. After sintering, lead tin alloy is injected into the hollow sites to form electrodes in the multilayer capacitor. The material costs involved are:

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic Material (BaTiO3)</td>
<td>14%</td>
</tr>
<tr>
<td>Organic Binder</td>
<td>2%</td>
</tr>
<tr>
<td>Electrode Pase (Ag-Pd)</td>
<td>36%</td>
</tr>
<tr>
<td>Terminal Pase (Ag)</td>
<td>48%</td>
</tr>
</tbody>
</table>

1.5 RAW MATERIALS

The major raw materials required for the manufacture of proposed product are:
- Barium Titanate Powder (SiO₂, Al₂O₃ content less than 1.5%)
- Silver/Palladium Pastes

These raw materials will have to be imported.
In a hybrid microcircuit, an insulating substrate has resistance and capacitance films deposited on it along with a printed connecting conductor grid. These films serve as capacitors and resistors and sometimes as discrete transistors. They are interconnected with ICS to form a hybrid circuit board. Normally alumina is used as ceramic substrate material. A 9 cm x 4 cm alumina ceramic board, with resistor and capacitor thick film deposits and associated connections in a telecommunication application with today's technology, can accommodate about 15 ICS. All manufacturers of hybrid microcircuits need the ceramic substrate. Moreover, hybrid microcircuits are an important component of miniaturization - an essential element for cost reduction in electronics packaging. The compositions are similar to the ones used for IC chip carriers and are primarily alumina, though beryllia and silicon carbide have also been used.

Hybrid microcircuit board has a large scale requirement in telecommunications market. The broadcasting, aerospace, defence and professional electronics sector, will also require hybrid microcircuits in large numbers. The other major sectors are defence, aerospace, automobile and professional electronics.

### 2.2 INDUSTRY STATUS

In India there are no indigenous manufacturers of ceramic IC substrates. Major would market is captured by Japanese companies. Large companies like IBM, Motorola, RCA have internal captive facilities for IC packaging.

The electronic grade alumina required for substrate manufacture is not available in the country.

### 2.3 MARKET POTENTIAL

The current (1991-92), Indian market for ICS is estimated to be about 128 million nos. (120 million of Linear/Digital ICs and 8.0 million of Hybrid Ics). Of these, large portion is supplied by imported sources (or coming as an integral part of the imported equipment).

The domestic production of ICs as reported by Department of Electronics, 1992 Report is about 24.7 million of Linear/Digital type and 7.75 million of Hybrid type. Of these, 40% are assumed to be based on ceramics.

Based on the estimated growth rate of 22.5% for Linear/Digital type ICs and 20% for Hybrid type ICs, the future market has been estimated as given in the following table:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>120</td>
<td>120</td>
<td>330</td>
</tr>
<tr>
<td>Digital</td>
<td>150</td>
<td></td>
<td>415</td>
</tr>
<tr>
<td>Hybrid</td>
<td>7</td>
<td>15</td>
<td>37</td>
</tr>
</tbody>
</table>

[In Million Nos.]
12. Packaging system consisting of scale, bag sealer/tape reel system etc.
13. Capacitance tester
14. Flash/IR Tester
15. Quantity testing equipments like bridges, viscometers baths etc.
16. Miscellaneous like compressor, distilled water plant, OG set, weighing machine etc.

1.9 TECHNOLOGY SOURCES
There are several well known technology sources for MLCs all over the world. Some of them are:

A. Japan
1. Murata Manufacturing Company Ltd.
2. Nichicon Capacitors Ltd.
3. Shimzu Ceramics Co. Ltd.
4. Shinee Ceramics Co. Ltd.

B. U.S.A.
1. Unitrode Corporation
2. Sprague Electric Company
3. AVX Corporation
4. Novacap
5. Johanson Dielectrics Inc.

C. West Germany
1. Sprague Elektronik GmbH
2. Siemens AG

1.10 INFRASTRUCTURE
Electricity : 275 KVA
Water : 40000 litres per day
Manpower : 55 Personal (40 Non-Supervisory 15 Supervisory)

1.11 RISK FACTORS

- Barium Titanate Powder, Silver/Palladium Paste are not available indigenously and will be needed to be imported for multilayer ceramic capacitor manufacture. Certain uncontrollable factors such as adverse exchange rate fluctuation, higher duties and levies, shortage of Barium Titanate powder in the international market, may have drastic effects on the project.
2.4 MANUFACTURING PROCESS (SUBSTRATE)

Ceramic substrates for IC chips and Hybrid circuit are formed by several methods using alumina, steatite and titanates.

The dry press method uses a spray-dried mix in carbide dies like those for low voltage insulators. However, due to the difficulties in uniformity of fill for very thin pieces and in brittleness in handling, this process is now seldom used.

For films over 0.03 inch in thickness the extrusion method is used. This consists in making a plastic body with water soluble polymeric organic binders and a water soluble plasticizer as well as a wetting agent.

The suggested composition of additives is given below:

Binder : 1 to 6% of polyvinyl alcohol, methyl cellulose or starch derivatives.
Plasticizer : 2 to 10% of propylene glycol, triethyl glycol or glycerine.
Wetting agent : 0.001 to 2% of Alkyl Ether or Polyethylene Glycol.

The mass is de-aired and extruded through a rectangular die onto a moving belt, through a dryer and coiled for storage.

The dried films are then fed through a high speed punch press which forms the outside and any holes demanded. The punched pieces are stacked on setters and fired.

When used for printing circuits, the surface must be smooth and free from impurities so that the lines, which may be only a few microns wide, will be of uniform with. For thin film application it is generally required that the surface have centre line average profile less than 10 micro inches and for thick films, 15 to 50 microinches.

The alumina substrate is fired at 1700° C. The substrate is then glazed.

2.5 RAW MATERIALS

For the manufacture of ceramic IC substrates electronic grade Alumina Powder is used. This alumina contains more than 99.5% alumina. (Na2O content less than 0.1% wt).

Glass frit is also added to the compound to aid in sintering. The particle size of compound should be 1 μm.

The Alumina compound required for IC substrate may have to be imported.
2.1 PRODUCT DESCRIPTION

A semiconductor device or an electronic chip has to be packaged before its use, so as to protect it against normal environmental hazards such as dust, humidity etc. The level of protection provided to the chip depends to a large extent on the specific use it is subjected to. Electronic chips used in professional equipments need to be protected to a greater extent than chips in consumer equipments.

Ceramic substrates are used to protect semiconductor devices mainly at two levels in the various stages of interconnection. These two levels are:

- as chip carriers at the basic chip level where they are used for protection of the chip,
- as hybrid printed board when chips are connected with each other in a hybrid microcircuit.

Ceramic chip carriers are used for protecting each individual chip. Plastics and Porcelain carriers are also used, particularly where environmental protection requirements are not so critical and lower cost of these carriers is the major consideration for its use for such purpose. Most professional electronic equipments have IC package carriers made out of ceramics.

Most ceramic chip carriers are made of electronic grade Alumina. Beryllia (BeO) and Silicon Carbide (SiC) are also used. One critical functional requirement for a chip carrier is that the carrier should have a co-efficient of Thermal expansion as close as that of Silicon, in order to avoid any failure of the interconnection due to stresses arising out of thermal gradients.

A typical chip carrier has a three layered structure. The top layer consists of the "seal ring". The middle layer has, "bonding pads", which connect to the "Seal ring" on the top and the "die pad" at the bottom. This middle layer has circuit conductors printed on it. It also has provisions for external connections. The bottom layer is called the "die pad".

Each layer is made of alumina. The individual layers are bonded together, the external connections are added and then the assembly is co-fired to sintering temperature to give the final carrier. The chip is placed inside the carrier and connected to the leads. A suitable cover is put on the seal ring and the whole package is sealed with epoxy or other specialised sealants depending on the application.

A typical final dimension of a ceramic carrier is 2 cm x 2 cm x 0.1 cm. The average weight of each carrier is about 1 gm.

Ceramic substrates are also used for interconnecting ICs in hybrid microcircuits. Hybrid microcircuits provide denser packaging of IC’s and reduce the cost of connections in electronics.
6. Punch press
7. High temperature kiln
8. Quality control equipments

2.9 TECHNOLOGY SOURCES

There are several well known technology sources for ceramic IC substrate manufacture all over the world. Some of them are listed below:

A) USA
1. Adolf Meller
2. Ceramtec Inc.
3. Champion Spark Plug Co.
4. Hybrid Tek
5. Hidensity

B) Japan
1. Kyocera Corporation
3. N.G.K. Spark Plug
4. Toshiba Ceramics
5. Soryu Co. Ltd.

C) West Germany
1. Hoechst Ceramtec AG

2.10 INFRASTRUCTURE

<table>
<thead>
<tr>
<th>Electricit</th>
<th>500 KVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>5000 litres/day</td>
</tr>
<tr>
<td>Manpower</td>
<td>55 persons including managerial, skilled, semi-skilled, un-skilled staff.</td>
</tr>
</tbody>
</table>

2.11 RISK FACTORS

- Electronic Grade Alumina powder required for the manufacture of substrate will be need to be imported. Certain uncontrollable factors such as adverse exchange rate fluctuation, higher duties and levies, irregular availability of alumina powder may have drastic effects on the project.
Assuming that current penetration of 20% by domestic supplier sill rise to 30% by 1004-95 and 50% by 1999-2000, the future domestic production of ICs has been estimated as given in the following table:

<table>
<thead>
<tr>
<th>IC type</th>
<th>1994-95</th>
<th>1999-2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear/Digital</td>
<td>110</td>
<td>370</td>
</tr>
<tr>
<td>Hybrid</td>
<td>15</td>
<td>37</td>
</tr>
</tbody>
</table>

Assuming that 40% of these IC chip carriers are ceramic based, demand forecast for ceramic carriers/substrates are as given below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>IC Chip carriers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Volume (Ml.Nos.)</td>
<td>9.88</td>
<td>44.00</td>
<td>148.00</td>
</tr>
<tr>
<td></td>
<td>- Value (Rs. Cr.)</td>
<td>3.00</td>
<td>13.20</td>
<td>44.00</td>
</tr>
<tr>
<td>2.</td>
<td>Hybrid Substrates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Volume (Ml.Nos.)</td>
<td>7.00</td>
<td>15.00</td>
<td>37.00</td>
</tr>
<tr>
<td></td>
<td>- Value (Rs.Cr.)</td>
<td>7.00</td>
<td>15.00</td>
<td>37.00</td>
</tr>
<tr>
<td></td>
<td>Total (Rs.Crores)</td>
<td>10.00</td>
<td>28.20</td>
<td>81.40</td>
</tr>
</tbody>
</table>

*Note:* Cost of Chip Carrier - Rs.3 per carrier  
Cost of hybrid substrates - Rs. 10 per substrates

Currently the entire requirement of ceramic carriers/substrates are met through imports.

The world market size in 1989-90 for ceramic carriers/substrates was 2.5 billion dollars i.e. around 5000 million nos. The average growth rate is 10% per annum.

The major players in the international market are few. The Japanese companies like Kyoto Ceramics, TDK Electronics, Murata, NGK Spark Plug, Toshiba Ceramics who together account for most of the world market. Kyoto ceramics is the world leader with over 60% of the market. Major US manufacturers include 3M, Monsanto Electronic, Brush Wellman, Interamics and Ceramic System.
2.6 PROJECT SIZE AND PROJECT COST

A minimum installed capacity of 100 million substrates per annum would be necessary to attain economical scale of production.

An estimated investment of Rs. 18.60 crores has been envisaged for the proposed plant size.

<table>
<thead>
<tr>
<th>[Rs. in Lacs]</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Land and Site development</td>
<td>20.0</td>
</tr>
<tr>
<td>Building</td>
<td>60.0</td>
</tr>
<tr>
<td>Plant and machinery</td>
<td>950.0</td>
</tr>
<tr>
<td>Misc. Fixed assets</td>
<td>80.0</td>
</tr>
<tr>
<td>Technical know-how, Engg. Fees etc.</td>
<td>150.0</td>
</tr>
<tr>
<td>Preliminary and preoperative expenses</td>
<td>200.0</td>
</tr>
<tr>
<td>Contingency</td>
<td>150.0</td>
</tr>
<tr>
<td>Margin money</td>
<td>250.0</td>
</tr>
<tr>
<td>Total</td>
<td>1860.0</td>
</tr>
</tbody>
</table>

2.7 ESTIMATED TURNOVER

Rs. 30.0 crpnes (at 100% capacity utilisation).
(Average price = Rs.3.00 per carrier of size 2 cm x0.1 cm)

2.8 PLANT AND MACHINERY

For the production of IC ceramic substrates, most of the equipment/machinery may have to be imported.

Indicative list of various equipments required for ceramic substrates for ICs is described below:

1. Roller mills
2. Slip caster
3. Cutter
4. Chip setter loader
5. Bake out oven
The current industrial status in India for Hard Ferrites comprises of 13 licensed manufacturers with total licensed capacity of 14100 tons. The installed capacity being 7200 tons.

There are 15 licensed manufacturers for soft ferrites with total licensed capacity of 8200 tons. The installed capacity being 2200 tons.

The import is reported to be Nil in India.

The world market size for 1988-89 has been 2,50,000 tons for Hard Ferrite and 1,05,000 tons for soft ferrite. The average growth rate is 6% per annum. The major markets in the world are Japan, USA, FRG and France.

Substitute products are available for hard and soft ferrites.

Transformer steels can be substituted for soft ferrites. But soft ferrites have lower eddy current losses and higher resistance compared to traditional magnetic materials. Hence they are quite useful in applications where magnetic fields have to be switched on and off very fast.

ALNICO, Cobalt Samarium magnets can substitute for hard ferrites. Inspite of inferior properties hard ferrites are still widely used as they are much cheaper.

Large reserves of ferric oxide is available in the country. This raw material can be developed for use in the manufacture of hard and soft ferrites for normal and varied sophisticated applications. But there are some problems linked with them. The inconsistent quality of indigenous raw material require special treatment for every batch of raw material. Another aspect is that raw materials for soft ferrites requiring better grades of raw materials, higher percentage of impurities like silica and alumina is causing serious concern.

3.3 MARKET POTENTIAL

The Indian market for hard Ferrites is given in table below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LS Rings</td>
<td>2900</td>
<td>4715</td>
<td>6615</td>
</tr>
<tr>
<td>Segments</td>
<td>475</td>
<td>790</td>
<td>1300</td>
</tr>
<tr>
<td>Plasto Ferrites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Isotropic</td>
<td>325</td>
<td>490</td>
<td>740</td>
</tr>
<tr>
<td>- Anisotropic</td>
<td>125</td>
<td>210</td>
<td>335</td>
</tr>
<tr>
<td>Total</td>
<td>3825</td>
<td>6205</td>
<td>8990</td>
</tr>
</tbody>
</table>

• The domestic market for ceramic substrates is quite limited and will not allow room for more than 2-3 producers. Avenues for exports are also limited as it is controlled by international giants. More new domestic entrants in this area may instill severe competition.

2.12 OPPORTUNITIES IN GUJARAT

* Special incentives for Electronic Sector Projects.
* Availability of necessary infrastructure required for the project.

2.13 PREFERRED PRODUCERS

* Major producers of IC Chips can integrate backwards.
* An independent production capacity for ceramic IC substrates can be thought of by companies which are not in this business. They can import unpackaged chips at low prices and package it and sell it in the Indian market.

2.14 PROFITABILITY

* Good Profits have been envisaged because:
* It is a value added product.
* Market is growing and supply driven.
MANUFACTURING PROCESS (FERRITES)

Ferrites are normally prepared by standard ceramic processes. The soft and hard ferrites have many similarities in preparation and some differences.

Manufacturing Of Soft Ferrites

The iron-oxide is raw milled. The input materials i.e Iron Oxide, Manganese dioxide, Manganese carbonate and zinc oxide, are weighed in the proper proportion and subjected to wet milling in a steel mill. The milled compound is filtered and dried. This is followed by a calcining step, in which the raw materials are heated about 770-1325°C, to form ferrite compound. The time of calcining and the temperature are crucial to achieving final properties. In process control of the composition and crystal structure by X-ray diffraction, measurement of the surface area of the calcined powder and inductance measurement from a toroid shaped sample, are often used to ensure that the required properties are obtained.

After the calcining step, the material is milled again and spray dried to give the fine ferrite powder, which is the basic material for producing most components. The method giving optimum results appears to be to add binders such as PEG or PVOH(1-4% by weight) and sufficient water, to form a slurry that is 65-70% ferrite by weight. This slurry can be spray dried to produce the required powder. This powder is then made into the required parts using normal ceramic processes.

Very thin parts are normally fabricated by tape casting. For parts which are long with small diameters, extrusion or isostatic pressing can be used. To control the magnetic properties of the final component, the oxygen content of the kiln has to be carefully controlled, during the cooling portion of the sintering cycle. This is quite a technological challenge. Soft ferrites are normally fired in continuous tunnel kilns at temperatures ranging from 1280° - 1450°C, with sintering time ranging from 20 minutes to 12 hrs.

Manufacturing Of Hard Ferrites

For hard ferrite manufacture, the steps are very similar. However, because of their higher iron oxide content and their relatively lower selling price compared to soft ferrites, lower grade raw materials are normally used.

Mined ferric oxide is dry milled in a vibro mill and then mixed with Barium carbonate or strontium carbonate in right proportion.
The market estimates for soft ferrites is given below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T.V</td>
<td>2110</td>
<td>3190</td>
<td>4360</td>
</tr>
<tr>
<td>Telecom</td>
<td>100</td>
<td>250</td>
<td>500</td>
</tr>
<tr>
<td>Industrial electronics and informatics</td>
<td>240</td>
<td>750</td>
<td>1500</td>
</tr>
<tr>
<td>Radio sector</td>
<td>800</td>
<td>1200</td>
<td>1560</td>
</tr>
<tr>
<td>Total</td>
<td>3250</td>
<td>5390</td>
<td>7920</td>
</tr>
</tbody>
</table>


The world market for Hard and Soft Ferrites is estimated to be about 2.5 lacs tons and 1.0 lacs tons respectively and it is growing at an average rate of 6% per annum.

India has good scope to enter the world market in both Hard and Soft Ferrites.

Some possible export growth areas are:

<table>
<thead>
<tr>
<th>Products</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hard Ferrites</strong></td>
<td></td>
</tr>
<tr>
<td>Rings</td>
<td>FRG, Sweden, UK, USA, USSR</td>
</tr>
<tr>
<td>Segments, Slabs</td>
<td>UK, USA, USSR</td>
</tr>
<tr>
<td>Plasto Ferrite</td>
<td>FRG, Italy, Taiwan, USA</td>
</tr>
<tr>
<td>Ferrite Powders</td>
<td>Taiwan, South Korea, Israel</td>
</tr>
<tr>
<td><strong>Soft Ferrites</strong></td>
<td></td>
</tr>
<tr>
<td>'U' Cores 'E' Cores</td>
<td>Western Europe, USA, USSR</td>
</tr>
<tr>
<td>Yoke Rings</td>
<td>Western Europe, USA, USSR</td>
</tr>
<tr>
<td>Ferrite Powder</td>
<td>Taiwan, South Korea</td>
</tr>
</tbody>
</table>

Again there are constraints. Very low prevailing international prices has led soft ferrite products to sell at less than 50% while hard ferrite products realise 50 to 65% of Indian prices.
Calcination takes place in a rotating (or oscillating) tube calciners, which are 2-3 meter in diameter and 20-30 meters long, at temperatures about 1225° - 1375° C. At this temperature, the material reacts to form the hexagonal ferrite. If calcining takes place at lower temperatures, magnetic properties are not seriously affected. However, the material is too soft and subsequent milling gives too fine a particle size, leading to difficulties in subsequent pressing and high shrinkage during sintering. If the calcination temperature is too high, the formed particles are too hard and coarse. Although these can be pressed easily, the shrinkage is high and the magnetic properties are affected.

Hard ferrites are prepared by dry or wet pressing of the calcined powder in the presence of an external magnetic field. Dry pressing is cheap. However, because of friction between adjacent particles, the magnetic alignment is not optimum. In wet pressing, the slurry coming from the ball mill (after calcination), is pumped into a die cavity where alignment takes place with the help of magnetic field. After alignment, the water is removed by applying a vacuum to the die cavity where alignment takes place with the help of magnetic field. After alignment, the water is removed by applying a vacuum to the die cavity. A fine filter paper prevents particles from being pulled out of the die cavity. The design for wet dies is more expensive and the pressing time is longer. Sintering can take place immediately for dry pressed parts. Wet pressed parts, however, have to be dried carefully before being placed in a kiln. The pressed parts are sintered in air at 1125 - 1375° C to yield a dense ceramic material.

3.5 RAW MATERIALS

Major raw materials for Hard Ferrites manufacture are Ferric Oxide (Mined), Barium Carbonate and Strontium Carbonate. Raw materials for soft ferrites include ferric oxide, manganese dioxide, manganese carbonate, zinc oxide, etc.

Ferric Oxide and Barium Carbonate are amly available indigenously. Strontium Carbonate needs to be imported.

3.6 PROJECT SIZE AND PROJECT COST

For economical scale of operation following plant capacities have been suggested for Hard and Soft Ferrites.

Hard Ferrites : 1500 TPA
Soft Ferrites : 1000 TPA

The estimated investment for above size of plant are shown below:

Hard Ferrites : Rs. 9.50 Crores
Soft Ferrites : Rs.21.00 Crores
**PROCESS FLOW CHART**

**HARD FERRITE**

- Mineral
  - Ferric Oxide
- Barium Carbonate or Strontium Carbonate
  - Dry Milling (Vibro Mill)
  - Dry Mixing of Raw Materials
  - Calcining in Rotary Furnace
  - Wet Milling in Attritors/Ball Mills
  - Settling
  - Pressing
  - Drying
  - Sintering in Tunnel Furnace
  - Grinding & Ultrasonic Cleaning
  - Inspection
  - Packing

**SOFT FERRITE**

- Ferric Oxide
- Raw Milling (Vibro Mill)
- Manganese Dioxide, Manganese Carbonate, Zinc Oxide
  - Wet Mixing of Raw Materials
  - Drying
  - Granulating & Sieving
  - Calcining in Rotary Furnace
  - Wet Milling in Attritors/Ball Mill
  - Spray Drying
  - Sigma Mixer for Paste
  - Extrusion
  - Sintering in Tunnel Furnace
  - Grinding & Ultrasonic Cleaning
  - Inspection
  - Packing
5. Tunnel Kiln
6. Granulator
7. Pelletiser
8. Oven
9. Grinding/Lapping Machine
10. Nitrogen Storage Tank
11. Quality Control Equipments

3.9 TECHNOLOGY SOURCES

Several renowned technology sources for Ferrites manufacture are listed below:

A) USA
1. Amperex Electronics Corporation
2. D.M. Steward Company
3. Ferrites Inc.
4. TDK Corporation
5. International Services Inc.

B) JAPAN
1. Fuji Electrochemical Company
2. Hitachi Metal
3. Murata Manufacturing Company
4. Nippon Ferrites
5. Sumitomo Special Metals
6. TDK Electronics Company Limited
7. Taiyoyoden
8. Nippon Ceramic Limited
9. Shin Etsu Chemical Company
10. Iron-NKK

3.10 INFRASTRUCTURE

Hard Ferrites
Power : 1000 KVA
Water : 15000 Litres/Day
Manpower : 100 persons including managerial, skilled, semiskilled and unskilled staff.
### Project Cost Break-up

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Hard Ferrites (1500 TPA)</th>
<th>Soft Ferrites (1000 TPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land and Site Development</td>
<td>20.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Buildings</td>
<td>70.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Plant and Machinery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Imported (incl. duty)</td>
<td>350.0</td>
<td>1100.0</td>
</tr>
<tr>
<td>- Indigenous</td>
<td>130.0</td>
<td>150.0</td>
</tr>
<tr>
<td>Misc. Fixed assets</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Technical know-how &amp; Engg. Fees</td>
<td>50.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Preliminary &amp; preoperative expenses</td>
<td>95.0</td>
<td>200.0</td>
</tr>
<tr>
<td>Contingency</td>
<td>80.0</td>
<td>170.0</td>
</tr>
<tr>
<td>Margin money</td>
<td>100.0</td>
<td>200.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>945.0</strong></td>
<td><strong>2095.0</strong></td>
</tr>
</tbody>
</table>

3.7 **ESTIMATED TURNOVER**

- Hard Ferrites: Rs. 7.50 Crores  
  (Average Price: Rs. 50/kg.)
- Soft Ferrites: Rs. 11.90 Crores  
  (Average Price: Rs. 100/kg.)

3.8 **PLANT AND MACHINERY**

For the production of Hard and Soft Ferrites, most of the equipments are similar. Most of these equipments are indigenously available except few like Electrically heated rotary furnace, presses and tunnel furnaces.

Indicative list of various equipments required for Ferrites manufacturing are mentioned below:

1. Ball Mills/Attritors
2. Filter Press and Diapharm Pump
3. Hydraulic Press with Accessories
4. Rotary Furnace (Electrically Heated)
Note: The Production of soft and hard ferrite powders, based on Indian Ferric Oxide seems to be one area offering excellent opportunity. The domestic requirement of Hard and Soft Ferric Powders is mentioned below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Hard Ferrite Powder Volume</th>
<th>Soft Ferrite Powder Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-92</td>
<td>3900</td>
<td>1.95</td>
</tr>
<tr>
<td>1994-95</td>
<td>6200</td>
<td>3.10</td>
</tr>
<tr>
<td>1999-2000</td>
<td>9000</td>
<td>4.50</td>
</tr>
</tbody>
</table>

The world market of Hard and Soft Ferrite Powders is about 3.5 lac tons per annum. Substantial export possibility exist in this area.

The powder preparation technology has been indigenised. Most of the equipments(except certain test equipments) are available indigenously. The list of equipments required for Ferrite Powder Processing is given below:

- Magnetic Separator
- Spray Drier
- Grinding Mills
- Auxiliary Equipments like Filter
- Test Equipment
- Quality Control Equipment
- Vibro Energy Mill

An investment of about 10 crores is required for a capacity of 25000 TPA.
4.1 PRODUCT DESCRIPTION

Ceramic materials are extensively used as detecting elements in a large variety of sensors. These include sensors for the measurement of physical parameters such as temperature, as well as sensors for the measurement of concentrations of various gases, oxygen, water vapour, etc.

Various types of ceramic sensors, their main materials of manufacture and the major applications are described in the following table:

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Material</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive temperature coefficient</td>
<td>Barium titanate with either strontium or lead titanate.</td>
<td>Temperature based control in colour TV, digital telephone exchangers, hair dryers, etc.</td>
</tr>
<tr>
<td>coefficient resistors (PTC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative temperature coefficient</td>
<td>Complex spinel structure of nickel manganese, cobalt and copper oxides</td>
<td>Non-liner circuit control, automobiles, medical thermometry.</td>
</tr>
<tr>
<td>coefficient resistors (NTC)</td>
<td>(minor additives)</td>
<td></td>
</tr>
<tr>
<td>Varistors</td>
<td>Zinc oxide</td>
<td>Over voltage protection in TV receivers, VCRs, microwave ovens, automobile electronics lightening arrestors.</td>
</tr>
<tr>
<td>Humidity sensors</td>
<td>Alumina (not used any more), Magnesia chrome titanate (MgCrO₄, TiO₂)</td>
<td>Microwave ovens, clean room air-conditioners for electronics and food processing industries.</td>
</tr>
<tr>
<td>Oxygen sensors</td>
<td>Zirconia (ZrO₂) with additions of yttria (Y₂O₃) and magnesia (MgO)</td>
<td>Automobile combustion control, steel making, furnaces, food and beverage packaging.</td>
</tr>
<tr>
<td>Gas sensors</td>
<td>Zinc oxide, tin oxide iron oxide.</td>
<td>Liquid petroleum gas leak detection, oil rigs, refineries, toxic gas detection systems.</td>
</tr>
<tr>
<td>Pyroelectric sensors</td>
<td>Lithium tantalate, lithium niobate, lead titanate.</td>
<td>Microwave ovens, burglar alarms, body sensors, space instruments.</td>
</tr>
</tbody>
</table>

In the Indian context, the most important sensors are PTC/NTC resistors and varistors.

**PTC Resistors**

These devices (usually made out of barium titanate), have a semi-conductors grain, which is interleaved with a very narrow insulating barrier layer. The insulating barrier layer here, is intrinsic to the material. This barrier layer arises by the substitution of barium atoms in barium titanate with lanthanum, titanium, antimony and niobium. The thickness of barrier layer is controlled by control of composition and cooling rates.

In $\text{BaTiO}_3$, which is a component of all PTC resistors, the resistivity change occurs near the Curie temperature at around 130°C. At temperatures below curie point, these materials behave like semi conductors. At curie point temperature, resistance suddenly rises, transforming the semiconductors into a material which offers high resistance to the flow of current. The resistance change is as high as 8 orders of magnitude. This characteristics of PTC ceramics make them extremely useful temperature sensing devices.

PTC ceramics are used as discs or rectangular bars and are supplied with low resistance electrodes. The curie temperature is normally around 130°C, which can be altered by controlling the additives and the cooling rates.

PTC resistors are used as degaussers elements for colour TV, in motor starters and crankcase heaters for refrigerators and air-conditioning compressors, time delay relays, air heaters for hair dryers, food dryers, etc. They are also used in digital telephone exchanges, self-regulating heating devices and current limiters.

**NTC Resistors**

In these sensors, the coefficient of resistivity decreases with increase in temperature i.e. as the temperature increases, the resistance decreases and more current flows through the sensing element. The sensing element is largely based on different solid state solutions, in a complex spinel structure, made up of oxides of nickel, manganese, cobalt and copper. NTC devices are mainly used in:

- Control of non-liner circuits
- Temperature measurement in automobile applications
- Medical thermometry.

They also find application in digital exchangers.

**Varistors**

Varistors based on ZnO are novel ceramic semi conductor devices with highly non-linear current-voltage characteristics, quite similar to Zener diodes but with much greater current and energy handling capabilities.

The varistors are produced by a ceramic sintering process that gives rise to a structure composed of conductive ZnO grains surrounded by electrically insulating barriers. These barriers are derived from trap states at the grain boundaries induced by additive elements such as Si, Co, Pr, Mn etc.
The non-linear electrical behaviour is caused by electrons trying to get past this barrier. Electron transport through the interface is believed to be a two step process, whereby first the electron goes from a ZnO grain to the interface and secondly on to the next ZnO grain.

The applications of ZnO varistors is predominantly in the field of circuit over-voltage protection, although it is used sometimes as a circuit element. These components have come into predominance with the advent of the solid state circuitry because the solid state components cannot in general withstand the amount of overvoltage imposed upon the circuitry by typical power system transients.

4.2 INDUSTRY STATUS

There are quite a few manufacturers of Thermistor (PTC/NTC) and varistors in the country. Major manufacturers of these items are listed below:

**PTC/NTC Thermistors**
1. Electronics Unlimited, Pune
2. Keltron Electre Ceramics Ltd., Kerala
3. Liberty Electronics, Pune
4. Telecommunication Components and Equipments Industry, Pune
5. Toshniwal Sensors Pvt. Ltd., Ajmer
6. Vico Electronics, Delhi
7. Solitronics, Pune
8. General Electronics, Pune
9. Universal Semiconductors, Pune

**Varistors**
1. Elpro, Pune
2. Telecommunication Components & Equipments Industries, Pune
3. Liberty Electronics, Pune
4. Keltron Varistors Pvt Ltd., Palghat

The current production of these items is around 2.5 million nos. (which is about 20% of the total potential demand).

4.3 MARKET POTENTIAL

Though the current consumption of Thermistors/Varistors in the country is about 7-8 million No., potential demand is much higher. The current and future demand potential for Thermistors/Varistors has been estimated as given in the following table:
### DEMAND POTENTIAL

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Applications</th>
<th>Qty. (M.Nos.)</th>
<th>Value (Rs.Cr.)</th>
<th>Qty. (M.Nos.)</th>
<th>Value (Rs.Cr.)</th>
<th>Qty. (M.Nos.)</th>
<th>Value (Rs.Cr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A.</strong></td>
<td>Thermistors (PTC/NTC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Colour T.V.</td>
<td>1.20</td>
<td>0.60</td>
<td>1.60</td>
<td>0.80</td>
<td>2.57</td>
<td>1.20</td>
</tr>
<tr>
<td>2.</td>
<td>Refrigerators</td>
<td>1.30</td>
<td>0.65</td>
<td>1.93</td>
<td>0.96</td>
<td>3.71</td>
<td>1.85</td>
</tr>
<tr>
<td>3.</td>
<td>Air-conditioners</td>
<td>0.08</td>
<td>0.04</td>
<td>0.15</td>
<td>0.08</td>
<td>0.45</td>
<td>0.22</td>
</tr>
<tr>
<td>4.</td>
<td>Telecom &amp; other professional elec.</td>
<td>1.00</td>
<td>0.50</td>
<td>1.33</td>
<td>0.67</td>
<td>2.14</td>
<td>1.07</td>
</tr>
<tr>
<td>5.</td>
<td>Others including mosquito coils</td>
<td>1.00</td>
<td>0.50</td>
<td>1.52</td>
<td>0.76</td>
<td>3.06</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>Sub-Total : A</td>
<td>4.58</td>
<td>2.29</td>
<td>6.53</td>
<td>3.26</td>
<td>11.93</td>
<td>5.97</td>
</tr>
<tr>
<td><strong>B.</strong></td>
<td>Varistors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>B/W T.V.</td>
<td>3.60</td>
<td>1.80</td>
<td>4.79</td>
<td>2.40</td>
<td>7.72</td>
<td>3.86</td>
</tr>
<tr>
<td>2.</td>
<td>Colour T.V.</td>
<td>1.20</td>
<td>0.60</td>
<td>1.60</td>
<td>0.80</td>
<td>2.57</td>
<td>1.20</td>
</tr>
<tr>
<td>3.</td>
<td>VCRs</td>
<td>0.07</td>
<td>0.04</td>
<td>0.12</td>
<td>0.06</td>
<td>0.30</td>
<td>0.15</td>
</tr>
<tr>
<td>4.</td>
<td>Others incl. Tele. Exch. refrigerator, computers &amp; power gen. &amp; distr. equipments.</td>
<td>2.00</td>
<td>1.00</td>
<td>2.66</td>
<td>1.33</td>
<td>4.29</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td>Sub-Total : B</td>
<td>6.87</td>
<td>3.44</td>
<td>9.17</td>
<td>4.59</td>
<td>14.88</td>
<td>7.44</td>
</tr>
<tr>
<td><strong>TOTAL : A+B</strong></td>
<td></td>
<td>11.45</td>
<td>5.73</td>
<td>15.70</td>
<td>7.85</td>
<td>26.81</td>
<td>13.40</td>
</tr>
</tbody>
</table>

Note: 1. The growth rates of end-use sectors considered for demand projections are:

- *B/W and Colour TV*: 10%
- *Telecom and others*: 10%
- *Refrigerators*: 14%
- Professional Equipment
- *Air-conditioners*: 24%
- *Others including*: 10%
- *VCRs*: 20%
- *Others including mosquito coils*:

2. Average price: Rs. 5 per thermistor/varistor.

The world market for Thermistors/Varistors has been estimated at about 1 billion dollars (i.e. 1500 million Nos) during 1989. The world market is dominated by few Japanese companies like TDK Electronics, Mitsubishi, Matsushita, Fuji and Hitachi.
4.4 MANUFACTURING PROCESS

Chart 4.1 highlights the steps involved in the manufacture of Thermistors and Varistors. All the basic ingredients required for the final product are mixed and calcined at high temperature. The obtained powder mix is then milled in a ball mill to get required particle size.

Ceramic Resistor discs (or Rectangular blocks) are produced by pressing the powders along with binders in disc shaped (or Rectangular) die.

The "green discs" are then subjected to binder burnout, to remove the organic binder. The "green body" is then sintered (temperature between 1200-1300°C).

The temperature and atmosphere of the kiln has to be carefully controlled. The ceramic Resistor Disc is then placed in a casing containing electrodes.

Resisters are tested for temperature coefficient and voltage coefficient characteristics, high frequency performance. Their mechanical aspects such as bending and Tensile Strength are also tested.

4.5 RAW MATERIALS

PTC Resistors : Barium Titanate with either strontium or lead Titanate (other minor additives)
NTC Resistors : Nickle, Manganese, Cobalt and Copper Oxides
Varistors : Zinc Oxide and Minor quantities of Sb₂O₃, Bi₂O₃, CaO, MnO, Cr₂O₃.

4.6 PROJECT SIZE AND PROJECT COST

The proposed project size is 3 million nos of ceramic thermistors/varistors. The estimated project cost for the above proposed project size is Rs. 1.31 crores.

Land and building : Rs. 20 lacs
Plant and Machinery : Rs. 60 lacs
Misc. Fixed Assets : Rs. 10 lacs
Know-how and Engg Fees : Rs. 10 lacs
Preliminary Expenses : Rs. 5 lacs
Pre-operative expenses : Rs. 10 lacs
Contingencies : Rs. 12 lacs
Margin Money : Rs. 10 lacs
Total : Rs.137 lacs

4.7 ESTIMATED TURNOVER

Rs. 1.50 Crores(at 100% Capacity Utilisation)
CHART - 4.1

MANUFACTURING STEPS

BaTiO₃
Strontium
or
lead titanate

Mixing
Calcining
Milling
Pressing
Binder Burning
Sintering
Packaging

Ni, Mn, Co
and
Cu Oxides

Mixing
Calcining
Milling
Pressing
Binder Burning
Sintering
Packaging

ZnO, Sb₂O₃,
Bi₂O₃, CaO
MnO, Cr₂O₃

Mixing
Calcining
Milling
Pressing
Binder Burning
Sintering
Packaging

FTR
RESISTORS

NTC
RESISTORS

VARISTORS

113
4.8 PLANT AND MACHINERY
Indicative list of various equipments required for the manufacture of Thermistors/Varistors is described below:
- Mixers
- Calcining Furnace
- Ball Mills
- Press
- Bake out oven
- High Temp kiln
- Testing equipment
- Packaging System

4.9 TECHNOLOGY SOURCES
Technology to manufacture Thermistors/Varistors is difficult to source indigenously. There are several well know technology sources for Thermistors/Varistors all over the world, from whom technology can be sources:

USA
1. Dale Electronics Inc.
2. General Electric
3. Leach Corporation
5. Betatherm Corp.

JAPAN
1. Hitachi Metal
2. Matsushita Electronic Components
3. Mitsubishi Mining and Cement Co.
4. MSK Corp.
6. NEC Corp.
7. Taiyo Yuden
8. Technol Seven
9. TDK Corp.
10. YS Porcelain Tube Mfg Co.
4.10 INFRASTRUCTURE
Electricity : 275 KVA
Water : 5000 litres per day
Manpower : 35 persons including technical and non-technical manpower.

4.11 RISK FACTORS
Already, there are several manufacturers of ceramic thermistors/varistors in the country. Severe competition may arise in the future.

4.12 OPPORTUNITIES IN GUJARAT
1. Good OEM market for the proposed product
2. Special incentives are available to electronic sector projects.

4.13 PREFERRED PRODUCERS
1. An existing electronic component manufacturer can take up this project as its logical extension to his present activity.
2. An independent small scale unit by a new entrepreneur can also be set up.
3. An existing ceramic disc type capacitor manufacturer can also set up this project.

4.14 PROFITABILITY
Moderate profits have been envisaged, as severe competition in the market due to many players may affect the capacity utilisation levels.
5.1 PRODUCT DESCRIPTION

(A) Grinding Media

There are varieties of grinding media i.e. cast iron, steel, porcelain, flint, agate and alumina. The choice of particular grinding media depends on the material being ground and the final particle size required.

Alumina grinding balls are widely used in certain applications, especially for grinding various ingredients used in white cement, paint, pharmaceuticals and ceramics. Use of alumina grinding media, does not cause any discoulouration of the products being milled.

The growth of the cement industry, particularly the market for white cement has created a good market for ceramic grinding media.

(B) Nozzles

Structural ceramics are suited for the manufacture of nozzles due to their wear and abrasion resistance at high temperatures. The reduced wear on the nozzle provides longer life as well as greater accuracy of operation. Nozzles are used in welding, sand blasting, water jet cutting. They are also used in torches for thermal cutting. Ceramic nozzles find application in TIG, MIG/MAG or saw welding and arc welding. Sand and shot blasting equipments are mainly used by the following industries:

- Casting
- Automobile
- Railways
- Steel

Currently, the nozzles used in sand blasting equipments are made of tungsten carbide. While alumina is largely used, zirconia and silicon nitride are also used for production.

5.2 INDUSTRY STATUS

(B) Grinding Media

Till recently, ceramic grinding media was mainly imported. Presently, quite a few companies have entered this market and attained significant penetration. Prominent amongst them are:

- M/s. Jyoti Ceramics, Nashik
- M/s. NTB International, Pune
M/s. ACC and IVP also trying to develop this product. M/s. Carborundum Universal also proposes to manufacture 100 tons of grinding media.

(B) Nozzles

Only in Arc welding application, ceramic nozzles are being used. Though, IVP Ltd., supplies such nozzles, large amounts are still being imported.

The nozzles used in sand blasting equipments are currently made of Tungsten Carbide. There are several manufacturers supplying Tungsten Carbide nozzles. Among them, M/s. Widia is the most important supplier.

Ceramic nozzles can be made from Alumina, Zirconia and Silicon Nitride. However, Alumina is most popular because of its lower cost compared to other ceramic powders.

5.3 MARKET POTENTIAL

(A) Ceramic Grinding Media

The demand and break-up of various types of grinding media is difficult to estimate as most users of this product are in the unorganised sector. Large imports (more than Rs.60 crores worth) have been reported.

The total market for various types of grinding media is estimated to be more than Rs. 15 crores.

The current market for ceramic grinding media is estimated to be about 150 tons (Value: Rs.1.50 crores). The demand for ceramic grinding media is expected to grow at an average rate of 20% per annum considering increased penetration into the market of other grinding media.

Based on above, the demand for the years 1994-95 and 1999-2000 has been estimated as given below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Qty.(Tons)</th>
<th>Demand Value(Rs.Crore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994-95</td>
<td>260</td>
<td>2.60</td>
</tr>
<tr>
<td>1999-2000</td>
<td>650</td>
<td>6.50</td>
</tr>
</tbody>
</table>

Excellent opportunities also exist for the export of ceramic grinding media.
(B) Ceramic Nozzles

Ceramic nozzles are used in various equipments, such as:

* Sand and Shot blasting equipment
* Gas Welding equipments
* Arc Welding equipments

At present, the use of Tungsten carbide nozzle is most predominant. However, recently alumina nozzles have started penetrating the Tungsten Carbide Nozzle markets, though marginally.

Ceramic Nozzles have better abrasion and heat resistance and hence significant penetration has been envisaged in the above markets.

The current market for Tungsten carbide sand blasting nozzles is about Rs. 2.0 crores, which is growing at an average rate of 5% per annum.

The current market for Gas welding nozzles is estimated to be about Rs. 3.0 crores, and growing at an average growth rate of 5%.

In the case of TIG, MIG/MAG or Waw welding equipment, ceramic nozzles have been used almost entirely. The current market for such nozzles is about Rs. 1.25 crores and it is growing at an average rate of 7% per annum.

Assuming easy availability of ceramics, penetration of ceramics is likely to increase. Penetration levels of 20% and 60% have been envisaged by ceramic nozzles by 1994-95 and 1999-2000 respectively.

Based on above, the demand for ceramic nozzles have been estimated as given under:

<table>
<thead>
<tr>
<th>Type</th>
<th>Current (1991-92)</th>
<th>Demand (Rs. Crores)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All types</td>
<td>Ceramic</td>
</tr>
<tr>
<td>Sand Blasting Nozzles</td>
<td>2.20</td>
<td>Nil</td>
</tr>
<tr>
<td>Gas Welding Nozzles</td>
<td>3.30</td>
<td>Nil</td>
</tr>
<tr>
<td>Arc Welding Nozzles</td>
<td>1.40</td>
<td>1.40</td>
</tr>
<tr>
<td>Total</td>
<td>6.90</td>
<td>1.40</td>
</tr>
</tbody>
</table>
5.4 MANUFACTURING PROCESS

For manufacture of Grinding media and nozzles calcined alumina low in soda is preferred. Alumina content may be between 85 and 99.5%. Compound higher in Alumina is more refractory and has higher strength. Kaolin may be added to give better pressing qualities as well as to reduce the sintering temperature. MgO, as talc or MgCO3 is added to control the fired grain size and also aids the pressing. A typical mix would be:

- 97% Al₂O₃
- 0.6% MgO
- 2.4% SiO₂

The calcined alumina is blended with the other ingredients and then ball milled for 16 hr to break down the grains to the ultimate crystal size of 1 to 4μ. Wet milling is preferred. Ball/alumina ratio of 4.2:1 is maintained in the mill. Small quantity of triethanolamine is added to aid the grinding.

The wet milled mix is spray dried to give a flowable powder of spheres strong enough to stand handling but crushable under pressure.

The spray dried alumina pellets are placed in rubber moulds of isostatic press. The mould is immersed in oil or water in a heavy chamber where it is exposed to hydrostatic pressure of 5000 to 20000 psi for a few minutes. It is desirable to de-air the fill with a hypodermic needle before pressing.

The use of iso-static pressing has many advantages as listed below:

1. Little or no organic binder is needed
2. A high density is reached, which reduces firing shrinkage.
3. The moulded balls have a nearly uniform density throughout, thus reducing warping and cracking.
4. High pressure reduces necessary maturing temperature.

After removal of the green from the mould, the outside surface is ground true.

Firing is carried out in gas fired kilns. The temperature schedule consists of 12 hr to bring up to temperature, 2 hrs at the maximum and 12 hr to cool. The soaking temperature of 1700 to 1750°C is maintained, although these would be influenced by a number of factors such as fineness of grinding and desired porosity.

As the alumina bodies have high shrinkage and low green strength, the setting in the kiln must be thought out to prevent warping and cracking of the product.
5.5 **RAW MATERIALS**

Reactive Grade calcined alumina (above 95% Al₂O₃) is required. (Required Particle size: 0.5-5.0 μm, Na₂O Content : 0.02-0.4%).

5.6 **PROJECT SIZE AND PROJECT COST**

Based on the potential market size a 200 tpa ceramic grinding media and 15 tpa nozzles manufacturing plant can be set up.

An investment of Rs. 7.80 crores has been estimated for the proposed plant capacity.

<table>
<thead>
<tr>
<th>[Rs. in Lacs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land and Site Development</td>
</tr>
<tr>
<td>Buildings</td>
</tr>
<tr>
<td>Plant and Machinery</td>
</tr>
<tr>
<td>Misc. Fixed Assets</td>
</tr>
<tr>
<td>Technical know-how and Engg. Fees</td>
</tr>
<tr>
<td>Preliminary and Preoperative Expenses</td>
</tr>
<tr>
<td>Contingency</td>
</tr>
<tr>
<td>Margin Money</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

5.7 **ESTIMATED TURNOVER**

Rs. 7.0 crores (At 100% Capacity Utilisation)
(Average price : Rs.200/kg. for Grinding Media  
: Rs. 2000/kg. for Nozzles)

5.8 **PLANT AND MACHINERY**

An indicative list of equipments required for ceramic grinding media/nozzles plant is given below:
1. Blenders
2. Ball Mills
3. Spray drier
4. Isostatic Press
5. High Temp Tunnel Kiln
6. Weigh balance
7. Polishing machine
8. Quality Control Equipments

5.9 TECHNOLOGY SOURCES

Technology to manufacture ceramic grinding media can be sourced indigenously.

Technology for ceramic grinding media can also be sourced from renowned ceramic wear parts manufacturers. Few possible sources for technology supply are listed below:

(a) Japan
1. Kyocera Corporation
2. Nagaoka Kanaanei Ltd.
3. Token Industries Co. Ltd.
4. Fujikin International Inc.
5. Toshiba Ceramics
6. Century Koeki Ltd.
7. Nagase and Co. Ltd.

(b) USA
1. Hoover Universal Inc.
2. Champion Spark Plug Co.
3. Ferro Corporation
5. Coors Porcelein Co.
6. Carborundum Co.

(c) West Europe
1. Meret SA, France
2. Paul Rauschert GmbH, Germany
3. Friedrichsfeld, Germany
4. Krupp Widia, Germany
5. Metoxit Ag, Austria
6. Staatliche Porzellan, Germany
7. Heinz Welte Ing. GmbH, Germany

121
8. Doulton Insulators Ltd., UK  
9. Smith's Industries Ceramics and Ignition Co., UK  
10. Ceramica Industriale di Lavene  
    Verbano Soc. Co-operation a.r.l., Italy  
11. Al Metal Laundry Ltd., UK  
12. Cetema Ltd., UK  
13. Walther Trowel Ltd., UK

5.10 INFRASTRUCTURE

<table>
<thead>
<tr>
<th>Power</th>
<th>500 KVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>10000 litre/day</td>
</tr>
<tr>
<td>Manpower</td>
<td>30 persons including managerial, skilled semiskilled and unskilled staff.</td>
</tr>
</tbody>
</table>

5.11 RISK FACTORS

* Severe competition may arise from existing as well as new entrants especially in the Grinding media market, as this product is relatively low tech compared to other structural ceramic products.

5.12 OPPORTUNITIES IN GUJARAT

* End use sectors for Grinding media (cement/paints/pharmaceuticals etc) and ceramic nozzles (i.e. engineering sector) are well developed in the Western Region and especially in Gujarat. This augurs good market prospects for such products within and around Gujarat.

* Infrastructure facilities required for this project are available in Gujarat. The need for fuel for such industry can be tapped from available natural gas resources in Gujarat.

5.13 PREFERRED PRODUCERS

* Existing conventional ceramic products manufacturer can take up this project.
* A new entrepreneur can also put up such project with technical support from technology supplier.

5.14 PROFITABILITY

Good profits have been envisaged because:

* It is a value added product
* Market is growing and supply driven.
6.1 PRODUCT DESCRIPTION

There has been a large increase in the requirements for thread guides due to the rise in production of synthetic threads as well as faster textile machinery. Thread guides are used for the following reasons:

- to give a route/passage to the yarn.
- to control the tension in the yarn.
- to prevent tupture/damage of yarn.

The various types of guides in use today are:

- Ceramic (generally alumina)
- Plasma Coated
- Hard Chrome Plated
- Bartec Coated(Plastic)

In India, the powerloom sector does make use of traditional materials like glass and iron. Ceramic guides are well suited for the faster thread speeds and for highly abrasive synthetic threads that are being used today. Since they are processed under very high tension, their use in industrial fibres like tyre cords are not possible. Friction discs on texturizing machinery are also made of ceramic. About several thousand different shapes and sizes of ceramic thread guides are found in use on virtually all well known spinning machinery.

6.2 INDUSTRY STATUS

There are several manufacturers of ceramic thread guides in India. Thread guides have attracted these manufacturers, mainly because the parts are complex shaped, small and fetch higher price per unit weight leading to higher margins. However, large portion of current requirement of ceramic thread guides are still met through imports.

The domestic manufacturers of ceramic thread guides are:

- Himson
- JVP
- Widia
- NTB Hi Tech Ceramics
- Jyoti Ceramics

123
Himson is the largest domestic supplier of thread guides. NTB Hi Tech and Jyoti Ceramics have recently entered in the market. They are also reported to have exported thread guides.

6.3 MARKET POTENTIAL

Various types of thread guides are being used in Indian textile sector i.e. Ceramic, plasma coated, hard chrome plated, Bartec Coated etc.

Ceramic guides are most suited for the faster thread speeds and for highly abrasive synthetic threads. Ceramics guides for spinning, texturising and winding machines are available in several shapes and sizes.

The market for thread guides is growing consistently with the growth of textile sector in the country.

The total market for thread guides is very difficult to estimate as they are largely being imported under the category of ‘accessories’ alongwith the imported textile machineries.

The total market for thread guides at present is estimated conservatively at about Rs. 25 crores.

The percentage share of various types of thread guides is estimated to be as follows:

* Ceramic - 40%
* Hard Chrome Plated - 20%
* Plasma Coated - 20%
* Bartec Coated - 20%

Based on above estimate, the ceramic thread guides market works out to be in the region of Rs. 10 crores. This includes both OE requirement and replacement requirement. Replacement sector demand represents more than 90% of the total market.

The average annual growth of 12% is envisaged for thread guides industry. The current penetration level of 40% is likely to go up to 55% by 1994-95 and 65% by 2000 A.D.

Based on above, the market for ceramic thread guides is estimated to increase to Rs. 20 crores in 1994-95 and to 40.0 crores by 2000 A.D.

The demand summary for thread guides is given below:
### Year  |  Demand of Thread Guides  |  Penetration of Ceramic Guides  
---|---|---
1991-92  |  25.0 | 40%  
1994-95  |  35.0 | 55%  
1999-2000  |  62.0 | 65%  

Assuming an average cost of Rs. 1000 per kg for these guides (alumina), the demand in terms of tonnage is estimated as given below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand (Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-92</td>
<td>100</td>
</tr>
<tr>
<td>1994-95</td>
<td>200</td>
</tr>
<tr>
<td>1999-2000</td>
<td>400</td>
</tr>
</tbody>
</table>

### 6.4 MANUFACTURING PROCESS

The calcined alumina (85 to 99.5%Al₂O₃) is blended with the other ingredients and then subjected to dry milling for 16 hrs in a ball mill (Ball/Alumina ratio of 4.2:1) to break down the grains to the ultimate crystal size of 1 to 4 microns. 0.6% of triethanolamine was added as a grinding aid, shortening the time by 35%.

The dry-milled mix is screened through a 14 to 20 mesh screen. Screened alumina is mixed with a 15 to 30 volume percent or organics which must thoroughly coat the particles, often by the use of emulsions.

The typical batch for injection moulding of ceramic thread guide composed of:

- Alumina: 63% Vol.
- Binder (Epoxy Resin): 7% Vol.
- PF Resin: 3% Vol.
- Hardner: 2% Vol.
- Plasticizer: 25% Vol.

The batch is then treated as an injection mouldable plastic. It is placed in a heated chamber and forced in a cooled die at 12000 to 20000 psi.
The moulded piece is then heated under controlled conditions to burn out the organics. The burning off of the organics is critical. The moulded article is heated from 120° to 180°C in 6 hrs, holding at 180°C for 8 hrs and then going from 180 to 450°C with the rise from 200 to 300°C at 10°C per hour.

The moulded pieces are machined before firing.

Firing is carried out in gas fired kilns. The temperature schedule consists of 12 hrs to bring up to temperature, 2 hours at the maximum and 12 hrs to cool. The soaking temperature of 1700°C to 1750°C is maintained, however, these would be influenced by a number of factors such as fineness of grinding and desired porosity.

As the alumina bodies have high shrinkage and low green strength, the setting in the kiln must be thought out to prevent warping and cracking.

6.5 RAW MATERIALS
Reactive Grade Calcined alumina (above 98% Al₂O₃) is required. (Required Particle size: 0.05-5.0μm, Na₂O content: 0.02-0.0%)"}

6.6 SUGGESTED PROJECT SIZE AND PROJECT COST
Based on the potential market size, 100 tpa thread guides, plant has been suggested. Estimated investment for the proposed plant capacity is about 9.15 crores.

<table>
<thead>
<tr>
<th>[Rs. in Lacs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land and Site Development</td>
</tr>
<tr>
<td>Buildings</td>
</tr>
<tr>
<td>Plant and Machinery</td>
</tr>
<tr>
<td>Misc. Fixed Assets</td>
</tr>
<tr>
<td>Technical know-how and Engg. Fees</td>
</tr>
<tr>
<td>Preliminary and preoperative expenses</td>
</tr>
<tr>
<td>Contingency</td>
</tr>
<tr>
<td>Margin money</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>
6.7 ESTIMATED TURNOVER

Rs.:10.0 crores (at 100% Capacity Utilisation)
(Average price: Rs.1000 per kg.)

6.8 PLANT AND MACHINERY

For the production of ceramic thread guides, most of the equipments can be procured indigenously except injection moulding machine, tunnel kilns and certain quality control equipments.

Indicative list of various equipments required for ceramic thread guides manufacture is given below:

1. Weighing machines
2. Ball Mills
3. Sieves
4. Blenders/Mixers
5. Injection Moulding machine
6. Dryer
7. Gas fired tunnel kilns
8. Grinding/Lapping machine
9. Ultrasonic Cleaner
10. Quality control equipments etc.

6.9 TECHNOLOGY SOURCES

Technology to manufacture ceramic thread guide may be available indigenously. Overseas suppliers of technology includes:

(a) Japan
1. Kyocera Corp.
2. Token Industries Ltd.
3. Toto Kiki K.K.
4. Fujikin International Inc.
5. Nippon Gaishi
6. Mitisubishi Metal

(b) USA
1. Astro Met Associates Inc.
2. Duramic Products Inc.
3. Coors Poreclein Co Inc.
4. ESK Corporation
5. Art Incorporation

(c) West Europe
1. Northern Mill Thread Guides, UK
2. Steatute and porcelein Products Ltd., UK
3. Paul Rauschert GmbH, Germany
4. Smith Industries Ceramics Co., UK
5. Maret SA, France
6. Staatl, Porzellan, Germany

6.10 INFRASTRUCTURE
Power : 300KVA
Water : 5000 litres/day
Manpower : 30 persons including, managerial, skilled, semiskilled and unskilled staff.

6.11 RISK FACTORS
Severe Competition may arise, from the existing manufacturers as well as new entrants, as the potential domestic market is not quite big enough to support many manufacturers of this product.

6.12 OPPORTUNITIES IN GUJARAT
- Good market prospects for Textile Thread Guides in Gujarat because of its well developed textile sector.
- Availability of necessary infrastructure for such project.

6.13 PREFERRED PRODUCERS
- Conventional ceramic products manufacturer may set up such project.
- Textile machinery manufacturer can include such project in the diversification plan as backward integration project.

6.14 PROFITABILITY
Good Profits have been envisaged because:

* It is a value added product.
* Market is growing and supply driven.
7.1 PRODUCT DESCRIPTION

In pumps and fittings, ceramics are being widely used because of their excellent wear and chemical resistance. The exceptional dimensional stability of ceramics makes them even more attractive.

Alumina is widely used to manufacture seal faces of mechanical seals and seal discs for domestic taps. It is also used for shaft sleeves, plungers, bearings for high pressure pumps, but usage is quite restricted.

7.2 INDUSTRY STATUS

Ceramic Seal Faces made from alumina have attained about 70% of the total market. Tungsten Carbide, Chrome plated steel and silicon carbide are other materials used to manufacture seal faces.

The ceramic seal faces for mechanical pumps are largely imported. M/s. WIDIA and IVP are the only domestic suppliers of ceramic seal faces made from alumina, however, their presence is marginal.

Household Tap Seal Discs (made from alumina) are entirely imported as there is no indigenous manufacturer of this item.

7.3 MARKET POTENTIAL

Ceramic seal faces (made from alumina) has cornered sizeable market (about 70%) of seal faces used in mechanical seals for power driven pumps.

The current market for mechanical seals for power pumps is about Rs. 50 crores. The cost of ceramic seal face is about 15% of the cost of seal. Based on these, the current market for ceramic seals is estimated at Rs. 5.25 crores per annum.

The market for mechanical seal faces is likely to grow at an average rate of 10%. The penetration of ceramic seal faces is likely to go up to 80% and 90% by 1994-95 and 1999-2000 respectively.

Based on above, potential demand for ceramic seal faces has been summarised as given in the following table:
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Total market for mechanical seals</td>
<td>50 Cr.</td>
<td>67 Cr.</td>
<td>108 Cr.</td>
</tr>
<tr>
<td>2.</td>
<td>Penetration of ceramic seal face</td>
<td>70%</td>
<td>80%</td>
<td>90%</td>
</tr>
<tr>
<td>3.</td>
<td>Market for ceramic seal faces *</td>
<td>5.25 Cr.</td>
<td>8.0 Cr.</td>
<td>14.50 Cr.</td>
</tr>
</tbody>
</table>

* Cost of ceramic seal face is about 15% of the cost of seal.

The current market for single lever mixing tap is about 35000 numbers/annum. The cost of one seal (imported) is about Rs.900. Hence, current market for ceramic cartridges is estimated at Rs. 3.15 crores.

The estimated growth (including substitution of dual knob taps) of single lever mixing taps is about as high as 20%. It is also envisaged that local manufacture of this product will reduce the unit price to Rs. 500 from the current price of Rs. 900. In fact, the high growth rate has been estimated taking into account the impact of price reduction.

The future potential market for ceramic tap cartridges has been estimated as summarised in the following table:

<table>
<thead>
<tr>
<th>Year</th>
<th>Market for Tap Cartridges</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-92</td>
<td>3.15 Crores</td>
</tr>
<tr>
<td>1994-95</td>
<td>3.00 Crores</td>
</tr>
<tr>
<td>1999-2000</td>
<td>7.50 Crores</td>
</tr>
</tbody>
</table>

Thus, the total market for ceramic wear resistant parts in this segment is estimated as given below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Market (Rs.Crores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994-95</td>
<td>11.00 (110 Tons)</td>
</tr>
<tr>
<td>1999-2000</td>
<td>15.50 (115 Tons)</td>
</tr>
</tbody>
</table>
7.4 MANUFACTURING PROCESS

The Calcined alumina (85 to 99.5% Al₂O₃) is blended with the other ingredients and then subjected to dry milling for 16 hrs in a ball mill (Ball/Alumina ratio of 4.2:1) to break down the grains to the ultimate crystal size of 1 to 4 microns. 0.6% of triethanolamine was added as a grinding aid, shortening the time by 35%.

The dry-milled mix is screened through a 14 to 20 mesh screen. Screened alumina is mixed with a 15 to 30 volume percent of organics which must thoroughly coat the particles, often by the use of emulsions.

The batch is then treated as an injection mouldable plastic. It is placed in a heated chamber and forced in a cooled die at 12000 to 20000 psi.

The moulded piece is then heated under controlled conditions to burn out the organics. The burning off of the organics is critical. The moulded article is heated from 120⁰C to 180⁰C in 6 hrs, holding at 180⁰C for 8 hr and then going from 180 to 450⁰C with the rise from 200⁰C to 300⁰C at 10⁰C per hour.

The moulded pieces are machined before firing.

Firing is carried out in gas fired kilns. The temperature schedule consists of 12 hrs to bring up to temperature, 2 hours at the maximum and 12 hrs to cool. The soaking temperature of 1700⁰C to 1750⁰C is maintained, however, these would be influenced by a number of factors such as fineness of grinding and desired porosity.

As the alumina bodies have high shrinkage and low green strength, the setting in the kiln must be thought out to prevent warping and cracking.

7.5 RAW MATERIALS

Reactive Grade Calcined alumina (above 98% Al₂O₃) is required. (Required Particle size: 0.05-5.0μm, Na₂O content: 0.02-0.4%)

7.6 PROJECT SIZE AND PROJECT COST

Based on the potential market size, 100 tpa plant size has been recommended for pump seal faces/rings and domestic tap cartridges. Estimated investment for the proposed plant capacity is about 9.25 crores.
Land and Site Development 20.00
Buildings 50.00
Plant and Machinery 420.00
Misc. Fixed Assets 50.00
Technical know-how and Engg. Fees 145.00
Preliminary and Preoperative Expenses 80.00
Contingency 80.00
Margin money 80.00
Total 925.00

7.7 ESTIMATED TURNOVER

Rs.:10.0 crores (at 100% Capacity Utilisation)
(Average price: Rs.1000 per kg.

7.8 PLANT AND MACHINERY

Most of the equipments required for this project are available indigenously, except high
temperature kilns, injection moulding machines.

An indicative list of equipments required for this project is given below:

1. Blenders/Mixers
2. Ball Mills
3. Sieves
4. Injection Moulding machines
5. Back out oven
6. High temperature tunnel kiln
7. Grinding/lapping machine
8. Quality control equipments
7.9 TECHNOLOGY SOURCES

1. Token Industries Ltd. Japan
2. Astromet Associates, USA
3. Champion Spark Plug, USA
4. Duramic Products Inc. USA
5. Coors Porcelain Co., USA
6. Paul Rauschert GmbH, Germany
7. Feldmuhle KG, Germany
8. Krupp Widia GmbH, Germany

7.10 INFRASTRUCTURE

Power : 300KVA
Water : 5000 litres/day
Manpower : 30 persons including managerial, skilled, semiskilled and unskilled staff.

7.11 RISK FACTORS

Severe Competition may arise, from the existing manufacturers as well as new entrants, as the potential domestic market is not quite big enough to support many manufacturers of this product.

7.12 OPPORTUNITIES IN GUJARAT

- Good market prospects for Ceramic Pump Seal faces in gujarat because of its well developed engineering sector in the western region.
- Availability of necessary infrastructure for such project.

7.13 PREFERRED PRODUCERS

- Conventional ceramic products manufacturer may set up such project.
- Pump manufacturers can include such project in the diversification plan as backward integration project.

7.14 PROFITABILITY

Good Profits have been envisaged because:

- It is a value added product.
- Market is growing and supply driven.
8.1 PRODUCT DESCRIPTION

Material handling systems of any plant are subjected to a large amount of wear. This is caused by both abrasion and erosion during material flow. These material handling systems are crucial to cement, steel and other plants. The wear resistance of these systems is very important in order to minimise downtime.

Alumina liners are widely being used as material handling liners because of its excellent abrasion resistance properties.

The application areas for alumina material handling liners are very diverse. Some of them are:

- P.C. bends and inner cones in power plants.
- Chutes and air separators
- Slurry pipes in coal washeries
- Hoppers, pipes, bends, elbows, etc.

8.2 INDUSTRY STATUS

Ceramic liners for material handling are currently made by two companies in India i.e. BHEL and Garden City Engineers.

BHEL manufactures about 800 tons per annum of Alumina Liners. The other company M/s. Garden City Engineers, accounts for about 300 tons of ceramic liners.

M/s. Carborundum Universal also plans to set up 400 TPA alumina liner plant in technical collaboration with Coors, USA.

8.3 MARKET POTENTIAL

Various materials are being used as material handling liners, such as nickle, steel, cobalt alloys, tungsten carbide, plasma spray coatings of metals, rubbers and plastics. Alumina based material handling liners are popularly being used in certain key sectors, such as coal, power, steel, cement and fertilizer.

High abrasion resistance of alumina liners are increasing their usage. However, in certain cases where impact abrasion is high, alumina liners, because of their brittleness problems, are not preferred.
The total potential market for ceramic liners is quite huge. However, only about 1000 TPA (Value: Rs. 10 crores) of ceramic liners is being used at present.

In India, currently, these alumina liners are being used in bends in coal based power plant. A 500 MW plant requires 30 Tons of liners every two years. The current installed capacity of coal based power plant is around 45000 MW. Based on this, the estimated yearly requirement of liners has been estimated at 1350 tons, in existing thermal power plants.

Considering existing resource constraints, capacity addition of coal based power is estimated 5000MW during 8th plan period and 15000 MW during 9th plan period.

Liners are also used in ash handling systems of power plant. In a typical coal based power plant it is found that ash generated is about 30% of coal used. Considering that ash is half as abrasive as coal, then the current requirement of liners for this application works out to 200 tons.

Steel industry consumes about 80 million ton of various raw materials such as coal, iron ore, limestone, scrap, manganese ore etc. Of this, coal would be about 30 million tonnes (which is about 1/4 of the coal requirement by power sector). If it is assumed that other materials are half as abrasive as coal, the total market of liners at present would be about 520 tonnes per annum.

The current steel production 14 million tonnes is likely to go up to 27 million tonnes by 2000 A.D. The potential demand for liners for this sector is estimated at 2400 tonnes for the year 2000 A.D.

The current production of cement in the country is about 50 million tonnes which is likely to go up to 100 million tonnes. For cement production of 50 million tonnes, about 10 million tonnes of coal and 50 million tonnes of other raw materials such as limestone are required. Based on these, the current requirement of liners in this sector is estimated to be about 400 tonnes. The potential demand of liners by 2000 A.D. is estimated to be about 800 tonnes.

Power, steel and cement sector collectively accounts for about 75% of the total coal produced in the country. Thus approximately 53 million tonnes of coal would be consumed in other sectors. Assuming that 50% of these users use liners, the current demand of liners in other sectors would be about 300 tonnes.

The demand estimates for all types of liners have been summarised as given under:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Sector</th>
<th>Demand (In Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Power sector</td>
<td>1550</td>
</tr>
<tr>
<td>2.</td>
<td>Steel sector</td>
<td>520</td>
</tr>
<tr>
<td>3.</td>
<td>Cement sector</td>
<td>400</td>
</tr>
<tr>
<td>4.</td>
<td>Other</td>
<td>300</td>
</tr>
<tr>
<td>5.</td>
<td>Coal mining</td>
<td>775</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>3545</strong></td>
</tr>
</tbody>
</table>

135
Currently, only 1000 tonnes of alumina liners are used, which indicates that only 28% of the total market for liners in these sectors is catered to by ceramic liners.

Penetration level of 50% and 70% by ceramic liners have been envisaged by 1994-95 and 1999-2000.

The potential market for ceramic liners (i.e. alumina based) is thus estimated as given below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand For Ceramic Liners</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantity (In Tonnes)</td>
<td>(In Rs. Crores)</td>
</tr>
<tr>
<td>1994-95</td>
<td>2065</td>
<td>20.65</td>
</tr>
<tr>
<td>1999-2000</td>
<td>3900</td>
<td>39.00</td>
</tr>
</tbody>
</table>

*Note: Price of alumina liner: Rs.1,00,000/Ton*

8.4 MANUFACTURING PROCESS

Material handling liners are made by hot pressing. The process is accomplished by first thoroughly milling natural or synthetic bauxite containing principally Al₂O₃, Fe₂O₃ and TiO₂ until the bauxite is chemically uniform. The wet milling is continued for 24 huts in a mill in which ball/alumina ratio is 2:1.

After milling the excess water is decanted off.

The wet, finely pulverised and intimately blended bauxite is then calcined at 1000°C for 4 hours.

On calcining, average particle size of 4-5 μ is obtained which is the average crystal size of the oxides found in the bauxite.

The calcined product is placed in a Graphite mould (or a mould of other suitable refractory material) of desired shape, under pressure of 5000 psi and temperatures of 1250°C (for 5 minutes) with pressure duration of up to 60 min, and cooled slowly for 12 hours.

The product obtained has a specific gravity of 3.88 gm/cc, average crystal size of 1-8 μ and wear factor of 0.16.

8.5 RAW MATERIALS

The main raw material required is Bauxite, which is amply available in India.
8.6 PROJECT SIZE AND PROJECT COST

Based on potential demand supply gap, 1000 TPA plant is suggested for Alumina liners. The estimated investment for the proposed plant size is about Rs.8.25 crores.

<table>
<thead>
<tr>
<th></th>
<th>[Rs. in Lacs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land and Site Development</td>
<td>20.0</td>
</tr>
<tr>
<td>Buildings</td>
<td>50.0</td>
</tr>
<tr>
<td>Plant and Machinery</td>
<td>450.0</td>
</tr>
<tr>
<td>Misc. Fixed Assets</td>
<td>50.0</td>
</tr>
<tr>
<td>Technical know-how and Engg. Fees</td>
<td>20.0</td>
</tr>
<tr>
<td>Preliminary and preoperative expenses</td>
<td>20.0</td>
</tr>
<tr>
<td>Contingency</td>
<td>70.0</td>
</tr>
<tr>
<td>Margin money</td>
<td>85.0</td>
</tr>
<tr>
<td>Total</td>
<td>825.0</td>
</tr>
</tbody>
</table>

8.7 ESTIMATED TURNOVER

Rs.8.5 to Rs.10.00 crores per annum.
(Average price: Rs.85000-100000 per ton)

8.8 PLANT AND MACHINERY

For the manufacture of Alumina liners, most of the equipments can be procured indigenously. However, certain critical equipments like high temperature tunnel kiln and few quality control equipments may have to be imported.

Various equipments required for alumina liners are listed below:

1. Blenders/Mixers
2. Ball Mills
3. Decanter
4. Rotary Furnace for Calcination
5. Hydraulic Press
6. Tunnel Kilns
7. Quality Control Equipments
8.9 TECHNOLOGY SOURCE

Technology/know-how for alumina material handling liners may be available indigenously. Ceramic Technological Institute (CTI), Bangalore have technology to offer for this product.

Worldwide, there are quite a few renowned technology suppliers for alumina liner manufacture. Following list indicated few companies capable of supplying technology know-how for this project.

1. Kyocera International, Japan
2. Carborundum Co., USA
3. Norton Co., USA
4. Coors Porcelain Co., USA
5. Kalenborn, Germany
6. Ferro Corporation, USA

8.10 INFRASTRUCTURE

Power : 500 KVA
Water : 10000 litre/day
Manpower : 75 persons including manage-rial, skilled, semiskilled and un-skilled personnel.

8.11 RISK FACTORS

Market may become competitive as there is a possibility of new entrants entering market because this product is relatively easy to manufacture compared to other structural ceramic products.

8.12 OPPORTUNITIES IN GUJARAT

- Bauxite, an important raw material is amply available in Gujarat.
- Availability of necessary infrastructure required for such project in Gujarat.
- Demand for such liners is well developed in the sestern region.

8.13 PREFERRED PRODUCERS

Any ceramic wear resistant parts manufacturer may include this project to extend its existing product range.

8.14 PROFITABILITY

Good Profits have been envisaged because:
* It is a value added product.
* Market is growing and supply driven.
9.1 PRODUCT DESCRIPTION

Various types of refractories are available. Special refractories are high performance refractories made from high purity alumina, zirconia, silicon carbide etc.

Such special refractories offers following benefits.

- Longer life of refractories
- Continuous operation
- Higher temperature resistance
- Energy conservation
- Better quality end-product
- Resistance to thermal shock, corrosion, erosion and oxidation.

Such refractories find extensive use in steel industry.

9.2 INDUSTRY STATUS

There are several companies in the country manufacturing refractories. However, majority among them are producing traditional refractories

Key producers of refractories made from synthetic ceramic powders are:

- Carborundum Universal
- Grindwell Norton- Orissa Cement
- Tata Refractories
- ACC Refractories

However, these parties can not meet entire requirement of such special refractories. Substantial imports (about 2700-3000 tons) have been reported.

The current requirement of continuous casting refractories (i.e. about 2000 tons) is being imported entirely. M/s. IFCL is in the process of setting up 1920 TPA capacity plant to manufacture CCR. The plant is likely to commence its production by 1992 end.

9.3 MARKET POTENTIAL

Refractories are used in process industries for lining high temperature furnaces, vessels, kilns etc. The steel making industry is the most important industry as far as consumption of refractories is concerned. It consumes about 70% of refractories consumed in India.
The other industries requiring refractories are cement, glass, non-ferrous metals, power etc.

Various types of refractory materials are being used, such as ordinary fire clay bricks, mullite, cordierite and high performance refractories made from high purity alumina, zirconia, silicon carbide etc.

The total usage of refractories in India is estimated to be about 9 lakh tonnes, valued at Rs. 475 crores.

The sectorwise consumption of various refractories is as given below:

- Steel industry - 70%
- Cement - 8%
- Power - 6%
- Glass - 5%
- Non-ferrous Metals - 5%
- Others - 6%

Special refractories made from Synthetic Ceramic Powders are being used mainly in the steel sector. The current market for such refractories at present is estimated to be about 9000 tonnes out of total 5.9 lakh tonnes of refractories consumed by the steel sector. In terms of value, the current market for such special refractories is about Rs.59 crores.

New developments in steel production technologies such as continuous casting have created more stringent performance conditions for refractories. Continuous casting refractories (CCR) are not available indigenously. Presently, the requirement of such refractories is met through imports. The current imports of CCR is reported to be about 2000 Tonnes (Valued at Rs.30.00 crores).

The current refractory consumption norm for the steel industry is about 42 Kg. per tonne of crude steel produced. Considering current steel production of 14 million tonnes, refractories consumption is estimated at 5.9 lakh tonnes per annum.

The total steel production in India in 1999-2000 is estimated to be about 27 million tonnes. The current refractory consumption norm of 42 kg. is likely to be reduced to about 25 kg. by 2000 A.D. This gives a figure of about 6.75 lakh tonnes/annum for refractory consumption by the steel industry.

Though, the overall consumption of refractories will remain stagnant, there will be increase in use of special refractories. In fact the use of advanced materials themselves will reduce the consumption of refractories because of increased life and greater productivity.

The growth in the market of special refractories is entirely dependent on the progress of modernisation plans by steel sector. It has been envisaged that steel sector will require around 30000 tonnes of special refractories by 2000 A.D. At current price level, this market size is valued at Rs. 195 crores. The share of continuous cast refractories in this
is estimated to be about 8000 tonnes.

The demand for refractories has been summarised as given below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>All types</td>
<td>5.9 Lac</td>
<td>-</td>
<td>-</td>
<td>6.75 Lac</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Special refractories (Advanced)</td>
<td>9000</td>
<td>59</td>
<td>14000</td>
<td>92</td>
<td>30000</td>
<td>195</td>
</tr>
<tr>
<td>3.</td>
<td>CCR</td>
<td>2000</td>
<td>-</td>
<td>3500</td>
<td>-</td>
<td>8000</td>
<td>-</td>
</tr>
</tbody>
</table>

9.4 MANUFACTURING PROCESS

Various raw materials (synthetic powders) are ball milled to obtain required size of particles. After milling they are blended and pressed in a iso-static press where the mix is subjected to hydrostatic pressure of 10000 psi for few minutes.

The green product is then dried in a tunnel dryer.

Firing is carried out in gas fired kilns. The temperature schedule consists of 12 hr to bring up to temperature, 2 hrs. at the maximum and 12 hrs. to cool. The soaking temperature of 1700°C to 1750°C is maintained.

Finally the products are machined in CNC lathe to the required sizes. Thereafter they are subjected to rigorous quality checks including ultrasonic tests for detecting any cracks/other flaws in the final products.

9.5 RAW MATERIALS

The principal raw materials required for the project are sintered alumina, fused alumina, fused silica, fused zirconia, calcined alumina. All the above material, except sintered alumina and fused zirconia are available indigenously.

9.6 PROJECT SIZE AND PROJECT COST

Based on the potential demand supply gap for special refractories, a 2000 TPA plant has been recommended.
The estimated investment for the proposed size of the plant is about Rs. 23.0 crores.

<table>
<thead>
<tr>
<th>[Rs. in Lacs]</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Land and Side Development</td>
<td>50.0</td>
</tr>
<tr>
<td>Buildings</td>
<td>265.0</td>
</tr>
<tr>
<td>Plant and Machinery</td>
<td></td>
</tr>
<tr>
<td>- Imported</td>
<td>640.0</td>
</tr>
<tr>
<td>- Indigenous</td>
<td>460.0</td>
</tr>
<tr>
<td>Misc. Fixed assets</td>
<td>175.0</td>
</tr>
<tr>
<td>Technical know-how and Engg. Fees</td>
<td>110.0</td>
</tr>
<tr>
<td>Preliminary and preoperative expenses</td>
<td>220.0</td>
</tr>
<tr>
<td>Contingency</td>
<td>195.0</td>
</tr>
<tr>
<td>Margin money</td>
<td>170.0</td>
</tr>
<tr>
<td>Total</td>
<td>2285.0</td>
</tr>
</tbody>
</table>

9.7 ESTIMATED TURNOVER

Rs. 23.0 crores (At 100% Capacity Utilisation)
(Average price: Rs. 115000 per ton).

9.8 PLANT AND MACHINERY

Most of the equipments required for the manufacture of special refractories (required by the steel sector) are available indigenously, except iso-static presses and high temperature tunnel kiln.

Various equipments required for this project are indicated below:

1. Blenders/Mixers
2. Ball Mills
3. Spray Dryer
5. Tunnel Dryer
6. Tunnel Kiln
7. CNC Lathe
8. Quality Control Equipments
9.9 TECHNOLOGY SOURCES

Technological know-how for such highly specialised refractories is not available indigenously.

World-wide there are very few suppliers of such specialised refractories. Prominent names among them are:

1. Didier Werke, West Germany
2. Dyson, UK
3. Vesuvious Corporation, USA
4. Harima Ceramic Co. Ltd, Japan
5. Carborundum Co., USA
6. Norton Co., USA
7. Ferro Corp., USA
8. Refratechnic GmbH, Germany
9. Terres Refractories du Boulonnais, France
10. Nibek Ltd, UK
11. Morgan Refractories Ltd. UK
12. Toshiba Denko Co. Ltd. Japan

9.10 INFRASTRUCTURE

<table>
<thead>
<tr>
<th>Power</th>
<th>750 KVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>20000 litres/day</td>
</tr>
<tr>
<td>Manpower</td>
<td>150 persons including managerial, skilled, semiskilled and unskilled labour.</td>
</tr>
</tbody>
</table>

9.11 RISK FACTORS

Certain raw materials like fused zirconia and sintered alumina will be needed to be imported. Various uncontrollable factors like adverse exchange rate fluctuation, higher duties and levies may increase input cost substantially.

Possibility of increased competition in the future from existing manufacturers as well as new entrants.

9.12 OPPORTUNITIES IN GUJARAT

- Availability of necessary infrastructure facilities required for this project in Gujarat.
- Growth of mini steel plants in Gujarat, Rajasthan and Madhya Pradesh augurs good market prospects also.
9.13 PREFERRED PRODUCERS

An existing conventional refractories/ceramic products manufacturer can set up this project.

9.14 PROFITABILITY

Good Parofits have been envisaged because:

* It is a value added product.
* Market is growing and supply driven.
10.1 PRODUCT DESCRIPTION
Several grades of Alumina powders are available viz. Abrasive/Refractory Grade, Reactive Grade and Tabular Grade.

Deagglomerated alumina powders of high purity with a sodium oxide content below 0.01 wt% and a high α-phase content (above 90%) are termed as ‘Reactive Alumina’ and are used for advanced structural applications.

100% α-Alumina with purity above 99.5% in known a ‘Tabular Alumina’.

Reactive aluminas enabled 85, 90 and 95% Alumina ceramics to be upgraded to the higher alumina content with improved mechanical, thermal and electronic properties. Advances in the micro-miniaturization of components for the electronic computer and aerospace industries have been directly related to the development of low sod reactive aluminas.

10.2 INDUSTRY STATUS
Commercially available alumina in India is manufactured by the calcination of Aluminium Trihydrate obtained in the Bayer process. This contains impurities of silica, ferric oxide, sodium oxide etc. The maximum purity achieved is 99.5%.

Indian Aluminium Company (INDAL) makes two grades of alumina powder ~SRM 30 (particle size 3-5 μm) and C-Grade (Particle size ~43 microns). These grades are mainly used by Refractory and abrasives manufacturers.

INDAL has recently (during 1990-91) started manufacture of reactive Grade Alumina for structural application at their Belgaum unit. The production of this grade of alumina by INDAL is quite limited. The currently available reactive grade alumina powder from INDAL has particle size of about 4μ, while for most of the structural applications particle size of about 1μ is desired. Few ceramic manufacturers use domestically available reactive grade after ball milling it to desired particle size.

Most manufacturers requiring this grade of alumina powder get it through import.

10.3 MARKET POTENTIAL
The current and future market for the reactive grade alumina powder for various structural applications are described below:
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Spark plug cores</td>
<td>650</td>
<td>850</td>
<td>1125</td>
</tr>
<tr>
<td>2.</td>
<td>Thread guides</td>
<td>100</td>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>3.</td>
<td>Grinding media</td>
<td>150</td>
<td>260</td>
<td>650</td>
</tr>
<tr>
<td>4.</td>
<td>Nozzles, seal faces etc.</td>
<td>50</td>
<td>105</td>
<td>240</td>
</tr>
<tr>
<td>5.</td>
<td>Other structural application</td>
<td>2500</td>
<td>4000</td>
<td>9000</td>
</tr>
<tr>
<td></td>
<td>like reactors, liners etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>3450</strong></td>
<td><strong>6514</strong></td>
<td><strong>11415</strong></td>
</tr>
</tbody>
</table>

The landed cost of this grade of powder is in the range of Rs. 75095 per kg.

10.4 MANUFACTURING PROCESS

Alumina Powder for structural ceramics is manufactured using one of the four processes. The Bayer Process, Thermal decomposition of ammonium-alum, hydrolysis of aluminium alkoxides and the treatment of aluminium flakes by electric arc discharge in water.

The various processing steps of these processes are described below:

- **Bauxite+NaOH** → **Al(OH)₃+H₂SO₄** → **(NH₄)₂ SO₄** → **Al-metal+ C₅H₇OH** → **Al-metal Pellets+H₂O**
  - Digestion
  - Precipitation

- **NH₄ Al(SO₄)₂ 12H₂O** → **Al(OH₃H₇)₃** → **NH₄ Al(SO₄)₂ 12H₂O** → **Arc Discharge**

- **Al(OH)₃** → **Purification** → **Hydrolysis** → **Al(OH)₃**
  - Calcination
  - Decomposition

- **Al₂O₃-Gel** → **Calcination** → **Alpha alumina**

- **Alpha alumina** → **Alpha alumina** → **Alpha alumina**

Bayer Process → Alum Process → Al-Isopropoxide Route → Iwatani Process
The Bayer Process produces a wide range of aluminas, some of which have Na$_2$O levels well below 0.01 wt% and varying grain sizes corresponding to specific surface areas of 0.5 to 20 m$^2$/g BET. Aluminas with lower values of Na$_2$O are produced via the alum process, the Itawani process or by the hydrolysis of aluminium oxides.

In addition to the fineness of the powder and the Na$_2$O impurity level, SiO$_2$, Fe$_2$O$_3$ and TiO$_2$ content and the composition of the various phases (alpha/gamma alumina) as well as the agglomerate factor of the powder are important. These determine to a very large extent the quality of the end-product and are also reflected in the cost of the powders.

Deagglomerated powders of high purity with a Na$_2$O content below 0.01 wt% and a high alpha alumina content are used for advanced structural ceramics.

**CALCINED ALUMINA APPLICATION REQUIREMENTS**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Application</th>
<th>Media Particle size (μm)</th>
<th>Na$_2$O Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Electro-ceramic</td>
<td>0.5 to 5.0</td>
<td>0.02 to 0.10</td>
</tr>
<tr>
<td>2.</td>
<td>Sodium vapour lamp</td>
<td>&lt;0.5</td>
<td>0.02 to 0.10</td>
</tr>
<tr>
<td>3.</td>
<td>Mechanical/Structural</td>
<td>0.5 to 5.0</td>
<td>0.02 to 0.40</td>
</tr>
<tr>
<td>4.</td>
<td>Polishing</td>
<td>0.5 to 5.0</td>
<td>0.02 to 0.40</td>
</tr>
<tr>
<td>5.</td>
<td>Fused abrasives</td>
<td>0.5 to 1.0</td>
<td>0.20 to 0.40</td>
</tr>
<tr>
<td>6.</td>
<td>Ceramic fibres</td>
<td>0.5 to 1.0</td>
<td>0.20 to 0.40</td>
</tr>
<tr>
<td>7.</td>
<td>Hi Tech Refractories</td>
<td>0.5 to 3.0</td>
<td>0.10 to 0.25</td>
</tr>
<tr>
<td>8.</td>
<td>Spark plug</td>
<td>2.5 to 75.0</td>
<td>0.02 to 0.20</td>
</tr>
<tr>
<td>9.</td>
<td>Chinaware</td>
<td>0.5 to 3.0</td>
<td>4.00</td>
</tr>
<tr>
<td>10.</td>
<td>Glass</td>
<td>0.5 to 3.0</td>
<td>4.00</td>
</tr>
<tr>
<td>11.</td>
<td>Refractories</td>
<td>0.5 to 5.0</td>
<td>0.2 to 4.00</td>
</tr>
<tr>
<td>12.</td>
<td>Fused cost refractories</td>
<td>2.0 to 50.0</td>
<td>4.00</td>
</tr>
<tr>
<td>13.</td>
<td>Procelain insulators</td>
<td>2.0 to 5.0</td>
<td>0.20 to 4.00</td>
</tr>
</tbody>
</table>

The manufacturing process for calcined alpha alumina from Bayer process is already described in chapter four. The particle size of alumina obtained from this process is about 4 μ, which is ball milled to obtain desired size.

10.5 **RAW MATERIALS**

The main raw material for alumina production is bauxite containing 15-30% of total alumina. India has large bauxite reserves.

The other raw materials used for the production of alumina are caustic soda, lime, flocculants, fuel oil/natural gas etc.