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.

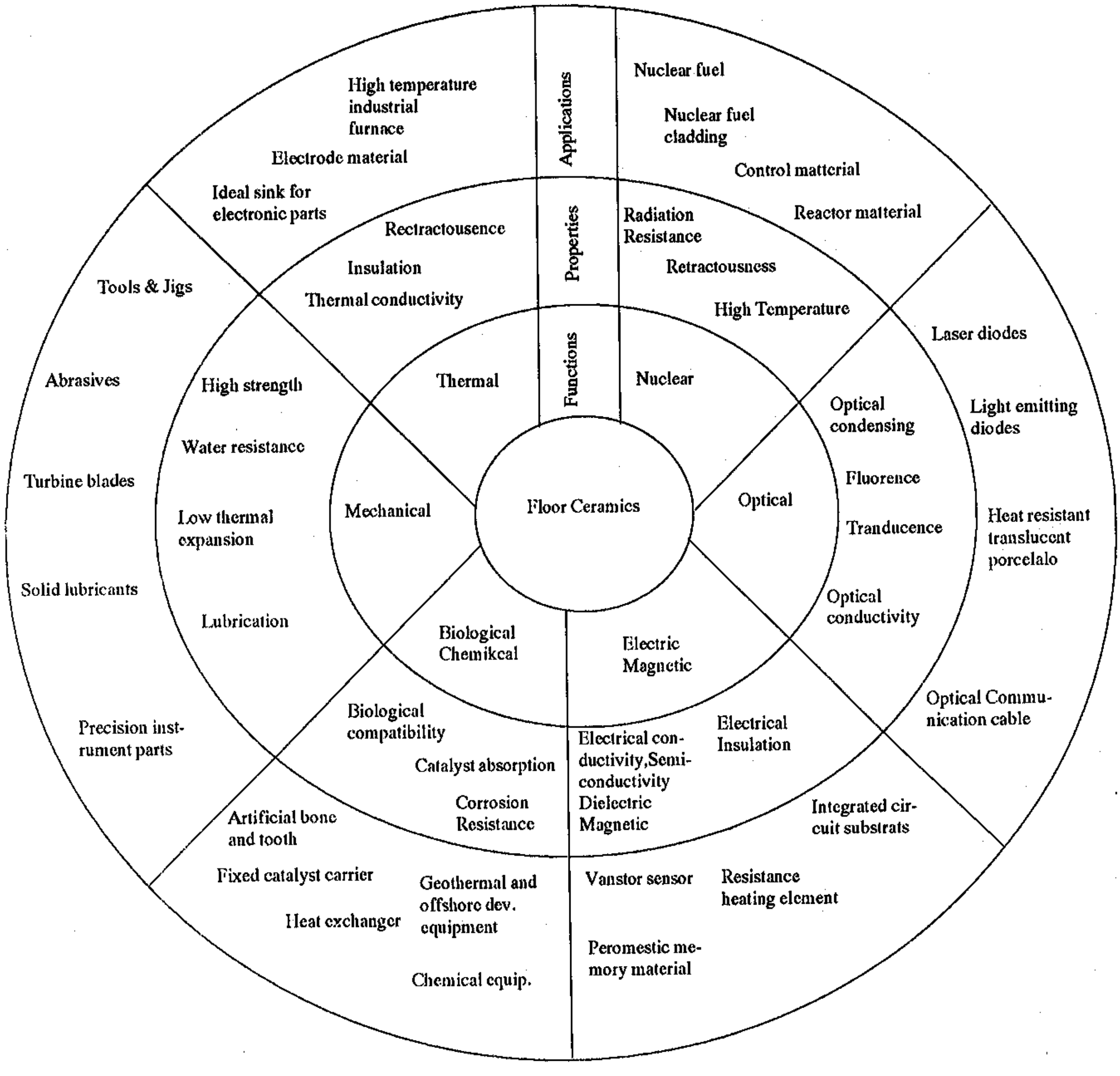
8.	**Dr. B K Sarkar** Director Central Glass & Ceramics Research Institute **Calcutta**	*Member*
9.	**Shri K D Sanghvi** Director Inter Kiln Hi-Temp Ceramics Pvt. Ltd. **Ahmedabad**	*Member*
10.	**Shri V D Patel** President Gujarat Ceramics Society **Ahmedabad**	*Member*
11.	**Shri P M Lodha** Jayshree Insulators Halol **Panchmahals**	*Member*
12.	**Dr. V C Joshi** Professor of Ceramic Engineering Department of Ceramic Engg. Banaras Hindu University Institute of Technology Varanasi, **U.P.**	*Member*
13.	**Dr. S Sensarma** Mineral Industries Directorate DGTD, Udyog Bhavan **New Delhi 110 011**	*Member*
14.	**Shri M P Palriwala** Managing Director Swastik Sanitary Wares Ltd. **Ahmedabad**	*Member*
15.	**Shri R J Shah** Chief Industrial Advisor Industries Commissionerate **Ahmedabad**	*Member*
16.	**Shri C K Joshi** Director of Geology & Mining **Ahmedabad**	*Member*
17.	**Dr. M K Jain** Executive Director **iNDEXTb**	*Member*
18.	**Shri J V Bhatt** Sr. Development Officer (Minerals) **iNDEXTb**	*Member Secetary*

Sd/-
P K LAHERI
Industries Commissioner &
Chairman, iNDEXTb

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

LIST OF ANNEXURE / APPENDIX

CHART 1.1
FUNCTIONAL APPLICATIONS OF ADVANCED CERAMICS



Functional Applications of Advanced Ceramics

(Source: Fine Ceramics Office, MITI, Tokyo

CHEMICAL FUNCTIONS	Gas sensor (ZnO_2, Fe_2O_3, SnO_2) Humidity sensor ($MgCr_2O_4$, - TiO_2) Catalyst carrier (cordierite) Organic catalyst Electrodes (titanates, sulfides, borides)	Gas leakage alarm,automatic ventilation fan,hydrocarbon, fluorocarbon detectors, etc. Cooking control clement in microwave oven, etc. Catalyst carrier for emission control Enzyme carrier, zeolites Electroinning aluminium, photochemical proceses, chlorine production
THERMAL FUNCTIONS (ZRO_2, TIO_3, CERAMICS)	Infrared radiator	
MECHANICAL FUNCTIONS	Cutting tools (Al_2O3, TiC, TiN others) Wear resistant materials ($Al_2O_3ZrO_2$) Heat resistant materials(SiC,Al_2O_3,Si_3N_4 others)	Cutting tools, sintered SBN Cermet tool, artificial diamond Nitride tool Material seal,ceramic liner,bearings,thread guide,pressure sensors Ceramic engine,turbine blade,heat exchangers,welding burner nozzle,high frequency combustion crucibles
BIOLOGICAL FUNCTIONS	Alumina ~~ceramics~~ implantation Hydroxyapatite biogass	Artificial tooth root, bone and joint
NUCLEAR FUNCTIONS	Nuclear fuels (UO_2, UO_2-PuO_2) Cladding material (C, SiC, BC_4) Shielding material (SiC, Al_2O_3, C, B4C)	

Source: George B Kenney and H Kent Bowen "High tech ceramics in Japan: current and future markets:, Americal Ceramic Society Bulletin, vol.62 no.5 (1983), p.591.

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 proceessing 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 merals, the highest temperature occurs before shaping. Therefore, there is a chance of correcting mistakes which might have occured 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.

Table1.

Comparison of Manufacturing Costs in High Performance Materials

Process	Structural Ceramics (%)	Metals and Others (%)
Starting materials	5-10	5-10
Physical processing	5-10	10.20
Chemical processing	10-20	20-30
Shaping	5-10	10-20
Thermochemical processing	15-20	5-10
Finishing	15-20	5-10
Inspection and rejection	40-50	5-10

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 (iNDEXTb) renders assistance to new enterpreneurs in identifying suitable projects. iNDEXTb 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	*Chairman*
02	Shri Rupeshbhai Shah	*Member*
03	Shri B D Kothari	*Member*
04	Shri Nimeshbhai S Bachkaniwala	*Member*
05	Shri H S Sethuram	*Member*
06	Shri Ganshyambhai Bhatt	*Member*
07	Shri B M Sedalila	*Member*
08	Dr. B K Sarkar	*Member*
09	Shri K D Sanghvi	*Member*
10	Shri V D Patel	*Member*
11	Shri P M Lodha	*Member*
12	Dr. V C Joshi	*Member*
13	Dr. S Sensarma	*Member*
14	Shri M P Palriwala	*Member*
15	Shri R J Shah	*Member*
16	Shri C K Joshi	*Member*
17	Dr. M K Jain	*Member*
18	Shri J V Bhatt	*Member Secretary*

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.

iNDEXTb
INDUSTRIAL EXTENSION BUREAU
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IEB:TP-CER:91:4122 **July 19, 1991**

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.

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

1. **Shri Achutrao Ganpule** — *Chairman*
   Chairman & Managing Director
   Parshsuram Pottery Works
   Morbi, **Rajkot**

2. **Shri Rupeshbhai Shah** — *Member*
   Manaing Director
   Soniya Ceramics Ltd,
   Ahmedabad

3. **Shri B D Kothari** — *Member*
   Managing Director
   Madhusudan Ceramics Ltd,
   Ahmedabab

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

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

6. **Shri Ghanshyambhai Bhatt** — *Member*
   Electro Porcelain Industries
   Ahmedabad

7. **Dr. B M Sedalia** — *Member*
   Consultants in Ceramic Technology
   Rajkot

SECTION - 1

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CHAPTER - 1

ADVANCED CERAMICS - AN OVERVIEW

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 occuring 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 termperature, 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- metalic abbrasives. 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 toughned zirconia, whisker and other fibre reinforced ceramic composited used in cutting tools and aerospace applicatiosn. Faster growth has been envisaged in the market of Ceramic Matrix Composites.

2.2.6 Major thrust of R&D activites 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 regractories.

2.3.2 There are very few players in the Hi-Tech Ceramics market and most of htem 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 secotr.

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 larg quantities on economic scale is much more difficult.

2.3.5 India has enough mineral deposits. In face, 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 produts.

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

ELECTRIC FUNCTIONS	Insulation materials (Al_2O3, BeO, MgO)	IC circuit substrate,package,wiring substrate resistor substrate,electronics interconnection substrate	
	Ferro electric materials ($BaTiO_3$, $SrTiO_3$)	Ceramic capacitor	
	Piezoelectric materials (PZT)	Vibrator, oscillator, filter, etc. Transducer, ultrasonic humidifier, piezoelectric spark generator, etc.	
	Semiconductor materials ($BaTiO_3$, SiC,, Zn-Bi_3O_3 and other transition metal oxides)	NTC thermistor	Temperature sensor,temperature compensation, etc.
		PTC thermistor	heat element switch,temperature compensation, etc.
		CTR thermistor	heat sensor element
		Thick film thermistor	infrared sensor
		Varistor	noise elimination,surge current absorber,lighting arrestor, etc.
		Sintered CdS material	solar cell
		SiC heater	electric furnace heater, miniature heater, etc.
		Solid electrolyte for sodium battery	
		ZrO2 ceramics	oxygen sensor, pH meter fuel cells
	Icon conduction materials ($-Al_2O_3ZrO_2$)		
MAGNETIC FUNCTIONS	Soft ferrite	Magnetic recording head, temperature sensor, etc.	
	Hard ferrite	Ferrite magnet, fractional horse power motors, etc.	
OPTICAL FUNCTIONS	Translucent alumina	High pressure sodium vapor lamp	
	Translucent magnesium mullite etc.	For a lighting tube,special purpose lamp,infrared transmission window materials	
	Translucent Y_2O_4, - ThO_2 ceramics	Laser material	
	PLZT ceramics	Light memory elements,video display & storage system,light modulation element,light shutter,light valve	

Sl. No.	Area/Product	Present Manufacturers	Likely New Entrants	Remarks
2.	Ceamic Cutting Tools	Sandvik, Widia supplies coated ceramic inserts.	-	Complete ceramic inserts are not manufactured. The future demand for complete ceramic inserts is not likely to be high.
3.	Ceramic Grinding Media	Several manufact-urers i.e. Jyoti Ceramics, NTB International etc.	Carborundum proposes to set up 100 T of grinding media per annum.	ACC, IVP are trying to develop products but have no significant market penetration.
4.	Ceramic Nozzles for Welding	IVP Ltd, the only supplier. Others supply tungsten carbide nozzles.	-	Current require-ment is imported.
5.	Ceramic Thread Guides	Himsons, NTB, IVP Widia are major suppliers.	Jyoti Ceramics and NTB HiTech Ceramics are trying to enter market.	Large quantity imports are reported.
6.	Mechanical Seal Faces and House-hold Tapseal Discs	IVP, Widia supplies mechanical seal faces. Household tapseal discs are not manufactured.	-	Most requirement is imported.
7.	Liners for Material Handling	BHEL and Garden City Engineers	Carborundum is setting up a new plant of 400 T in collaboration with Coors, USA.	The raw material alumina is amply available indigenously.
8.	Refractories	Several manufactur-ers. Major are Carborundum, Grind-wel Norton, Tata Refractories.	Several units are coming up like ACC Refractories, IFGL etc.	Special refractories required for conti-nuous casting of steel is not availa-ble indigenously. IFGL's plant to manufacture this refractory is coming up.
9.	Insulating Alumina Fibres	Carborundum, Orient Cerwool, Lloyds Insulation.	-	Carborundum also makes zirconia fibres.

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 virtally 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 Vatiation in Industry structure is observed among different regions. For instance, most US Companies active in ceramics are gragmented 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 leve, 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, unigersities and industrial organisations involved in ceramics research around the world, indicate the massive efforts and resources being poured into this ares.

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 tecjmologies 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, BHEL, 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 woek 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 2.

High Tech Ceramics Products Current Status - India

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

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, regractories, 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 divices 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 discribed below:

* Raw Materials of ceramic grade need to be improted. 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 henmce 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 pruity 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 recrysallised 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-0 system) - synthesis and fabrication - Bulk production of powders.
4. Metallisation of Ceramics for seals and feed throughs.

RESEARCH AND DEVELOPMENT STATUS

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 occuring 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 Instutute (CTI) is being set up by Bharat Heavy Electricals Limited (BHEL) with United Nations Development Programme (UNDP) assistance.

The main objective of the instutute is to support the Induan 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 priot 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 :

- Benefication 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 Diiffractometer
* 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 4.

Advanced Ceramics Market (1989)

Sector	Market US $ Billion	Share Percentage
Electronics	10.00	70
Structural	2.50	18
Coatings	1.70	12
TOTAL	14.20	100

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 4.

World Market For Electronic Ceramics (1989)

Application	Market US $ Billion	Share Percentage
Chip carriers	2.50	25
Capacitors	2.50	25
Ferrites	2.00	20
Piezoelectrics	1.25	13
Resistors	1.00	10
Others	0.75	8
TOTAL	10.00	100

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

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 Toughned Alumina(TTA)

A major time targetted 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 fuurnace, blow pipes, laddles, burners etc. of iron and steel industry. The process has been transferred to the industy.

7. High density Dolomite Sinsters

Tar/pitch bonded dolomite sinters are used at the wearling in LD converters. The instutute 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 quanitites 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 quanitites.

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:

1.	Defence Metallurgical Research Lab., Hyderabad	:	Hexagonal Boron Nitride, Zirconia & Zirconia based ceramics to meet defence requirements.
2.	Nuclear Fuel Complex Hyderabad	:	Nuclear grade zirconia for making fuel bundles.
3.	Indian Rare Earth Ltd Kerala	:	Lab Scale technology for PSZ manufacture.
4.	IIT, Bombay	:	Lab Scale synthesis of Zirconia by Sol-gel technology.

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 commerciation of R & D efforts.
- Enhance interaction between industry and R & D institutes so as to absorb and commercialise new technologies quickly and competitively.

1.	2.	3.	4.	5.	6.	7.	8.	9.
6.	Varistors (Ref. Profile No.4)	6.87 Mln.	3.44 Cr.	9.17 Mln.	4.59 Cr.	14.88 Mln.	7.44 Cr.	Consistently growing market. Substantial demand-supply gap is envisaged.
7.	Sensors	Small	Small	Small	Small	Small	Small	
	SUB-TOTAL (A)		169.00 Cr.		424.00 Cr.		1358.00 Cr.	
B.	**Structural Ceramics**							
1.	Ceramic Engine Components	NIL	NIL	NIL	NIL	NIL	NIL	It is unlikely that there will be any significant use of ceramic engine component in India before 2000 AD.
2.	Spark Plug Cores	12.6 Mln.	10.00 Cr.	17.0 Mln.	13.60 Cr.	22.50 Mln.	18.00 Cr.	Indigenous spark plug manufacturer either imports spark plug ceramic body or alumina powder required for spark plug. Substantial demand-supply gap exists.
3.	Catalytic Converter (Honeycomb Type)	NIL	NIL	NIL	NIL	NIL	NIL	Large potential market (about 400 crores by 2000 AD). But there are several constraints to growth. Use of ceramic converter possible only if MTBE used as octane enhancer and Govt. would make its use mandatory for pollution control. However, this seems to be a distant possibility.
4.	Ceramic Cutting tool inserts	Negligible	Negligible	Negligible	Negligible		5.00 Cr.	Market for complete ceramic cutting tool inserts will be very limited because the volume of cutting operations in very high-tech sectors such as aerospace is not likely to be high. However, market for coated ceramic inserts is likely to increase. Ceramic coating worth Rs.20 crrores by 2000 AD.
5.	Super Abrasives	1300 Tons	10.0 Cr.	1800 Tons	14.0 Cr.	2600 Tons	20.00 Cr.	Super abrasives are used only in bonded abrasives such as seeded gel type or super abrasives. The penetration of advanced ceramics will rise from the current 10% to 15% by 2000 AD.
6.	Mechanical Seal faces (Ref. Profile No.7)	-	5.0 Cr.	-	8.00 Cr.	-	15.00 Cr.	The current pentetration of ceramic seal faces is about 70% which is likely to go upto 90% by 2000 AD. The market for seal faces is likely to grow at 10% per annum at least.

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 relevent technologies, indigenously.

All these factors have stunted the market grwoth. 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

Sr. No.	Product/Group	Current Requirement (1991-92)		Market Size (Estimated) 1994-95		1999-2000		Remarks
		Volume	Value	Valume	Value	Volume	Value	
1.	Alumina							Except for Refractory and Abrasive grade
	- Electro-ceramic Grade	17.0 Tons	0.65 Cr.	59.0 Tons	4.3 Cr.	185.0 Tons	12.75 Cr.	Alumina, all other grades are available
	- Spark Plug Grade	630 Tons	3.80 Cr.	850 Tons	5.10 Cr.	1125 Tons	6.80 Cr.	largely imported.
	- Structural Grade	2800 Tons	16.80 Cr.	4565 Tons	27.40 Cr.	10290 Tons	61.75 Cr.	
2.	Barium Titanate	60 Tons	1.2 Cr.	400 Tons	8.00 Cr.	1600 Tons	32.0 Cr.	Barium Titanate is not available indigenously.
3.	Silicon Carbide (Structural applications)	2000 Tons	30.0 Cr.	4000 Tons	60.0 Cr.	8000 Tons	120.0 Cr.	Silicon carbide for metallurgical, abrasive and refractory grade is available indigenously.
4.	Silicon Nitride	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Silicon Nitride is not available indigenously.

4.3.6 Demand Summary

The market for various application area would be as under :

Product Group	Year (Value in Rs. Crores) Current	1994-95	1999-2000
Electro-Ceramics	169 (59%)	424 (60%)	1358 (78%)
Structural Ceramics	118 (41%)	191 (31%)	378 (22%)
Total	287 (100%)	615 (100%)	1736 (100%)

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)

Application Area	Market US $ Billion	Share Percentage
Automotive	1500	60
Industrial	625	25
Aerospace	250	10
Others	125	5
TOTAL	2500	100

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)

Types	Market US $ Billion	Share Percentage
Oxides	870	51
Carbides	320	19
Nitrides	119	7
Others	390	23
TOTAL	1700	100

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

3

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 decompositionof 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**

Discription of the Process:

The ore bauxite is refind by Bayer process to obtain Alumina.

The reactions involved are:

$$A1(OH)_3+NaOH \rightleftharpoons NaAlO_2+2HO$$

$$AlO(OH)+NaOH \rightleftharpoons NaAlO_2+H_2O$$

Following are the operations that are performed.

* Dissolution of the alumina at high temperature.
* Separation and washing of the isoluble 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

Gibbisite, $Al(OH)_3$ (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 containing120-135 g/L Na_2O is used at about 140°C. Bochmite (AlOOH) and diaspore (AlOOH) 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 μ m). 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

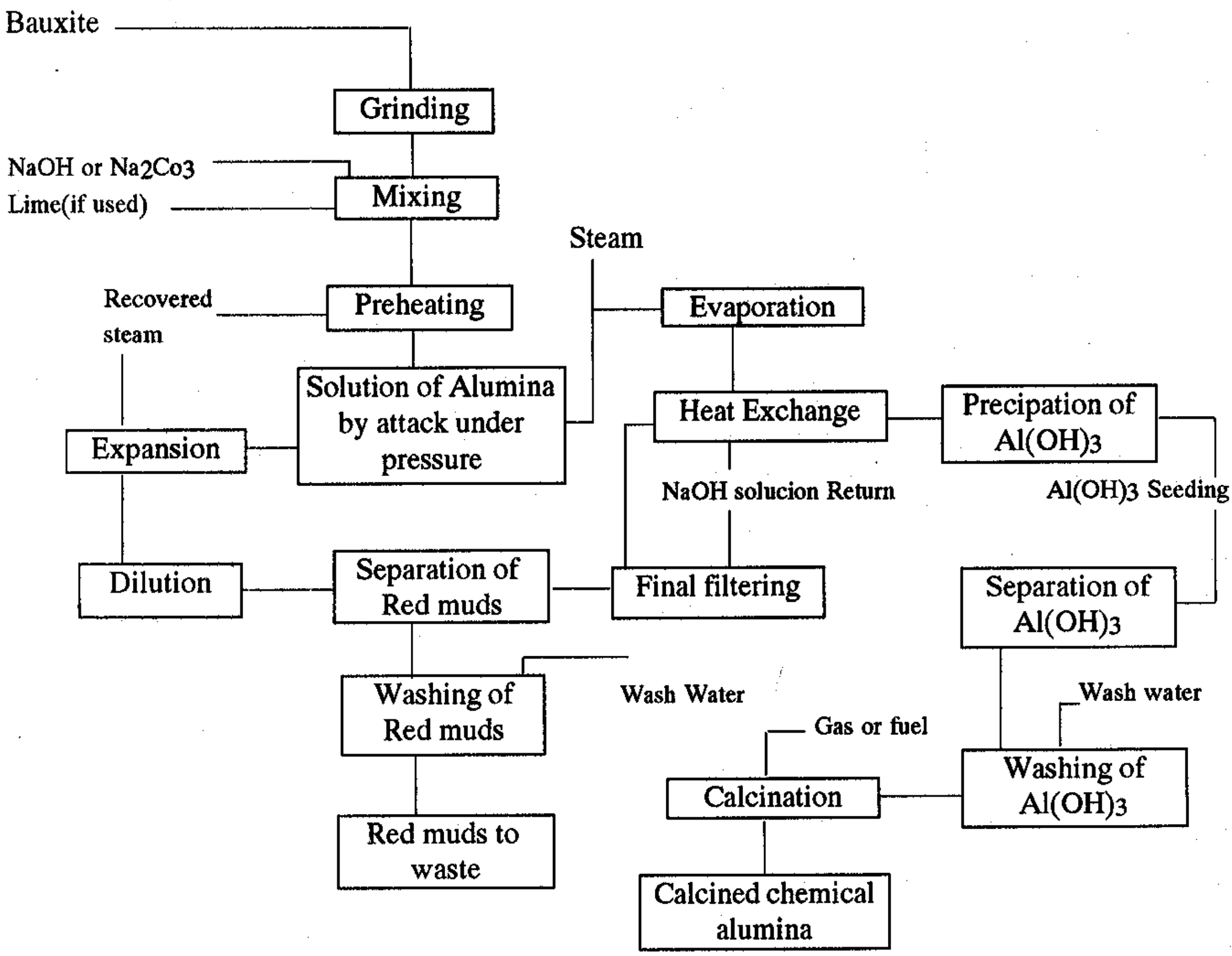
After a final filtration to remove the last traces of insoluble mud, the liquors have a $Na_2O:Al_2O_3$ molar ratio between 1.5 and 1.8.

Table 4.5

Demand Estimates : Hi-Tech Ceramics In India

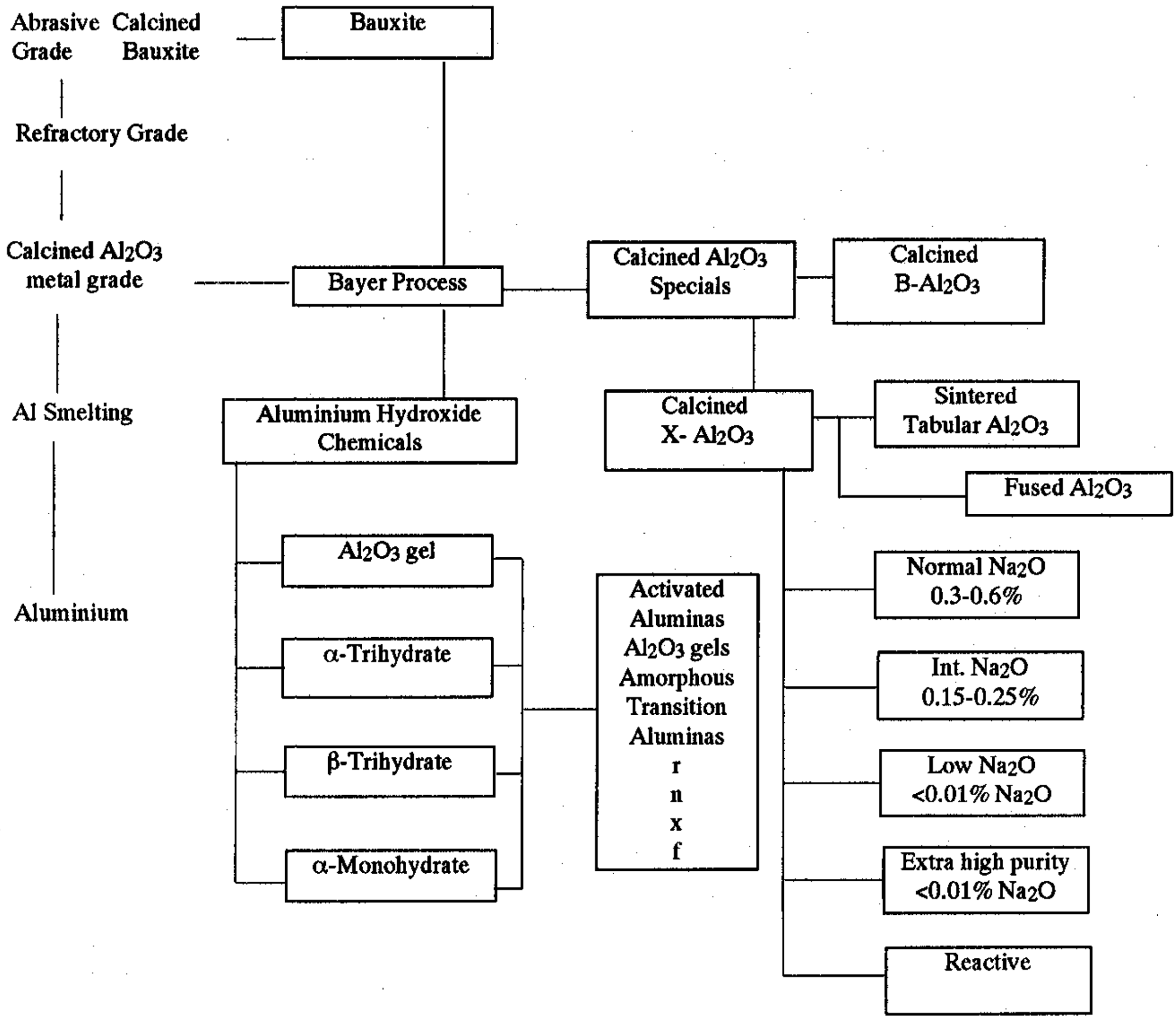
Sr. No.	Product/Group	Current Requirement (1991-92) Volume (Nos.)	Current Requirement (1991-92) Value (Rs.Crore)	Market Size (Estimated) 1994-95 Valume (Nos.)	Market Size (Estimated) 1994-95 Value (Rs.Crore)	Market Size (Estimated) 1999-2000 Volume (Nos.)	Market Size (Estimated) 1999-2000 Value (Rs.Crore)	Remarks
1.	2.	3.	4.	5.	6.	7.	8.	9.
A.	**Electro Ceramics**							
1.	Ceramic Capacitors							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.
	* Disc type	530 Million	53.0 Crore	900 Million	90.0 Crore	1075 Million	107.50 Crore	
	* Multilayer type (MLC)	120 Million	18.0 Crore	800 Million	120.0 Crore	3225 Million	784.00 Crore	
	(Ref.Profile No.1)							
2.	Substrates for IC Chip Carriers and Hybrid Circuits (Ref. Profile No.2)	16.88 Mln.	17.00 Cr.	59.00 Mln.	59.00 Cr.	185 Mln.	185.00 Cr.	40% share of cramic carriers have been envisaged in various types of carriers used for IC packaging. Substantial demand-supply gap is envisaged.
3.	Ferrites							Consistently growing market for both Hard and Soft Ferrites. Substantial demand-supply gap is envisaged for soft ferrites.
	* Hard Ferrites	3825 Tons	19.10 Cr.	6200 Tons	31.00 Cr.	9000 Tons	45.00 Cr.	
	* Soft Ferrites	3250 Tons	32.5 Cr.	5400 Tons	54.00 Cr.	7900 Tons	79.00 Cr.	
	(Ref. Profile No.3)							
4.	Piezo-Electrics							Consistently growing market for both Single Crystal and Polycrystalline Piezo-Electrics. Substantial demand-supply gaps exists for single crystal devices for wrist watches and PZT ceramic filters & delay lines.
	* Single Crystal	15.00 Mln.	9.90 Cr.	26.0 Mln.	29.40 Cr.	65.0 Mln.	73.50 Cr.	
	* Polycrystalline	13.00 Mln.	8.30 Cr.	20.0 Mln.	13.00 Cr.	40.0 Mln.	26.00 Cr.	
5.	Thermisters (PTC/NTC) (Ref. Profile No.4)	4.58 Mln.	2.29 Cr.	6.53 Mln.	3.26 Cr.	11.93 Mln.	5.97 Cr.	Market is growing consistently. However, future demand-supply gap is envisaged to be very marginal.

FLOW SHEET OF THE BAYER PROCESS



1.	2.	3.	4.	5.	6.	7.	8.	9.
7.	Domestic Tap Catridges (Ref. Profile No.7)	35,000 Nos.	3.15 Cr.	60,480 Nos.	3.0 Cr.	150,500 Nos.	7.50 Cr.	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.
8.	Ceramic Bearings	NIL	NIL	Negligible	Negligible	Negligible	Negligible	Ceramic bearings are unlikely to find application even by 2010 AD. Use is likely to be limited to defence or aerospace.
9.	Textile Thread Guides (Ref. Profile No.6)	100 Tons	10.0 Cr.	200 Tons	20.0 Cr.	400 Tons	40.00 Cr.	Good replacement market. Market is expected to grow consistently because of good prospects for textile machinery and increased penetration of ceramics.
10.	Ceramic Nozzles (Ref. Profile No.5)	-	1.40 Cr.	-	3.0 Cr.	-	7.40 Cr.	Ceramic nozzles have started penetrating tungster carbide nozzle market used for and shot blasting equipment and welding equipments. 65% penetration is envisaged by 2000 AD.
11.	Grinding Media (Ref. Profile No.5)	150 Tons	1.50 Cr.	260 Tons	2.60 Cr.	650 Tons	6.50 Cr.	Market for white cement is creating a good market for ceramic grinding media. Substantial demand-supply gap is envisaged in future.
12.	Material handling ceramic liners (Ref. Profile No.9)	1000 Tons	10.0 Cr.	2100 Tons	21.0 Cr.	3900 Tons	39.00 Cr.	Potential demand for material handling liners is in power, steel, cement and coal sector. Ceramic liners will become more popular in the coming years.
13.	Special Refractories (made from synthetic ceramic powders) (Ref. Profile No.9)	9000 Tons	59.0 Cr.	14,000 Tons	92.0 Cr.	30,000 Tons	195.00 Cr.	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.
14.	Coatings	-	8.0 Cr.	-	14.0 Cr.	-	25.00 Cr.	Increased penetration envisaged in certain applications like gas turbines, aerospace and textile machinery.
	SUB-TOTAL (B)		118.00 Cr.		191.00 Cr.		378.00 Cr.	
	TOTAL (A + B)		287.00 Cr.		615.00 Cr.		1736.00 Cr.	

VARIOUS GRADES OF ALUMINA POWDERS FROM BAUXITE



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 Carbode * 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

Materials	Melting Point (^0C)	Density (gm/CM^3)	Modulus of Elasticity (MPa)	Fracture Tughness (MPa m 1/2)	Bond strength (MPa)	Vickers Hardness (GPa)	Co-efficient of Thermal Expansion (1/k x 106)
Alumina	2050	3.95	300-370	3-4.5	350-580	16-17	8.1
Zirconia (TZP)	2500-2600	5.90	200	6-15	900-1000	12	10.5
Zirconia (PSZ)	2500-2600	6.05	200	6-12	900-1000	11	10.5
Cordierite (Porous)		1.5-2.0	130	1.5-2.5	100-200	8	08-1.2
SiC*	2300-2500	3.17	420	4	450-520	20	4.3
RBSN*	1750-1900	2.60	150	2.5-3.5	200-300	5-7	3.0
Si3N4(Dense)*	1750-1900	3.20	230	6	500-600	15	3.3
Aluminium Titanate*	1860	3.20	20		40		2.0

* 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:

	Capacity (TPA)	Production (TPA)
Orient Abrasives	18,000	14,000
Carborandum Universal	8,000	8,000
Cut Fast Abrasives	1,500	1,200
Grindwell Norton	5,000	3,000

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:

Grades	Prices (Rs./Ton)
Metallurgical	8,000
Refractory	15,000-20,000
Tabular	US $ 1750 (Rs.52,500 without duty) (Rs.1,23,500 with 135% duty)

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 AlO_2 to yeild aluminium trihydroxide.

$AlO_2 + 2H_2O$ ----> $Al(OH)_3 + OH$

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 precipitationis 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 μ m.

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 μ m.

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% Na_2O) soda levels. Extra-high purity 0.5 μm calcined, typically 99.95% Al_2O_3 with less than 0.01%Na_2O, 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% Al_2O_3 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% Al_2O_3 grinding ball because the wear rate runs about twenty times higher than in dry grinding. Commercialisation of 99.8% Al_2O_3 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% Al_2O_3 media.

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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% Al_2O_3 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-Al_2O_3. Processing is quite similar to that required for making sintered Al_2O_3 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/m^3 bulk specific gravity product (99.5% Al_2O_3) exhibits closed spherical porosity typical of a fully sintered ceramic with secondary recrystallisation. Typical impurities include about 0.05% SiO_2, 0.05% Fe_2O_3, and less than 0.1-0.25% Na_2O.

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 Al_2O_3 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 Al_2O_3 spheres made by pouring white fused Al_2O_3 ito 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-are 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 charges 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(lower 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 potteries and sanitary ware. Zirconia of high purity (99.8% pure) is also produced by Nuc;ear 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, ceremics and plastics, etc.

5.5.0 FERITES

5.5.1 Certain classes of ceramic materials normally termed ferrites, exhibit unsual magnetic properties due to particular nature of their crystal structure. All ferrites have Iron Oxide(Fe_2O_3), 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 Iit is hard to demagnetisc 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 inferrior 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 concer. 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 ($BaTiO_3$)

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 tetrogonal form which exhibits spontaneous electrical polarisation is piezoelectric. Above 130°C, barium titanate has cubic structure and paraelectric.

White fused grains normally exceeds 99% Al_2O_3 . The crushed and ground grits are not only magnetically separated, but are often acidwashed. A typical composition is 99.53% 0.33% Na_2O, 0.10% Fe_2O_3, and 0.03% C. The 0.03-0.05% Na_2O in Bayer alumina primarily forms β-Al_2O_3, concentrated in the centre of large ingots by zone refining of the Na_2O 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% Cr_2O_3 to form pink and red fused Al_2O_3 abrasives. Brown fused aluminas containing 94-98% Al_2O_3 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(C_3H_7OH). The resultant mix is hydrolised in a alcohol-water solution to produce suspension of fine oxide particles. The alumina gel is seperated 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 Na_2O 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:

Sr. No.	Speciality Application	Particle Size (in km)	Na_2O content (% wt)
1.	Electronic Ceramic	0.5 - 5.0	0.02 - 0.10
2.	Sodium Vapour LamO	< 0.5	0.02 - 0.10
3.	Mechanical/Structural	0.5 - 5.0	0.02 - 0.40
4.	Polishing	0.5 - 5.0	0.02 - 0.40
5.	Fused Abrasives	0.5 - 1.0	0.20 - 0.40
6.	Ceramic Fibres	0.5 - 1.0	0.20 - 0.40
7.	Hi-Tech Refractories	0.5 - 3.0	0.1 - 0.25
8.	Spark Plug Cores	2.5 - 75.0	0.02 - 0.20
9.	Chinaware	0.5 - 3.0	4.00
10.	Glass	0.5 - 3.00	4.00
11.	Refractories	0.5 - 5.00	0.2 - 4.00
12.	Fused cast Refractories	2.0 - 50.0	> 4.00
13.	Porcelain Insulators	2.0 - 5.0	0.20 - 4.0

5.7.6 In India, there are two major manufacturers of silicon carbide powder, viz. Carborundem Universal Grindwell Norton, besides couple of other smaller manufacturers. The current installed capacity and production of silicon carbide powder is given below:

Company	Installed Capacity (TPA)	Production
Carborundum	5,000	2,000
Grindwell Norton	10,000	3,500
Others	NA	1,00
Total		6,500

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 tungston carbide products.

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

Grade	Price per Tonne
Glack SiC	Rs.40,000-45,000
Green SiC	Rs.60,000

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, resitance 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% Al_2O_3 . The crushed and ground grits are not only magnetically separated, but are often acidwashed. A typical composition is 99.53% 0.33% Na_2O, 0.10% Fe_2O_3, and 0.03% C. The 0.03-0.05% Na_2O in Bayer alumina primarily forms β-Al_2O_3, concentrated in the centre of large ingots by zone refining of the Na_2O 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.

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Sr. No.	Speciality Application	Particle Size (in km)	Na_2O content (% wt)
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8.	Spark Plug Cores	2.5 - 75.0	0.02 - 0.20
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10.	Glass	0.5 - 3.00	4.00
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12.	Fused cast Refractories	2.0 - 50.0	> 4.00
13.	Porcelain Insulators	2.0 - 5.0	0.20 - 4.0

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 and acronym derived from Silicon, Aluminium, Oxyged 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, tutbine 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 abundently available in the Kachchh and Saurashtra region of Gujarat. Estimated reserves & production of various ceramic minerals are indicated below:

Ceramic Mineral	Estimated Reserves (Million Tonnes)	Production(1988) (Tonnes)
Ball Clay	Not assessed	-
Bauxite	87.42	4140
Bentonite	82.56	3382
Chromite	Nil	Nil

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 spheroie 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 resudual 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:

Company	Production(TPA)
IREL	18000
KMML	~1000
Total	19000

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% Al_2O_3). This indicates good prospects for Alumina based ceramic units. However, it is very essntial 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 obtainde at a temperature of about 300°C in the presence of additives. It is very difficult to obtain the exact stochiometric proportion in the fired product. When the TiO_2 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% SiO_2 and Al_2O_3 drastically deteriorates the required properties.

5.6.5 M/s. Thermo Chemical Industry, Junagadh has laboratory scale technology to produce high purity electronic grade $BaTiO_3$ 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 pute silicon carbide was imported valued at about Rs.2.5 crores. M/s. Shin-Et-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

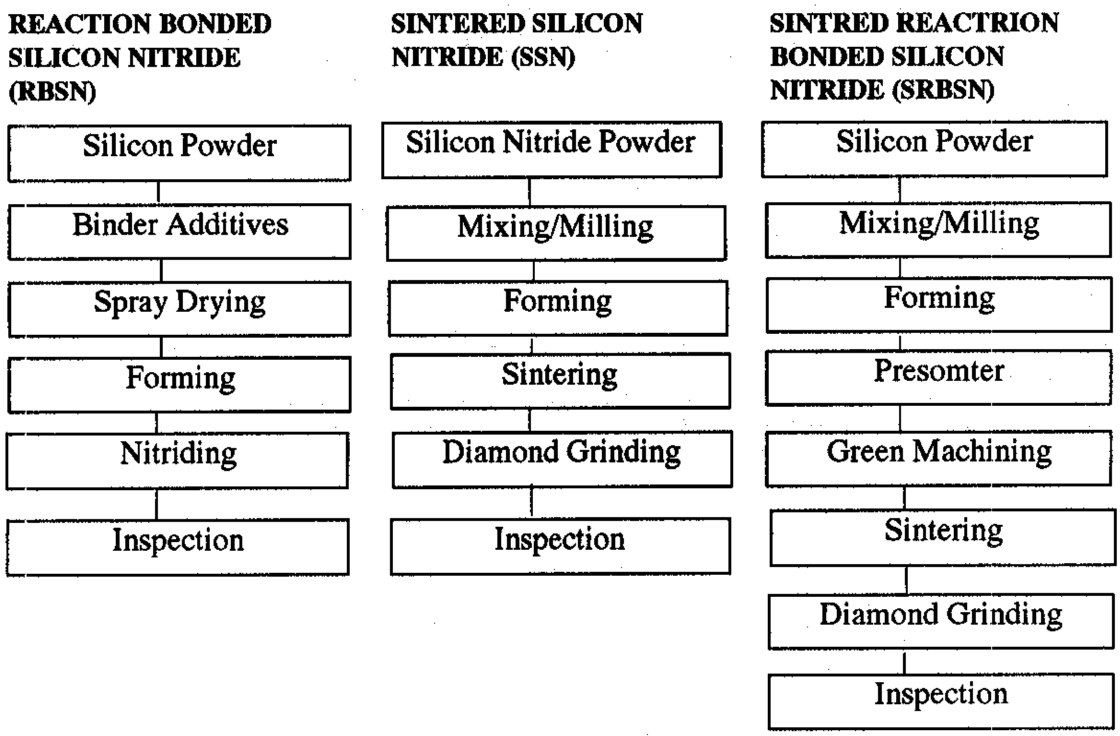
Table 6.1
Comparative Evaluation (Electro Ceramics)

Sr. No.	Parameters	Multilayer Ceramic Capacitors	Substrates for IC Chips and Hybrid Circuits	Ferrites(Hard and Soft)	Piezo-Electrics	Thermistors (NTC/PTC)	Varistors	Ceramic Sensors
1.	Market Potential	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.	The current market for ceramic substrates is quite large (about 17.0 mln.Nos). Demand for ceramic substrates likely to go upto 59.0 mln.Nos by 1994-95 & 185 mln. Nos. by 2000 AD.	The current market for hard & soft ferrittes 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 hard ferrites.	Substantial demand exists for single crystal devices required for wrist watches, polycrystalline piezo-electric devices for ceramic filters, delay lines for consumer and electronics applications.	Substantial demand(about 5 mln.Nos) exist in the domestic market. Demand is likely to go upto 10 mln.Nos. by 1994-95 & 18 mln.Nos.by 2000 AD. Substantial gap exists today, but it will be marginal in future.	Substantial demand (5.5 mln.Nos) exists in the domestic market which is likely to go upto 34 mln.Nos. by 2000 AD. Substantial gap exists today, but it will be marginal in future.	The current market for ceramic bases sensors are very limited. Future market is also not very encouraging.
2.	Supply Scenario	Present installed capacity is about 320 million pieces (GM Chip Components & Dalmia Cement Ltd). Gujarat Poly AVX and ICICON are planning to set up 250 mln and 100 mln. MLC mfg. plant respectively. Commercial prodn. likely by 1992 end.	Currently, entire requirement is imported.	Enough indigenous capacity exists for hard ferrite manufacture. For soft ferrites, indigenous capacity is not sufficient to cater to its demand.	Several mfrs. of Quartz crystal for clocks, crystal based oscilloscopes including crystals, PZT piezo-electric element. Single crystal devices required for wrist watches are imported from Japan.	Several mfrs. of NTC/ PTC resistors in the country. However, capacity is not enough to meet domestic demand.	Several manufacturers. However, installed capacity is not enough to meet domestic demand.	No indigenous manufacture.
3.	Raw Material (Compound) Availability.	Barium titanate powder not available indigenously. Even technology to produce high grade $BaTiO_3$ at commercial scale is not available.	The compound i.e. electronoc 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.	Compounds(ferric oxide) are manufactured in the country by Ferrite mfrs. Technology for powder preparation has been indigenised. Large reserves of ferric oxide in the country. However, inconsistent quality of ferric oxide is the major problem.	No indigenous supplier of compounds (i.e. lithium niobate, PZT and PLZT).	No indigenous supplier of compounds (barium titanate with sirontium or lead titanate, complex spinel structure of nickel manganese, cobalt and copper oxide). Lack of technology to produce high grade $TaTiO_3$ powder.	Semiconductor compounds like ($BaTiO_3$, SiC, ZnO-Bi_3O_3 and other transition metal oxides). These compounds are not available freely.	Alumina and Zirconia compounds. Required grades are not freely available.

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



5.8.3 The reaction bonded silicon nitride process uses dry pressing or injection moulding ofr forming the required shape in the case of high volume production. For low to medium volume production, wet bag isotatic 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 6.2

Comparative Evaluation (Structural Ceramics)

Sr. No.	Parameters	Spark Plug Body (1)	Catalytic Convertor (2)	Grinding Media (3)	Thread Guides (4)	Cutting Tool Inserts (5)	Mechanical Seal faces & Domestic Tap cartridges (6)	Nozzles for Welding and Sand blasting equipments (7)
1.	Market Potential	Currently market for spark plug in India is about 12.6 mln.Nos. per annum, which is likely to go upto 22.50 mln.Nos. by 2000 AD.	Large potential market (about 400 crores by 2000 AD). But there are certain constraints to growth. Use of ceramic converter possibble only if MTBE used as octane enhancer and Govt. would make its use mandatory. However, this seems to be a distant reality.	The current market of 150 tons is likely to go upto 400 tons by 2000 AD.	The current market size of 10 crores is likely to go upto 40 crores by 2000 AD. Consistent growth envisaged because good prospects of textile machinery and increasing penetration of ceramics in this sector.	The market for complete cutting tool inserts is very negligible. Future potential is also envisaged to be limited.	The current market of 8 crores is likely to go upto 30 crores by 2000 AD. Penetration is likely to increase if available from indigenous source.	The current market is very small. However, good future demand has been envisaged.
2.	Supply Scenario	Enough capacity exists for spark plug manu-facturer (MICO, Modi Champion and IVP are the major players). However, they do not have facility to manu-facture ceramic bodies required for plug. They import the green blank and after firing it is assembled.	No indigenous manu-facturers at present.	Few indigenous suppliers of ceramic grinding media. M/s Carborundum is planning to set up 100 ton plant for alumina grinding balls.	Major part of the current requirement is imported. Himson Jyoti, NTB International are major domestic manufacturers.	Complete ceramic inserts are not avaiable. indigenously. However, WIDIA and Sandwik supplies coated ceramic cutting tools.	Major part of the requirement is imported. M/s IVP and Widia are the only domestic suppliers.	IVP supplies ceramic nozzles for welding. A large amount is imported.
3.	Raw Material (Compound Availability)	Alumina powder is mix (90% Al_2O_3 with additions of silica, calcium oxide and magnesia) is not easily available indigenously. However, alumina-the main raw material is amply available in the country.	Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is amply available in the country.	Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is amply available in the country.	Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is amply available in the country.	Silicon motrode. sialon powders are not manufactured indigenously.	Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is amply available in the country.	Alumina powder mix suitable for use in this application is not easily available indigenously. However, alumina-the main raw material is amply available in the country.

Ceramic Mineral	Estimated Reserves (Million Tonnes)	Production(1988) (Tonnes)
Diaspore	-	-
Dolomite	696.33	232652
Limestone	8109.56	5546000
Feldspar	Not assessed	-
Nepheline Synite	14.00	-
Fire Clay	134.52	146503
Graphite	11.60	53
Gypsum	0.022	237
Magnesite	10.32	NA
Mica	Nil	Nil
Pyrophillite	Nil	Nil
Quartz & Quartizite	28.76	8081
Kaolin	3.78	34687
Andalusite	-	-
Kyanite	-	-
Silimante	Nil	Nil
Talc (Steatite)	-	-
Wollastonite	-	-
Zircon	-	-
Zirconia(Baddelyite)	-	-
China Clay	63.00	NA

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 abundently 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:

Bauxite Grate	Estimated Reseve ('000 Tonnes)
Chemical Grade	3929
Refractory/Abrasive Grade	3986
Chemical Mixed with others	24303
Metallurgical Grade I	5061
Metallurgical Grade II	226
Metallurgical Grade III	617
Metallurgical, Mixed	4141
Low Grade	4186
Mixed Grade	35865
Others	568
Not-known	4541
Total	87423

Sr. No.	Parameters	Super Abrasives (8)	Ceramic Bearings (9)	Material Handling Liners (10)	Special Refractories (11)
1.	Market Potential	The current market of 1300 tons is likely to go upto 2600 tons by 2000 AD. The current penetration of super abrasives in bonded abrasives market is likely to increase from the current 10% to 15%.	The market for ceramic bearings is very negligible today. Future demand estimates are also not very encouraging.	The current market of 1000 tons is likely to grow to 5000 tons by 2000 AD. Substantial demand-supply gap has been envisaged in the future.	The current market of special refractories (such as CCR) is about 8000 tons which is likely to grow to 30000 tons by 2000 AD. Substantial demand-supply gap is envisaged.
2.	Supply Scenario	Indian abrasives market has two major players i.e. Carborundum Universal and Grindwell Norton. However, 9-10% of the market consisting of advanced abrasive grains is entirely imported.	No indigenous supplier of ceramic bearing at present.	BHEL and Garden City Engineers supplies alumina liners at present. Carborundum Universal is planning up a new plant in foreign collaboration.	Only few manufacturers like IFGL, Tata, ACC manufacture such specialised refractories.
3.	Raw Material (Compound) Availability	High purity alumina, silicon carbide, CBN, polycrystalline diamond are compounds used for super abrasives. These compounds are not available indigenously.	Silicon nitride, which is used for ceramic bearing is not available indigenously. Indigenous manufacture of silicon nitride powder is not likely in the near future.	Bauxite - the major raw material required for the purpose is abundantly.	Sintered alumina, fused alumina, fused silica, fused zirconia, calcined alumina and carbon are the major raw materials required. Except for sintered alumina and fused zirconia all other raw materials are available indigenously.
4.	Acquisition of Technology	Relatively easy to acquire technology.	Relatively difficult to acquire technology.	Technology may be sourced indigenously.	Relatively easy to acquire technology.
5.	Export Potential	Not very encouraging as many manufacturers worldwide.	Not very encouraging as low demand for such specialised item.	Not very encouraging as many manufacturers worldwide.	Not very encouraging as many manufacturers worldwide.
6.	Risk Factors	Non availability of required compounds. Low export potential. Likely competition from new entrants.	Non-availability of required compound. Low domestic as well as export demand.	Low export potential. Likely competition from new entrants.	Non-availability of certain critical raw material like sintered alumina and fused zirconia. Low export potential. Likely competition from new entrants.
7.	Opportunities	Good opportunities for the manufacture of super abrasives.	Limited as very specialised market.	Good opportunities in the domestic market.	Good opportunities for the manufacture of special refractories.

CHAPTER - 6

COMPARATIVE EVALUATION AND SELECTION OF RELEVANT HIGH-TECH PROJECTS

6.1.0 INTRODUCTION

6.1.1 A comparative evaluation based on vrious 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 (ilel 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

Sr. No.	Parameters	Multilayer Ceramic Capacitors	Substrates for IC Chips and Hybrid Circuits	Ferrites(Hard and Soft)	Piezo-Electrics	Thermistors (NTC/PTC)	Varistors	Ceramic Sensors
4.	Acquisition of Technology	Easy acsuisitionas many foreign companies are willing to offer technology.	Technology acquisition is not very easy as most of the technology suppliers have their own stake in the manufacture and supply of this item.	Good technical know-how is available fairly easily and at low cost.	Technology can be acquired easily. Indigenous know-how available.	Technology can be acquired easily indigenously.	Technology can be acquired easily indigenously.	Technology can be acquired easily.
5.	Export Potential	Limited as international market is already inundated. However, it is possible if buy-back arrangements are made with technology supplier.	Possibility of export is bleack as severe competition from international giants. However, it is possible if a buy-back arrangement is made with technology suppliers.	Good scope for India to enter world market in both hard & soft ferrites. Possibility also exists for export of ferrite powders.	Possibility of export is bleak as severe competition from international giants.	Limited as there are many competitive manufacturers worldwide.	Limited as there are many competitive manufacturers worldwide.	Limited as there are many competitive manufacturers worldwide.
6.	Risk Factors	Chronic shortage of raw materials. Fierce competition anticipated from new entrants.	Shortage of electronic grade alumina compound as very few suppliers worldwide. Fierce competition ancitipated from international giants.	Inconsistent quality of raw material. Domestic demand not big enough. Low international prices.	Chronic shortage of raw materials and compound. Limited scope for export.	Chronic raw material shortage (barium titanate). Already many manufacturers exist.	Chronic raw material shortage (barium titanate). Already many manufacturers exist.	Chronic raw material shortage (barium titanate). Already many manufacturers exist.
7.	Opportunities	Good opportunities for MLC manufacture and barium titanate powder manufacture.	Good opportunity for substrate as well as electronic grade alumina powder.	Production of hard & soft ferrite powders based on Indian Ferric Oxide - a worthwhile opinion.	Opportunity exist in import of quartz ingot/ polycrystalline powders and processing them into the required piezo-electric elements.	Ceramic bases thermistors manufacture represents good business opportunity since most requirements are currently met by imports.	Ceramic bases varisters manufacture represents good business opportunity.	Less opportunity in the near future.

7.7.0 In the essence, prospects for Hi-tech ceramics industry in Gujarat seems quite bright.

7.8.0 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.

Sr. No.	Product	Preferred	Remarks
1.	Alumina Powder	Jamnagar/ Junagadh/ Kachchh Dist.	Raw material bauxite is available abundantly in theese rgions.
2.	Abrasive Grains	Jamnagar/ Junagadh Dist.	Raw material bauxite is available abundantly in these regions.
3.	High Alumina Bricks	Jamnagar/ Junagadh Dist.	Raw material bauxite is available abundantly in these regions.
4.	Alumina Castables & Kiln Furniture	Jamnagar/ Junagadh Dist.	Raw material bauxite is available abundantly in these regions.
5.	Barium Titanate Power	Gandhinagar Dist.	Special incentives for electronics industry are available in this region.
6.	Multilayer Ceramic Capacitors	Gandhinagar Dist.	Special incentives for electronics industry are available in this region.
7.	Ceramic Substrates for IC Chips and Hybrid Circuits	Gandhinagar Dist.	Special incentives for electronics industry are available in this region.
8.	Grinding Media	Any industria-lly developed location.	
9.	Welding Nozzles	Any industria-lly developed location.	
10.	Ceramic Seal Faces	Any industria-lly developed location.	
11.	Thread Guides	Ahmedabad, Surat Dist.	Good market prospects due to well developed textile sector.
12.	Material Handling Liners	Jamnagar, Junagadh Kachchh Dist.	Raw material bauxite is amply available in the region.

Sr. No.	Parameters	Spark Plug Body (1)	Catalytic Convertor (2)	Grinding Media (3)	Thread Guides (4)	Cutting Tool Inserts (5)	Mechanical Seal faces & Domestic Tap cartridges (6)	Nozzles for Welding and Sand blasting equipments (7)
4.	Acquisition of Technology	Technology to manufacture ceramic body for spark plug can be available easily.	Relatively easy to acquire technology.	Relatively easy to acquire technology.	Relatively easy to acquire technology.	Relatively difficult to acquire technology, as there are few established suppliers.	Relatively easy to acquire technology.	Relatively easy to acquire technology.
5.	Export Potential	Not existing as the market is captured by major spark plug manufacturers like Bosch, AC Champion and NGK.	Difficult as there are many already established manufacturers in the world.	Subsnatial export earning can be made if manufacturers can compete on price front.	Subsnatial export earning can be made if manufacturers can compete on price front.	Difficult to penetrate. Already established suppliers worldwide.	Subsnatial export earning can be made if manufacturers can compete on price front.	Subsnatial export earning can be made if manufacturers can compete on price front.
6.	Risk Factors	Existing spark plug manufacturers may undertake manufacture of ceramic bodies also. In that case, the investment may turn out to be redundant.	MTBE may not be used as Gasoline octane enhancer. Govt. may not make use of catalytic converter mandatory.	Likely competition from other new entrants.	Likely competition from other new entrants.	Extremely low domestic demand for complete ceramic inserts. Export market difficult to penetrate. Indigenous non-availability of silicon nitride and salalon.	Likely competition from other new entrants.	Likely competition from other new entrants.
7.	Opportunities	Good opportunities for ceramic spark plug body manufacture and for alumina compound required for spark plug.	Good opportunities to manufacture ceramic catalytic converter if above mentioned constraints are removed.	Good opportunities to cater to domestic as well as export market.	Good opportunities to cater to domestic as well as export market.	Good opportunities for coated ceramic tools but less opportunities for complete cutting tool inserts.	Good opportunities to cater to domestic as well as export market.	Good opportunities to cater to domestic as well as export market.

8.4.2 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 compoenents are given in the following table :

Sr. No.	Description	Customs Duty (%)			
		Basic	Auxiliary	C.V.D	Total
1.	Barium Titanate based ceramic compositions	35	5	15+2.25	64.15
2.	Ferric Oxide (above 99% purity)	35	5	15+2.25	64.15
3.	Manganese Oxide (above 99% purity)	35	5	15+2.25	64.15
4.	Manganese Dioxide (above 99% purity)	35	5	15+2.25	64.15
5.	Manganese Carbonate (above 99% purity)	35	5	15+2.25	64.15
6.	Nickel Oxide	35	5	15+2.25	64.15
7.	Strontium Carbonate	35	5	15+2.25	64.15
8.	Ceramic/Alumina Substrates	35	5	15+2.25	64.15
9.	Alumina Powder of purity 99.9% and above	35	5	15+2.25	64.15
10.	Reactive Alumina (Super Ground)	35	5	15+2.25	64.15

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.
- Vitramon
- Adolf Melter
- Champion Spark Plug
- DM Steward

Cutting Tools & Wear Parts

- Kennametal
- TRW/Wendt
- Astro Met
- Norton
- ESK Corp.
- Coors Porcelain
- Armeco
- Carborundum
- Lambertsville
- Art Inc.

Heat Engines & Parts

- Ford Motor
- Garret Corp.
- International Harvestor
- Pratt and Whitney
- General Motors
- General Electric
- Caterpillar

Composites

- DuPont
- Celanese

C. **U.K.**

Ceramic Powders

- Magnesium Elektron
- Lucas Cookson
- Visuvius

Cutting Tools & Wear Parts

- Doulton Industries
- Morgan
- Smiths
- Magnesium Elektron
- ICI
- Lucas Cookson
- Royal Worcestor
- Alcan International
- AED

Automotive Engines & Parts

- Leyland Diesel
- Ford UK
- Perkins Engine
- BL Technology
- Rolls Royce
- AE Turbine Components

D. **Germany**

Ceramic Powders

- Bayer
- Hermann Stark
- Hoechst
- Harshaw Chemie

Electro Ceramics

- Asternetics
- Siemens
- Hoechst

CHAPTER - 7

HI-TECH CERAMICS PROSPECTS IN GUJARAT

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 pripritities of the industries. Natural gas for a 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 quanity. 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

ANNEXURE - 2.2

COMMERCIALLY AVAILABLE STRUCTURAL CERAMIC PRODUCTS

Sr. No.	Product	Material	Manufacturer
1.	Automobile water pump seal ring	"Hexoloy SA" Sintered SiC	Carborundum Co.
2.	Armour Protection for gunship aircraft	"Hexology SA" Sintered SiC	Carborundum Co. Keramount Corpn.
3.	Oil Field Components, abrasive cleaning nozzles, bearings and guides	SiC/TiB_2, particulate composite	Standard Oil Engineered Materials Co.
4.	Ceramic bearings, hybrid ceramic bearings for aerospace, defence machine tools, biotechnology and automotive		Joint venture between Torrington Co. and Norton Co.
5.	Bearing components (balls, roller raceway blanks), water plates	Si_2N_4	Norton Co.
6.	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.	"AmAlox 68" High density ceramic	Astro Met Associates, Cincinnati, Ohio USA
7.	Parts upto 2 m long for large rollers pump seals, conveyor rollers, non-lubricated bearings for severe service conditions and a variety of structural & aerospace applications.	Si_3N_4	Enprotech Corporation, USA
8.	Precision fabricated nuts & bolts, other threaded components for applications such as high voltage insulators, electrode holders, gas stream deflectors for heat shield assemblies.	Various ceramics	Aremco Products Inc., USA
9.	Tool bits	Si_3N_4, SiC Whisker reinforced composites	Greenleaf Corpn. and several other manufacturers
10.	Liquid metal filters, precombustion chambers, exhaust manifold liners, ceramic rocker arm bearings.	Zirconia-Mullite	Ceramique et Composite, France
11.	Pump Cylinder liners and pistons, valve seals, mill lining blocks, gringing media, wear tile, computer tape guides, die plates.	Alumina	Diamonite Products, USA
12.	Diesel engine glow plugs, prechamber cups, turbocharger rotors.	Si_3N_4	Turbocharger with ceramic rotor installed in the GM automobile "Regal Grand National".

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 excluses 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 :

Sr. No.	Description	Customs Duty (%)				Remarks
		Basic	Auxiliary	Counter-vailing	Total	
1.	Calcined Alumina (99% pure & above)	55	45	15+2.25	134.5	Chap:28, 2818.20 Noti.No.49 dt.1-3-87
2.	Tabular Alumina (99% pure & above)	55	45	15+2.25	134.5	Chap:28, 2819.20 Noti.No.49 dt.1-3-87
3.	Zirconia Bubbles (99% pure & above)	55	45	15+2.25	134.5	Noti.No.49 dt.1-3-87
4.	Silicon Carbide (other than used for Grinding Wheels and Abrasive products)	65	45	15+2.25	146.225	Chap.28, 2849.20
5.	Silicon Carbide (for Grinding Wheels and Abrasive products)	40	45	15+2.25	128.64	Chap:28, 2849.20 Noti.No.37 dt.1-3-89
6.	Silicon Carbide (for the manufacture of Crucibles)	35	45	15+2.25	111.05	Chap:28, 2849.20 Noti.No.56 dt.25-7-91
7.	Barium Titanates	65	45	15+2.25	146.225	Chap:28, 28.51
8.	Silicon Nitride	65	45	15+2.25	146.225	Chap:28, 26.51

ANNEXURE - 2.4

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, Slovania
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

ANNEXURE - 2.1

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
- Unizon
- 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

Collaborator	:	Lamertville Ceramics and Mfg. Co., USA
Year of Collaboration	:	1987
Foreign Equity	:	-
Royalty	:	-
Lumpsum	:	US $ 0.1 Million
Duration	:	10 years

IVP Ltd., Bombay

Collaborator	:	Feldmuhle KG, Germany
Year of Collaboration	:	1986
Foreign Equity	:	DM 0.375 Million
Royalty	:	3% for 5 years
Lumpsum	:	-
Duration	:	5 years

Indoswe Engineers Ltd., Pune

Collaborator	:	Stettner & Co., Germany
Year of Collaboration	:	1986
Foreign Equity	:	DM 0.8 Million
Royalty	:	5% for 5 years
Lumpsum	:	-
Duration	:	5 years

E. REFRACTORIES

Orissa Industries Ltd., Cuttack

Collaborator	:	Taiko Refractories Co., Japan
Year of Collaboration	:	1985
Foreign Equity	:	-
Royalty	:	2% for 2 years
Lumpsum	:	Japanese Yen 300 lakhs
Duration	:	-

Cutting Tools & Wear Parts

- Krupp Widia
- Paul Rauschert
- Stall. Porzellan
- Feldmuhle
- Friedrichsfield
- Heinz Welte

Heat Engines & Parts

- Annawaerk-Degussa
- Feldmuhle
- HC Stark
- Diemler Benz
- ESK
- Sigri
- Rosenthall
- Volkswagen

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

ANNEXURE - 2.3

LIST OF EXISTING COLLABORATIONS IN THE FIELD OF ADVANCED CERAMICS

Sr. No.	Product	Indian Company	Collaborator
A.	**Electro-Ceramics**		
1.	Multilayer Ceramic Capacitors	GM Chip Components Dalmia Cement Gujarat Poly-AVX ICICON	Novacap, USA Novacap, USA AVX Corp., USA Iskara Commerce,Slovania
2.	Hard Ferrites	Morris Electronics GP Electronics Ltd Bihar State Electronics Corp. KSIDC	Hitachi Metal, Japan Tokyo Kikal Sanyo, Japan Iskara Commerce,Slovania Iskara Commerce,Slovania
3.	Soft Ferrites	Morris Electronics Permanent Magnets Suchitra Electronics Webel Electro Ceramics Ltd	Nippon Ferrites, Japan Sumitomo Special Metals Japan DEG, Germany Unitra Polfer, Poland
4.	Ceramic Substrates for	Kerala State Electronics Dev. Corpn. Ltd	YS Porcelain Tubes Mfg. Co. Ltd., Japan
5.	Ceramic tubes	BEL	NEC Corp., Japan
6.	Piezo Electronic Ceramic devices	MK Vijayshankar	Interquip Ltd., Hongkong
B.	**Structural Ceramics**		
1.	Advance (Tech.) Ceramics	NTB International P.Ltd	Lambertville Ceramics, USA
2.	Ceramic Thread Guides	NTB International P.Ltd	Lambertiville Ceramics, USA
3.	Sintered Ceramic Thread Guides	Himson Industrial Ceramics Pvt. Ltd	Allied Insulators Indl. Products Ltd., UK
4.	Industrial Ceramics using Injection Moulding	IVP Ltd	Feldmuhle KG, Germany
5.	Industrial/Technical Ceramics	Carborundum Universal Ltd Widia (India) Ltd	Coors Ceramic Co., USA Krupp Widia, Germany
C.	**Refractories**		
1.	Alumina & other refractories	Orissa Industries Ltd	Harbson Walker, USA
2.	Continuous casting refractories	IFGL Rectractories Ltd	Harima Ceramic, Japan
3.	Refractories (Monolithics)	Grindwell Norton Ltd	Norton Co., USA

ANNEXURE - 3.3

STRUCTURAL CERAMIC PRODUCTS CURRENTLY UNDER DEVELOPMENT

Sr. No.	Product	Material	Manufacturer
1.	Engine components-cum spring cap, fulcrum, roller followers, valve, valve guide.	Si_3N_4	Norton/TRW Ceramics Northboro, Ma, USA
2.	Prechamber for fuel injection in diesel engines.	Reaction bonded Si_2N_4	Diamler Benz, Germany
3.	Ceramic reinforced pistons for Mack tractors.	(80% Al_2O_3 + 20% SiO_2) fibre preform+squeeze cast aluminium	Wickes Manufacturing USA
4.	Valves for marine diesel engines.	SiC or Si_2N_4 bonded to Nimonic 80	
5.	Gas turbine hot section components blades, vanes, rotors, combustor, liners, flame holders, struts.	Si_3N_4	Norton/TRW Ceramics Northboro, Ma, USA
6.	All ceramic bearings for aircraft engines.		Japanese companies
7.	Components for piston driven IC engines.		GTE and Eaton jointly USA
8.	Parts of compressor turbines for 150 HP two shaft engine.		Toyota, Japan
9.	Combustor liners for commercial aircraft.	SiC fibre reinforced aluminosilicate glass ceramic.	
10.	Components for high temperature ballistic application.		DuPont and Landixe jointly, USA
11.	Rollers for cold rolling of steel, aluminium sheets.	Sialon	
12.	Coal gas filter.		

ANNEXURE - 3.1

WORLD-WIDE RESEARCH CENTRES IN HI-TECH CERAMICS

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

ANNEXURE - 3.2

MAJOR STRUCTURAL CERAMICS PROGRAMMES CURRENTLY UNDER PROGRESS

Sr. No	Name	Organisation	Scope
1.	National Ceramic Programme	Board for Technical Development Sweden	Engine, armour, tools biotech, industrial (duration 1989-94).
2.	Japanese Ceramic Gas Turbine Programme	New Energy and Industrial Technology Organisation	Gas turbines for portable electric generators to 300 KW, turbine inlet 1350°C, efficiency 42% (upto 1996).
3.	AGT 100 and AGT 101 Projects	US Dept. of Energy	First phase lasting 5 years concluded without testing at designed operating temperature of 1350°C, projects being continued.
4.	Ceramics Engine Research Programme	Department of Trade & Industry	Development of matrials for substitution on conventional engines (US $ 3.3 million).

C. SILICON CARBIDE POWDER

U.S.A.

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

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

Japan

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

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

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. Elken Metals
PO Box 266
Pitsburgh, PA - 15230
USA
Tlx: 866365, Fax: 412-787-1346

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

Japan

1. Toyo Soda Mfg. Co.
Speciality Products Division
1-7-7 Akasaka, Minata Ku, Tokyo
Japan
Tel: 03-585-3311

2. UBE Industries
7-2 Kasumigaseki 3-Chome
Chiyoda ku, Tokyo 100
Japan
Tlx: 2224645, Fax: (03) 505-9234

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

ANNEXURE - 3.4

INDIAN ORGANISATIONS ACTIVE IN R & D

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

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

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

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

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

APPENDIX - 1

LIST OF CERAMIC POWDER MANUFACTURWERS

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

6. Alcan Chemicals
3690, Orange Place, Suite 400
Cleveland, Ohio-4412-4438
USA
Fax: 216/765-2570

Japan

1. Chiba Ceramics Mfg. Co.
10-14, Inage Higashi 2-Chome
Chiba-281
Japan
Tel: 0472-43-7321

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

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

4. Murata Manufacturing Co.
26-10, 2 Chomo Tenjin
Nagaokyo Shi, Kyoto-617
Japan
Tlx: J 64270

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

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

B. ZIRCONIA POWDER

U.S.A.

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

U.K.

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

Germany

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

Japan

1. Toyo Soda Mfg. Co.
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, ML 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, Kearhy 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. Paktee Incorporated
7025, Brethare Drive, San Jose
CA 95120, USA
Tlx: 650-131-9707

13. Honeywell Inc.
Solid State Electronics Division
1150, East Cheyenne Mountain, Boulevard
Colorado, Springs, CO 80906
USA
Tlx: 650-131-9707

Japan

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

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

3. Murata Mfg. Co.
26-10, 2 Chomo Tenjin
Nagaokyo Shi, Kyoto-617
Japan
Tlx: J 64270

4. NGK Spark Plug
14-18, Takatsuji Cho, Mizohu-Ku
Nagoya 476-91
Japan
Tlx: J59592, 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-Cho
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
Niagra 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 Greenvilla, SC 29606
USA

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

Japan

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

2. Murata Mfg. Co.
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

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

Japan

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

2. Murata Mfg. Co.
4926-10, 2 Chomo 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

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

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

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

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

6. Murata Mfg. Co.
4926-10, 2 Chomo Tenjin
Nagaokoyo Shi, Kyoto 617
Japan
Tlx: J 64270

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

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

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

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

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

E. **CERAMIC SENSORS**

U.S.A.

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

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

3. Sohio Engineered Materials Co.
Refractories Division
PO Box 187
Keasbey, NJ 68832
USA
Tel: 201-738-4600

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
Tlx: 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, Sovrento Valley Road
Sam Diego, CA 92121
USA
Tel: 619-453-8020

7. Vitramon Inc.
PO Box 544, Bridgeport
CT 06601
USA
Tlx: 710-450-3640, Fax: 203-261-4446

Japan

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

2. Murata Mfg. Co.
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

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 Bashi 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

8. 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

Germany

1. Asternetics GmbH
Linden resig 3, DD-8028
Tajkinchen
Germany

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
Nucermet, 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. Carmet 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

9. Norton Co.
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 Carbide Tools Div.
205 N 13 Str.
Rogers, Arkansas 72755
USA
Tel: 501-636-1515

13. Valenite Div.
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
Yamachinaku, Kyoto 607
Japan
Tlx: 5422-479, Fax: 075-502-3696

2. Mitsubishi Metals
5-2, Otemachi 1-Chome
Chiyoda Ku, Tokyo 100
Japan
Tel: (03) 270-8451

C. FERRITES

U.S.A.

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

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

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

4. TDK Corp.
   1600, Feehanville Drive
   Mount Prospect, IL 60056
   USA
   Tel: 708-803-6100

Japan

1. Fuji Electro Chemical Co.
   Hamagomu Building
   36-11, Shinbashi 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

3. Murata Manufacturing Co.
   46 26 10 , 2 Chomo Tenjin
   Nagaokoyo Shi, 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 Electronics Co. Ltd
   13-1, Nihon Bashi 1-Chome
   Chuo 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

10. Shin Etsu Chemical Co
    6-1 Ohke machi 2-Chome
    Chiyoda Ku, Tokyo 100
    Japan
    Tel: (03) 246-5011

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, UT84115
   USA
   Tlx: 388-315, Fax: 801-486-3846

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

4. Murata Erie North America Inc.
   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, Coloroda 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 Nihonbashi 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
Kitakyush 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 Yuraka 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
Tlx: 932-499

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

7. Mine Safety Appliances Co.
600, Penn State Boulevard
PO Box 426, Pittsburgh
PA 15235, USA
Tlx: 812-453, Fax: 412-967-3451

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

Japan

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

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

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

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

5. Murata Mfg. Co.
4926-10, 2 Chomo Tenjin
Nagaokoyo Shi, Kyoto 617
Japan
Tlx: J 64270

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

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

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

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

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

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

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

13. New Cosmos Electric Co.
5-4 Mitsuya Naka 2-Chome
Yodogawa Ku
Osaka 532
Japan
Tel: (06) 308-2111

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
BahnhofstraBe-1
Postfach 1120
D-8644, Pressig
Germany
Tlx: 642626

2. Feldmuehle KG
Feldmuehle Aktiengesellchaft
Postfach 3029
D-4000
Dusseldorf-1
Germany

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

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

5. Staatliche Porzellan
WegelystaBe-1
D-1000, Berlin
Germany
Tlx: 181356

6. Heinz Welte Ing. GmbH & Co.
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: J 59592, Fax: (0568) 76-1297

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

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

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

Germany

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

U.K.

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

B. CERAMIC WARE PARTS

U.S.A.

1. Coors Porcelein 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

6. Lamberville Ceramics Mfg. Co.
245 North Main Street
PO Box 128
Lamberstville, NJ-08530
USA
Tlx: 642-212

7. Norton Co.
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 Sohhull
West Midlands B90 4LL
U.K.
Tlx: 338526

2. Vesuvius Zaylons
Tonyrefail Porth
Mid Glamorgan
CF 39 8 YW, Wales
U.K.

3. Doulton Insulators Ltd
Two Gates, Tamworth
Staffs B 77 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 Porcelein Products Ltd
Bewdley Road
Stourport - on - Seven
Worcestor 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, Cavendsh 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

11. Smiths Industries Ceramics and Ignition Co.
St. Peters Road
Rugby, Warwickshire CV 21 3 QR
U.K.

APPENDIX - 4

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

ALUMINA POWDER	BARIUM TITANATE POWDER
99% Alumina	Organic Solution of $Ti(O^{n}Bu)_4$ or $Ti(O^{i}Pr)_4$, or $Ti(OEt)_4$
Al-Metal	Saturated Solution of $Ba(OAC)_2$ in H_2O + AcOH added
High Purity Al-Metal	Complexation Homogenous Solution Prepared
Organo-Metallic Product	Slow/Fast Hydrolysis Condensation
Boehmite Precipitation	Alcohol-Acetic Monolithic Gel
Stable Solution to films or pasten	Drying
Calcination	Reactive amorphou $BaTiO_3$ Ceramic Precursors
Product purity above 99.99% with particle size from 25 n-m to 100 μm	Ceramic Capacitors

SECTION - 2

PROJECT PROFILES

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:

Sr.No.	Company	Capacity per annum
1.	GM Chip Components Ltd., Hyderabad	200 million MLCs
2.	Dalmis Cement (Bharat) Ltd.	120 million MLCs

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.

Types of Capacitors	Value in Million Nos. 1991-92	1994-95	1999-2000
Plastic film	350	800	2300
Electrolytic	575	1300	3700
Tamtalum	5	20	60
Ceramic - Disc type - MLC	650	1600	4300
Gang Condensors	8	-	-
Total	1588	3720	10360

Source: Electronics Information and Planning

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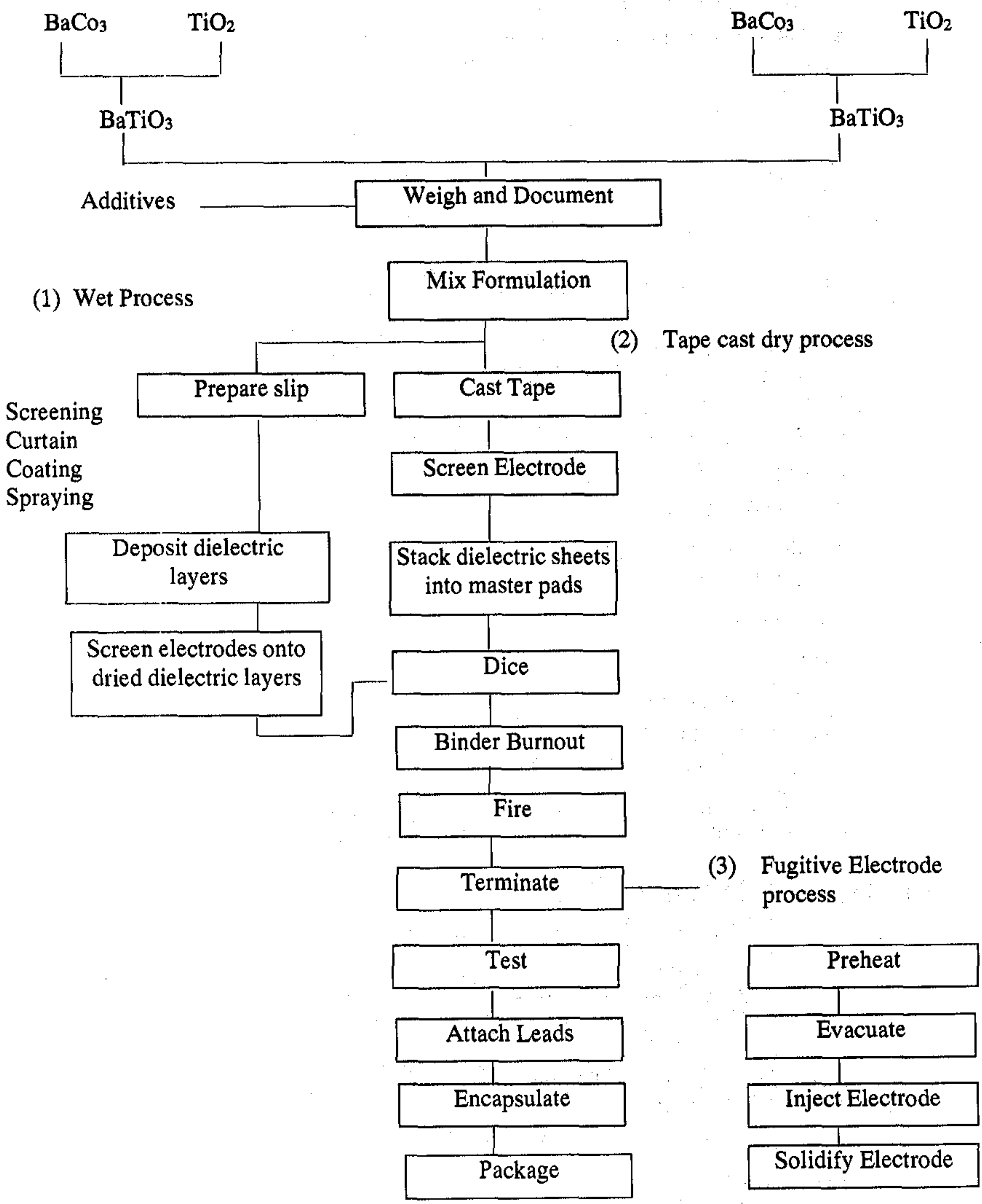
CHART-1

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



PROFILE - ONE

MULTILAYER CERAMIC CAPACITORS

1.1 PRODUCT DESCRIPTION

A capacitor is a component in an electronic/electrical circuit which stores electric charg. 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 cpacitor 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. Sufrace 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 intergration in electronic circuits, discrete monolithic capacitors will be replaced by multilayer chip type capacitors.

Barium Titanate ($BaTiO_3$) 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.

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

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.

	1994-95	1999-2000
Optimistic	50% (800)	75% (3225)
Pessimistic	40% (600)	60% (2580)

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 (TiO_2) and Barium Carbonate ($BaCO_3$) and calcininig them at high temperature. The obtained powder is then milled in a ball mill to get $BaTiO_3$ 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 OPPOURTUNITIES IN GUJARAT

- Good OEM Market for the proposed product as several OEMs are situated in the specially developed Electronic estates of the state.
- Guajarat 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 entreprenuer 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 elctrodes 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 1200^0 to 1300^0 C. A metal paint is then applied to make connection between the conductive coating and all the sandwitched electrodes in the body. This is then fired to about 800^0 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 dey process, except for one major change. In the other processes, the dielectric layer, with printed elctrodes 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 invovled are:

Ceramic Material ($BaTiO_3$)	-	14%
Organic Binder	-	2%
Electrode Pase (Ag-Pd)	-	36%
Terminal Pase (Ag)	-	48%

1.5 RAW MATERIALS

The major raw materials required for the manufacture of proposed product are :

- Barium Titanate Powder (SiO_2, Al_2O_3 content less than 1.5%)
- Silver/Palladium Pastes

These raw materials will have to be imported.

In a hybrid microcircuit, an insulating substrate ha sreistance and capacitance films deposted on it alongwith a printed connecting conductor grid. These films serve as capacitors and resistors and sometimes as descrete 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 accomodate about 15 ICs. All manufacturers of hybrid microcircuits need the ceramic substrate. Moreover, hybrid microcircuits are ian 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 large scale requirement in telecommunciations 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 substates.

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 mullion 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:

[In Million Nos.]

IC type	1991-92	1994-95	1999-2000
Linear	120	120	330
Digital		150	415
Hybrid	7	15	37

12. Packaging system consisting of scale, bag sealer/tape reel system etc.
13. Capcitance 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. Shinei 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^{o} 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. (Na_2O 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.

PROFILE - TWO

CERAMIC IC SUBSTRATES

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 tbe 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 imcrocircuits 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
2. Murata Mfrg. Co.
3. N.G.K. Spark Plug
4. Toshiba Ceramics
5. Soryu Co. Ltd.

C) **West Germany**

1. Hoechst Ceramtec AG

2.10 INFRASTRUCTURE

Electricity	:	500 KVA
Water	:	5000 litres/day
Manpower	:	55 persons including managerial, skilled, semi-skilled, un-skilled staff.

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:

[In Million Nos.]

IC type	1994-95	1999-2000
Linear/Digital	110	370
Hybrid	15	37

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

Sr. No.	Carriers/Substrates	1991-92	1994-95	1999-2000
1.	IC Chip carriers			
	- Volume (Ml.Nos.)	9.88	44.00	148.00
	- Value (Rs. Cr.)	3.00	13.20	44.00
2.	Hybrid Substrates			
	- Volume (Ml.Nos.)	7.00	15.00	37.00
	- Value (Rs.Cr.)	7.00	15.00	37.00
	Total (Rs.Crores)	10.00	28.20	81.40

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 minium 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.

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

2.7 ESTIMATED TURNOVER

Rs. 30.0 crpres (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:

[In Tons]

Hard Ferrites	1989-90	1994-95	1999-2000
LS Rings	2900	4715	6615
Segments	475	790	1300
Plasto Ferrites			
- Isotropic	325	490	740
- Anisotropic	125	210	335
Total	3825	6205	8990

Source: Electronics Information and Planning, March 1991.

- 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 ceramicIC 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.

3.4 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^{0} 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^{0} -1450^{0} 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:

[In Tons]

Soft Ferrites	1989-90	1994-95	1999-2000
T.V	2110	3190	4360
Telecom	100	250	500
Industrial electronics and informatics	240	750	1500
Radio sector	800	1200	1560
Total	3250	5390	7920

Source: Electronics Information and Planning, March, 1991

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:

Products	Countries
Hard Ferrites	
Rings	FRG, Sweden, UK, USA, USSR
Segments, Slabs	UK, USA, USSR
Plasto Ferrite	FRG, Italy, Taiwan, USA
Ferrite Powders	Taiwan, South Korea, Israel
Soft Ferrites	
'U' Cores 'E' Cores	Western Europe, USA, USSR
Yoke Rings	Western Europe, USA, USSR
Ferrite Powder	Taiwan, South Korea

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 optimim. 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 vaccum to the die cavity where alignment takes place with the help of magnetic field. After alignment, the water is removed by applying a vaccum 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.

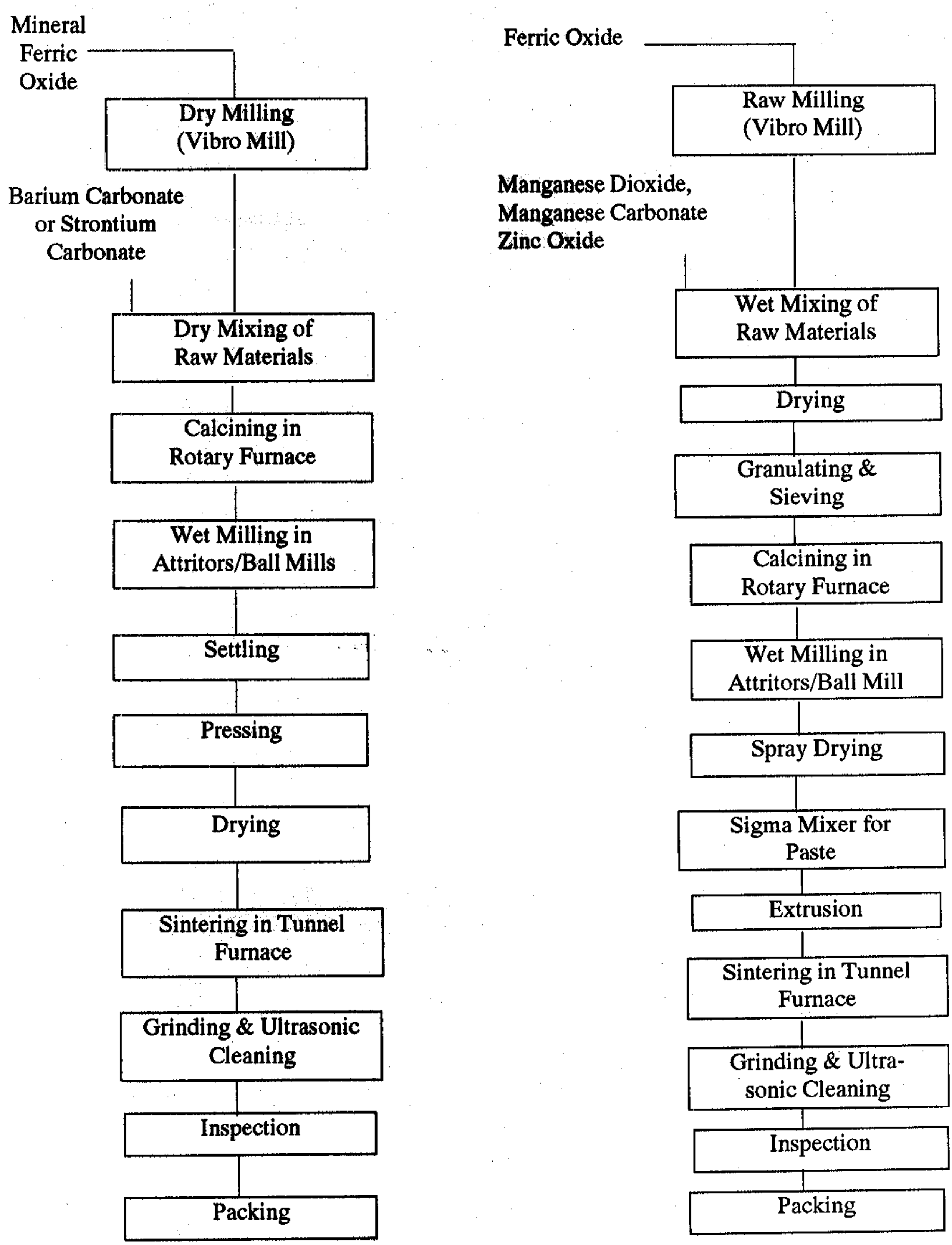
Hard Ferrites	:	1500 TPA
Soft Ferrites	:	1000TPA

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 ***SOFT FERRITE***



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 renouned 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

[Rs. in Lacs]

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

3.7 **ESTIMATED TURNOVER**

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

[Volume in Tons/Value in Rs.Cr.]

Year	Hard Ferrite Powder Volume	Hard Ferrite Powder Value	Soft Ferrite Powder Volume	Soft Ferrite Powder Value
1991-92	3900	1.95	3500	3.50
1994-95	6200	3.10	5400	5.40
1999-2000	9000	4.50	7900	7.90

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.

PROFILE - FOUR

CERAMIC SENSORS

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 :

Types of Ceramic Sensors

Sensor Type	Material	Applications
Positive temperature coefficient resistors (PTC)	Barium titanate with either strontium or lead titanate.	Temperature based control in colour TV, digital telephone exchangers, hair dryers, etc.
Negative temperature coefficient resistors (NTC)	Complex spinel structure of nickel manganese, cobalt and copper oxides (minor additives)	Non-liner circuit control, automobiles, medical thermometry.
Varistors	Zinc oxide	Over voltage protection in TV receivers, VCRs, microwave ovens, automobile electronics lightening arrestors.
Humidity sensors	Alumina(not used any more),Magnesia chrome titania ($MgCrO_4$, TiO_2) Zinc oxide chrome (ZnO-$Cr2O_4$)	Microwave ovens, clean room air-conditioners for electronics and food processing industries.
Oxygen sensors	Zirconia($ZrO2$) with additions of yttria (Y_2O_3) and magnesia (MgO)	Automobile combustion control, steel making, furnaces, food and beverage packaging.
Gas sensors	Zinc oxide, tin oxide iron oxide.	Liquid petroleum gas leak detection, oil rigs, refineries, toxic gas detection systems.
Pyroelectric sensors	Lithium tantalate, lithium niobate, lead titanate.	Microwave ovens, burglar alarms, body sensors, space instruments.

Source: **Materials for the year 2000; National priorities, KL Rao and S. Ranganathan.**

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 thicnkess of barrier layer is controlled by control of composition and cooling rates.

In $BaTiO_3$, 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 semidonductor 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 degausser 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 re 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 predominence 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

Sr. No.	Applications	1991-92 Qty. (M.Nos.)	1991-92 Value (Rs.Cr.)	1994-95 Qty. (M.Nos.)	1994-95 Value (Rs.Cr.)	1999-2000 Qty. (M.Nos.)	1999-2000 Value (Rs.Cr.)
A.	**Thermistors(PTC/NTC)**						
1.	Colour T.V.	1.20	0.60	1.60	0.80	2.57	1.20
2.	Refrigerators	1.30	0.65	1.93	0.96	3.71	1.85
3.	Air-conditioners	0.08	0.04	0.15	0.08	0.45	0.22
4.	Telecom & other professional elec.	1.00	0.50	1.33	0.67	2.14	1.07
5.	Others including mosquito coils	1.00	0.50	1.52	0.76	3.06	1.53
	Sub-Total : A	4.58	2.29	6.53	3.26	11.93	5.97
B.	**Varistors**						
1.	B/W T.V.	3.60	1.80	4.79	2.40	7.72	3.86
2.	Colour T.V.	1.20	0.60	1.60	0.80	2.57	1.20
3.	VCRs	0.07	0.04	0.12	0.06	0.30	0.15
4.	Others incl.Tele.Exch. refrigerator,computers & power gen.& distr. equipments.	2.00	1.00	2.66	1.33	4.29	2.14
	Sub-Total : B	6.87	3.44	9.17	4.59	14.88	7.44
	TOTAL : A+B	11.45	5.73	15.70	7.85	26.81	13.40

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

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

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

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 ingradients 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 alongwith 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 Sb_2O_3, Bi_2O_3, CaO, MnO, Cr_2O_3.

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.

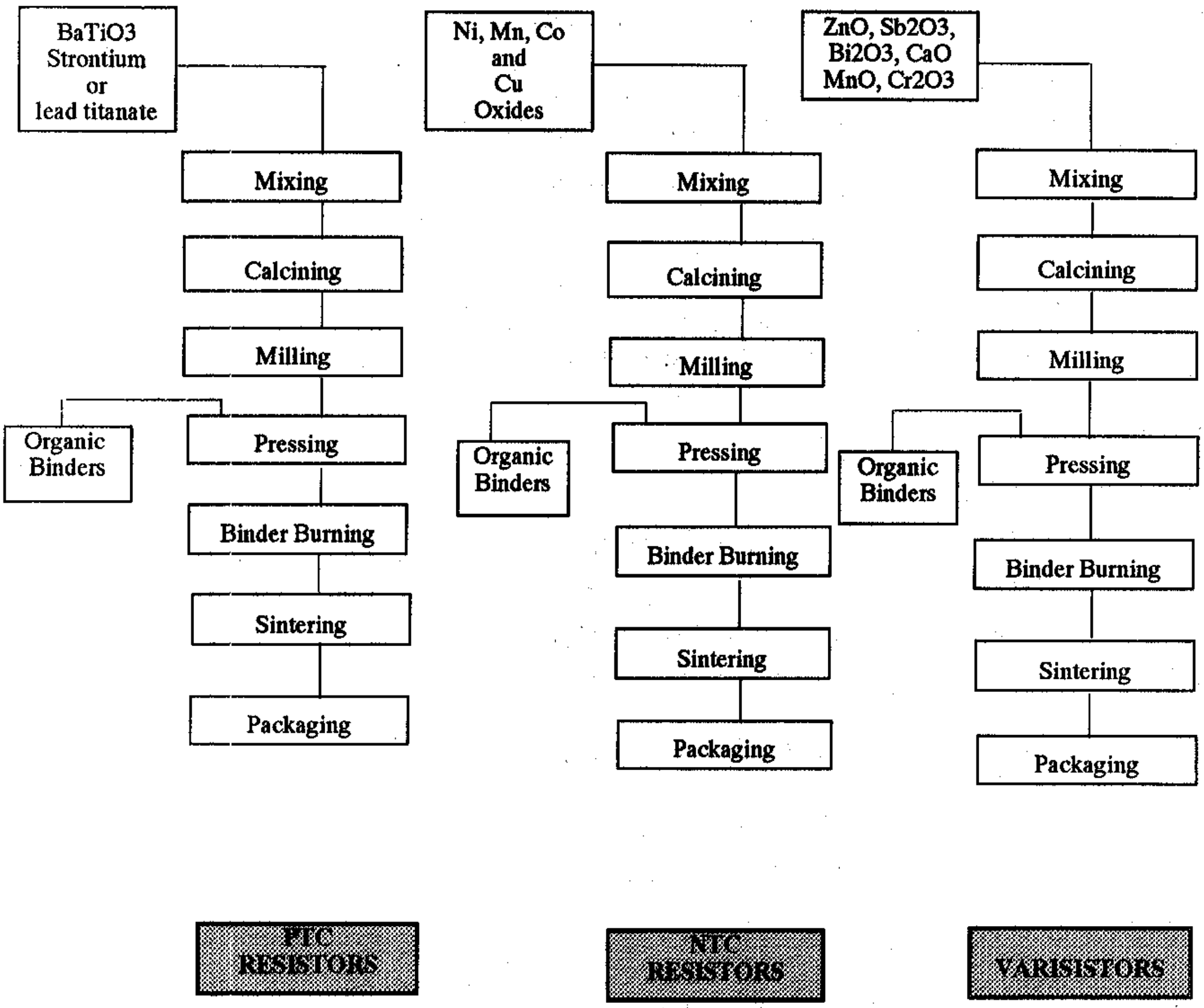
Land and building	:	Rs. 20 lacs
Plant and Machinery	:	Rs. 60 lacs
Misc. Fixed Assets	:	Rs. 10 lacs
Know-how and Engg Fees	:	Rs. 10 lacs
Preliminary Expenses	:	Rs. 5 lacs
Pre-operative expenses	:	Rs. 10 lacs
Contingencies	:	Rs. 12 lacs
Margin Money	:	Rs. 10 lacs
Total	:	Rs.137 lacs

4.7 ESTIMATED TURNOVER

Rs. 1.50 Crores(at 100% Capacity Utilisation)

CHART - 4.1

MANUFACTURING STEPS



4.8 PLANT AND MACHINERY

Indicative list of various equipments required for the manufacture of Thermistors/Varistors is described below:

- Mixers
- Calcining Furnance
- 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 tecnology can be sources:

USA

1. Dale Electronics Inc.
2. General Electric
3. Leach Corporation
4. Sohio Engineered Materials Co.
5. Betatherm Corp.

JAPAN

1. Hitachi Metal
2. Matsushita Electronic Components
3. Mitsubishi Mining and Cement Co.
4. MSK Corp.
5. Murate Mfg. Co.
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.

PROFILE - FIVE

CERAMIC GRINDING MEDIA & NOZZLES

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, pharmacueticals and ceramics. Use of alumina grinding media, does not cause any discolouration 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 aslo 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 significan penetration. Prominent amingst 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 m,anufacture 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 enstimate 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 avrage 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 :

Year	Demand	
	Qty.(Tons)	Vaue(Rs.Crore)
1994-95	260	2.60
1999-2000	650	6.50

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 predominent. 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 pentration 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:

Type	Demand (Rs. Crores)					
	Current (1991-92)		1994-95		1999-2000	
	All types	Ceramic	All types	Ceramic	All type	Ceramic
Sand Blasting Nozzles	2.20	Nil	2.60	0.50	3.30	2.00
Gas Welding Nozzles	3.30	Nil	3.80	0.80	4.90	3.00
Arc Welding Nozzles	1.40	1.40	1.70	1.70	2.40	2.40
Total	6.90	1.40	7.30	3.00	10.60	7.40

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% Al_2O_3
- 0.6% MgO
- 2.4% SiO_2

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 dired 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 mazimum 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% Al_2O_3) is required. (Required Particle size: 0.5-5.0 μm, Na_2O 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.

	[Rs. in Lacs]
Land and Site Development	20.0
Buildings	50.0
Plant and Machinery	400.0
Misc. Fixed Assets	50.0
Technical know-how and Engg. Fees	50.0
Preliminary and Preoperative Expenses	70.0
Contingency	70.0
Margin Money	70.0
Total	780.0

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
4. Lambertville Ceramics and Mfg. Co.
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

8. Doulton Insulators Ltd., UK

9. Smiths Industries Ceramics and Ignition Co., UK

10. Ceramica Industriale di Laveno
    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

Power	:	500 KVA
Water	:	10000 litre/day
Manpower	:	30 persons including managerial, skilled semiskilled and unskilled staff.

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 taped 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.

PROFILE - SIX

CERAMIC THREAD GUIDES

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
- IVP
- Widia
- NTB Hi Tech Ceramics
- Jyoti Ceramics

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% bt 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:

[Value in Rs. Crores]

Year	Demand of Thread Guides All types	 Ceramic Guides	Penetration of Ceramic Guides
1991-92	25.0	10.0	40%
1994-95	35.0	20.0	55%
1999-2000	62.0	40.0	65

Assuming an average cost of Rs. 1000 per kg for these guides (alumina), the the future demand in terms of tonnage is estimated as given below:

Year	Demand (Tonnes)
1991-92	100
1994-95	200
1999-2000	400

6.4 MANUFACTURING PROCESS

The calcined alumina (85 to 99.5%Al_2O_3) 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 microsons. 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^{0} to 180^{0}C in 6 hrs, holding at 180^{0}C for 8 hrs and then going from 180 to 450^{0}C wwith the rise from 200 to 300^{0}C at 10^{0} Cper 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 upto temperature, 2 hours at the maximum and 12 hrs to cool. The soaking temperature of 1700^{0}C to 1750^{0}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% Al_2O_3) is required. (Required Particle size:0.05-5.0μm, Na_2O 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.

	[Rs. in Lacs]
Land and Site Development	20.0
Buildings	50.0
Plant and Machinery	420.0
Misc. Fixed Assets	50.0
Technical know-how and Engg. Fees	120.0
Preliminary and preoperative expenses	80.0
Contingency	75.0
Margin money	100.0
Total	915.0

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. Mitusubishi Metal

(b) USA

1. Astro Met Associates Inc.
2. Duramic Products Inc.
3. Coors Porecelein Co Inc.

4. ESK Corporation
5. Art Incorporation
6. Lambertville Ceramics and Mfg. Co.

(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.

PROFILE - SEVEN

MECHANICAL SEAL FACES / SEAL DISCS

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:

Sr. No.	Particulars	Year 1991-92	1994-95	1999-2000
1.	Total market for mechanical seals	50 Cr.	67 Cr.	108 Cr.
2.	Penetration of ceramic seal face	70%	80%	90%
3.	Market for ceramic seal faces *	5.25 Cr.	8.0 Cr.	14.50 Cr.

* 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:

Year	Market for Tap Cartridges
1991-92	3.15 Crores
1994-95	3.00 Crores
1999-2000	7.50 Crores

Thus, the total market for ceramic wear resistant parts in this segment is estimated as given below:

Year	Market (Rs.Crores)
1994-95	11.00 (110 Tons)
1999-2000	15.50 (115 Tons)

7.4 MANUFACTURING PROCESS

The Calcined alumina(85 to 99.5% Al_2O_3) 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 microsons. 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 owganics 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 120^{o} to 180^{o} C in 6 hrs, holding at 180^{o} C for 8 hr and then going from 180 to 450^{o} C with the rise from 200^{o} to 300^{o} C at 10^{o} 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 upto temperature, 2 hours at the maximum and 12 hrs to cool. The soaking temperature of 1700^{o}C to 1750^{o} 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.

7.5 RAW MATERIALS

Reactive Grade Calcined alumina(above 98% $Al2O3$) is required. (Required Particle size:0.05-5.0um, $Na2O$ 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.

	[Rs. in Lacs]
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 kulns, 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 sectlr 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.

PROFILE - EIGHT

MATERIAL HANDLING LINERS

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 cruçial 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 seperators
- 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 cerammic 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 Ton 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 secotr 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:

Sr. No.	Sector	Demand (In Tonnes) 1991-92	1994-95	1999-2000
1.	Power sector	1550	1720	2240
2.	Steel sector	520	665	1000
3.	Cement sector	400	520	800
4.	Other	300	365	500
5.	Coal mining	775	860	1040
	Total	3545	4130	5580

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:

Year	Demand For Ceramic Liners	
	Quantity (In Tonnes)	Value (In Rs. Crores)
1994-95	2065	20.65
1999-2000	3900	39.00

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 Al_2O_3, Fe_2O_3 and TiO_2 until the bauxite is chemically uniform. The wet milling is continued for 24 hus 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^oC 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_oC(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.

	[Rs. in Lacs]
Land and Site Development	20.0
Buildings	50.0
Pand and Machinery	450.0
Misc. Fixed Assets	50.0
Technical know-how and Engg. Fees	20.0
Preliminary and preoperative expenses	20.0
Contingency	70.0
Margin money	85.0
Total	825.0

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 MACHINARY

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 eequipments 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), Banglore 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.

PROFILE - NINE

SPECIAL REFRACTORIES

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. IFGL 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. Presentely, 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 AD. 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:

[Qty. in tons/Value in Rs.Cr.]

Sr.	Type of	Year					
		1991-92		1994-95		1999-2000	
		Qty.	Value	Qty.	Value	Qty.	Value
1.	All types	5.9 Lac	-	-	-	6.75 Lac	-
2.	Special refractories (Advanced)	9000	59	14000	92	30000	195
3.	CCR	2000	-	3500	-	8000	-

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 upto 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.

	[Rs. in Lacs]
Land and Side Development	50.0
Buildings	265.0
Plant and Machinery	
- Imported	640.0
- Indigenous	460.0
Misc. Fixed assets	175.0
Technical know-how and Engg. Fees	110.0
Preliminary and preoperative expenses	220.0
Contingency	195.0
Margin money	170.0
Total	2285.0

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
4. Hydraulic Press/Isostatic Press
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 Boulonnals, Framce
10 Nibek Ltd, UK
11. Morgan Refractories Ltd. UK
12 Toshiba Denko Co. Ltd. Japan

9.10 INFRASTRUCTURE

Power	:	750 KVA
Water	:	20000 litres/day
Manpower	:	150 persons including managerial, skilled, semiskilled and unskilled labour.

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 PROFITIBILITY

Good Parofits have been envisaged because:

* It is a value added product.
* Market is growing and supply driven.

PROFILE - TEN

ALUMINA POWDER FOR STRUCTURAL CERAMICS

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 a-phase content(above90%) are termed as 'Reactive Alumina' and are used for advanced structural applications.

100% α-Alumina with purity above99.5% 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 ,icrominiaturization of components for the eletronic 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 size3-5μ m) 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:

[In Tonnes]

Sr. No.	Application	Current Requirement (1991-92)	Future Requirement 1994-95	Future Requirement 1999-2000
1.	Spark plug cores	650	850	1125
2.	Thread guides	100	200	400
3.	Grinding media	150	260	650
4.	Nozzles, seal faces etc.	50	105	240
5.	Other structural application like reactories, liners etc.	2500	4000	9000
	Total	3450	6514	11415

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:

<u>Bayer Process</u>	<u>Alum Process</u>	<u>Al-Isopropoxide Route</u>	<u>Iwatani Process</u>
Bauxite+NaOH	$Al(OH)_3+H_2SO_4+(NH_4)_2SO_4$	Al-metal+ C_3H_7OH	Al-metal Pellets+H_2O
↓	↓	↓	↓
Digestion Precipitation	$NH_4Al(SO_4)_2 12H_2O$	$Al(OH_3H_7)_3$	Arc Discharge
↓	↓	↓	↓
$Al(OH)_3$	Purification	Hydrolysis	$Al(OH)_3$
↓	↓	↓	↓
Calcination	Decomposition	Al_2O_3-Gel	Calcination
↓	↓	↓	↓
Alpha alumina	Alpha alumina	Calcination Alpha alumina	Alpha alumina

The Bayer Process produces a wide range of aluminas, some of which have Na_2O 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_2O 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_2O impurity leve, SiO_2, Fe_2O_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_2O content below 0.01 wt% and a high alpha alumina content are used for advanced structural ceramics.

CALCINED ALUMINA APPLICATION REQUIREMENTS

Sr. No.	Application	Media Particle size (μm)	Na_2O Content (%)
1.	Electro-ceramic	0.5 to 5.0	0.02 to 0.10
2.	Sodium vapour lamp	<0.5	0.02 to 0.10
3.	Mechanical/Structural	0.5 to 5.0	0.02 to 0.40
4.	Polishing	0.5 to 5.0	0.02 to 0.40
5.	Fused abrasives	0.5 to 1.0	0.20 to 0.40
6.	Ceramic fibres	0.5 to 1.0	0.20 to 0.40
7.	Hi Tech Refractories	0.5 to 3.0	0.10 to 0.25
8.	Spark plug	2.5 to 75.0	0.02 to 0.20
9.	Chinaware	0.5 to 3.0	4.00
10.	Glass	0.5 to 3.0	4.00
11.	Refractories	0.5 to 5.0	0.2 to 4.00
12.	Fused cost refractories	2.0 to 50.0	4.00
13.	Procelein insulators	2.0 to 5.0	0.2o to 4.00

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.