CERAMIC WHITEWARES

Their Technologies and Applications

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OXFORD & IBH PUBLISHING CO. PVT. LTD.
New Delhi Bombay Calcutta

ISBN 81-204-0675-3

Published by Mohan Primlani for Oxford & IBH Publishing Co. Pvt. Ltd., 66 Janpath, New Delhi 110 001, composed by Laser Words, Madras, and processed and printed at Chaman Offset Printers, Suiwalan, Delhi 110 002.

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Preface

During my service at Central Glass and Ceramic Research Institute, Calcutta and my long association with the Indian Ceramic Society as well as with the Indian Institute of Ceramics since its inception, I had felt the absence of an Indian publication on ceramics, particularly whitewares, which not only deals with their general technology and application avoiding constant reference to foreign publications, but also brings out the Indian industrial practices in their true perspective. This feeling was further endorsed by the graduate and other students of ceramic technology. This book has, therefore, been planned and written to help the diploma and graduate students as well as the technical and managerial people engaged or interested in the field of ceramics.

The field of products covered by the term 'whitewares' has now become so wide and the study of their properties, technologies of manufacture, and use so intensive and extensive that it becomes necessary to treat some areas, like electronics ceramics, only briefly in such a concise book. However, wherever possible, references have been cited for the benefit of readers. Specialised materials, like nitrides and carbides (non-oxides) have been left out.

It goes without saying that no book on ceramics can be written or even framed without the help of and frequent references to such standard books as *Introduction to Ceramics* by W. D. Kingery, H. K. Bowen and D. R. Ullmann, 2nd Ed., John Wiley, New York, 1976; *Fine Ceramics* by F. H. Norton, McGraw-Hill, New York, 1970; *Elements of Ceramics* by F. H. Norton, Addison Wesley, London, 1974; *Industrial Ceramics* by F. Singer and S. S. Singer, Chapman and Hall, London, 1963; *Ceramic Whitewares* by R. Newcomb, Jr., Pitman Publishing Corp., New York, 1947; *Ceramics*, Vol. I, II and III by E. P. McNamara, Penn. State College, USA, 1940; and *Ceramic Glazes* by C. W. Parmelee, Industrial Publ. Inc., Chicago, 1948. Sustained reading of the works of these authors as well as personal contact with some of them has entitled me, to the privilege of appreciating them, to the extent

of rehearsing them in some places of my book, and thereby conveying my obligation and thanks to them.

I would also like to thank Dr. B. N. Samaddar, Principal, College of Ceramic Technology, Calcutta University, for his encouragement. Occasional discussions with him, in spite of his busy schedule, on the subject matters helped me in restructuring some of the chapters.

Lastly, I thank my wife, Mrs. Roma Sen, for her constant help and for bearing with me the difficulties faced while writing this book.

SUDHIR SEN

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CHAPTER 1

Whitewares and the Indian Industry

The art, craft and science of the ceramic industry and its step-by-step development followed closely the advancement of human civilisation. Samples of 'pottery', as it used to be known in its original form, a term still used to refer to some sections of the ceramic industries, have been found in excavations in Egypt (now U.A.R.), Asia Minor, Crete, and Greece, which date back to several thousand years B.C. Samples of crude pottery found on the Tigris in Selencia have been said to be made as early as 7000 B.C. Glazed pottery has been found dating from 5000 B.C. These wares were mainly of a soft, low-burned type and were quite fragile.

It was only in the early centuries A.D. that high temperature firings were undertaken by the Chinese. These wares were more rugged and can be said to be of the stoneware type. The steps in the development were fragileware to crude earthenware to stoneware. Near the 15th century, the stoneware in England used purer clays to produce a greyish-white body. It was mostly salt-glazed. This process continued over several centuries. About this time vitrified wares more akin to true procelain were made in China. There is indication that a variety of feldspathic glazes was also used. The composition of the body and the glaze were a closely guarded secret.

In the early 17th century, attempts to imitate the Chinese 'porcelain' were made in Europe, especially in Germany: It was found that to produce it, a combination of kaolin, flint, and feldspar was needed. The result was the setting up of renowned factories for producing whitewares in Sevres (France), Copenhagen (Denmark), and Meissen (Germany).

In India too, leaving aside historical findings of pottery in excavations at Mohenjodaro and other places, the trend in producing precursors of modern-day whitewares followed the footsteps of European manufacturers, more closely the British ones, in the late 19th century and early 20th century while earthenware and terracotta came up on their own in certain regions.

It is generally believed that the discovery of china clay in the Rajmahal hills in Bihar gave the impetus to the setting up of a factory in Gwalior on modern lines for the production of fine earthenware by Dr. D.C. Mazumdar in 1858. Another earthenware factory was put up in Calcutta in 1860 by the Maharaja of Cossimbazar. A few years later the western region had a factory at Thane.

The localised centres got impetus for increasing and somewhat improving their products due to the scarcity of imported ceramicwares, particularly crockeries, during and after the World War I. The *swadheshi* (indigenisation) movement in the 1920s, 1930s, and 1940s, instilled the spirit of adventure in some people who put up factories to manufacture basic products like iron and steel, chemicals, medicines, and textiles. Ceramicwares followed suit. Some had visited ceramic centres in England (notably Stoke-on-Trent) and Japan and became eager to put up ceramic factories in India. It was about this time that one of the biggest factories producing crockeries was put up in Calcutta, of course on the foundations laid by its predecessor several decades ago. Several other factories were set up to produce fine earthenware, stoneware, and even porcelain with up-to-date equipment and tunnel kilns.

The second peak in the growth of the ceramic industry in India was in the late 1940s and early 1950s (after Independence) when ceramic factories producing tiles, sanitarywares, and insulators were put up in different parts of India. Within a couple of decades the ceramic industry in India was producing quality ware including bone-china crockeries, which industry started in 1960 and now has five units. India now not only can avoid any imports but also can claim to export ceramics (Table 1.1), even to Western countries.

Table 1.1. Export of some whiteware

	Value in lakhs of Rs.	
	1980–81	1984–85
Insulators	370	360
Glazed tiles	67	45
Sanitaryware	145	135
Tableware	56	92

The development of the ceramic industry in the country, like that of many other industries, has followed a double course of mass production and production by the masses. Small units using more labour than machines were producing mass consumption wares of common quality while others were set up to produce quality wares on a larger scale with imported machinery and technology. With an increase in the demand for quantity as well as quality, the later section gradually gained ground. As a result, many small units producing wares like insulators, sanitarywares, or even crockeries had to close down. Even then, small-scale units, often called the 'unorganised sector', having the government's blessings of exemption from excise duty, still hold the lion's share of production of some mass consumption items like crockeries and low tension insulators. Table 1.2 shows the recent trend in production of some whitewares in the two sectors.

Table 1.2. Trend in production of some whitewares

Type of ware	Total production in tonnes, 1985	Organised sector		Small-scale sector	
		Production	Approx. %	Production	Approx. %
High tension insulators	35,600	30,000	86	5,600	14
Low tension insulators	23,000	3,450	15	19,550	85
Glazed tiles	102,050	99,250	97	2,800	3
Sanitaryware	52,427	37,151	71	15,276	29
Tablewares, crockeries	81,700	10,700	13	71,000	87

Data compiled from:

DGTD, Development Panel for Ceramic Industry Reports 1986–88.

Presidential Address, Indian Ceramic Society, TICS, 47(3), 76 (1988).

'Indian Ceramic Industry: An overview', G. Banerjee and K.K. Bhattacharjee, Indian Ceramic Society, 50th Annual Session Publication (Smarak) p. 20 (1986).

'Status Report of Ceramic Industry in India' Ed. S.K. Banerjee, All Ind. Pot. Mfrs. Assn. (AIPMA), Calcutta, 1988.

'Economic Study of Ceramic Industry in India', N.S. Bist, Ariana Publishing House, New Delhi, 1988.

'Guideline for Industry, 1983–84', Govt. of India publication, Ministry of Industry.

The trend of production growth of the whiteware industry during the Five Year Plan periods can be judged from the growth of production of the three main items of conventional ceramicwares — sanitarywares, tiles and high tension insulators — which are mainly concentrated in the large-scale sector. Whereas the first two are connected with housing development and sanitation, the last is related to power generation and transmission and had therefore been linked with their growth. The examination of the production figures for the Sixth and Seventh Plan periods given in the DGTD Development Panel for Ceramic Industry Reports show that the yearly growth rate, though variable, has been on the average 8–9%. Since the beginning of the Sixth Plan, the growth rate has received further spurt. The capacity utilisation, however, of the factories has generally been low, 50–60%, for tiles with some exceptions, and fairly good for sanitarywares, 70–80%, in the large-scale sector but below 50% in the small-scale sector. For crockeries and tablewares, the capacity utilisation has been the reverse, about 25% for organised sector (production of 10,700 tonnes against installed capacity

39,530 tonnes in 1985) and 54% in the small-scale sector (71,000 tonnes against 1,30,000 tonnes), as seen from Table 1.3.

Table 1.3. Comparative production and capacity utilisation of some ceramicwares

Type of wares	Organised sector			Small-scale sector		
	Installed capacity (tonnes)	Production (tonnes)	No. of units	Installed capacity (tonnes)	Production (tonnes)	No. of units
High tension insulators						
1981	34,600	31,900	8	NA	NA	NA
1985	60,400	30,000	10	NA	5,600	NA
Glazed tiles						
1981	NA	57,467	NA	NA	NA	NA
1985	1,99,000	99,250	15	NA	2,800	NA
Sanitarywares						
1981	33,880	27,193	NA	9,800	5,000	NA
1985	46,740	37,151	11(+5)	37,770	15,276	58
Tablewares						
1981	36,692	15,306	13	NA	NA	NA
1985	39,530	10,700	11(+2)	1,30,000	71,000	1,191

Various estimates have been made of the demands of the different wares by the end of the Seventh Plan period (1990), though they are not always based on solid reasoning. Additional licenses have also been given to put up factories in the large-scale sector to meet those demands with an eye on export potential. Updating the technology, including import of state-of-the-art technology and modern machinery along with rapid-firing kilns, as well as more efficient use of the installed capacity, has been the objective of the industry in current and future years. A good amount of success has already been achieved.

In the first three years of the Seventh Plan period (1986–1988), there was a major thrust in the tile industry, (installation and production). Factories in the organised sector came up, all with foreign collaboration, with large production capacities, 12,000 to 25,000 tonnes per annum (TPA), mainly for production of floor tiles with some wall tiles. Most of them are provided with roller-hearth kiln, spray drier, and other modern equipment. Naturally, their capacity utilisation has gone up to 80–90% and the fuel consumption has been reduced to about half, the two primary objectives of the present-day industry.

At present there are 12 units that make both floor and wall tiles, 9 that make floor tiles, and 4 that make only wall tiles.

Some such improvements, though in a limited way but without much technical collaboration, have taken place in the sanitaryware industry. Currently there are 13 units with a production capacity of 79,100 TPA. There has been only a marginal growth in the high tension insulator industry due to slackness in demand from consumers, mostly state electricity boards. Attention is now being given to produce solid core and higher voltage insulators of the order of 800 kV.

From their experiences, these major groups of ceramic industry, along with their development organisations, have now identified the bottlenecks or impediments to further growth and refinement to match the quality, productivity, and cost of production of products from developed countries.

(a) Non-availability of proper equipment like heavy duty presses, automatic jigger-jolley, roller machine, and spray drier.

(b) Non-development of new design and construction of fuel-efficient furnaces. Use of low-thermal mass refractory for construction of kilns or their renovation is yet to become common.

(c) Instrumentation, even partial automation, and process control method are not used to the extent possible even when within the range of investment capability.

(d) Non-availability of quality fuel like natural gas.

(e) Non-availability of standardised quality and gradation of raw materials, especially china clay and plastic clay, at a reasoanable cost.

In recent years the development of a newer generation of ceramic materials with special properties have provided technological breakthrough the world over, particularly in the developed countries. These materials are variously called 'advanced ceramics', 'high-tech ceramics', or 'fine ceramics' (whitewares) because of the use of improved technological processes and skills for their production and newer applications of the materials in engineering, for high temperature, electrical, electronic, and optoelectronic applications. Each of these advanced ceramic materials has opened up separate chapters to modern technological advances. High temperature ceramic superconductors, for instance, are expected to lead to wide technological changes in power generation, transportation, microelectronics and computers, medical diagnostics, and defence. In India also, different R&D organisations, science institutions, and universities are working on them. The electronic ceramic industry has made considerable progress in meeting the growing demand of the industry. Simultaneously with the imported technology, R&D efforts in national laboratories have contributed much to the development of high alumina substrates (tape casting), trimmer bases, conductive paste, screen printing, etc.

Although several government and private organisations indicate that a number of factory units are producing (and about to produce) electronic ceramics, many of them with foreign technological collaboration or collaboration with some Council of Scientific & Industrial Research laboratories, their actual production capacity, type of products, and production figures

Table 1.4. Units producing electronic ceramics

Type of ceramics/systems	No. of units
Soft ferrite	15
Hard ferrites	10
Disc/tube capacitors	13
Integrated circuits	9
Hybrid circuits	6
Thermisters/transducers/varistors	10 + 4

Data procured courtesy of Dr. B.K. Sarkar, Director, and Mr. K.K. Bhattacharya, Data Centre, Central Glass and Ceramic Research Institute, Calcutta.

Table 1.5. Demand projection for electronic ceramics (*value in crores of Rs.)

Ceramic type	Present capacity	Production in 1987	Projected in 1990	Demand in 2000
Soft ferrite (MT)	900	850(*7.7)	3000(*45)	7000(*1000)
Hard ferrite (MT)	4200	3600(*13)	5000(*20)	15000(*60)
Ceramic capacitors (million)	1000	275(*7)	1000(*25)	1500(*38)
Multilayer capacitors (million)	—	—	200(*20)	500(*50)
Ceramic substrates (million)	—	—	50(*5)	100(*10)
Multilayer ceramic IC packages (million)	—	—	10(*1)	20(*2)
Thermistors (million)	—	—	5(*8)	10(*16)
Transducers (million)	—	0.1(*0.01)	2(*0.2)	5(*0.5)

**Source*: Detailed Project Report and 8th Plan Document for CSIR Thurst Area on C. 16—Advanced Ceramics, 8 pp., January 1989.

Note: IC = Integrated Circuit

are hard to obtain. Table 1.4 gives the number of units claiming to produce different types of electronic ceramics. It is interesting to note that the southwestern region of the country is more densely dotted with such units, centred around Pune, Bangalore, and Trivandrum, than the rest of the country. Quite a few units are in the public sector or joint state ventures and consume a large part of their own production, for example, Bharat Electronics Ltd., Bangalore; Electronic Corporation of India Ltd., Hyderabad;

Indian Telephone Industries Ltd., Bangalore; Keltron Electron Ceramics, Trivandrum; and Webel Electroceramics, Calcutta.

Table 1.5, giving the demand projection, shows the scope of expansion of the electronic ceramic industries.

Similarly, many engineering components of high alumina ceramics (96% to 99.9%), steatites, etc. are now being commercially produced. Table 1.6 gives the estimated demand of such ceramics for industrial use.

Table 1.6. Estimated demand of ceramics in industrial use (Abrasion, corrosion and heat resistant, high strength and with special property) in 1992

Type of articles/ ceramics	Units engaged	Demand		
		tonnes	Nos.	Value (Rs. crores)
Pump Seals (water pumps)	4	10	4,000	2.00
Thread guides	10	50	10 million	10.00
Nozzles	2	5	25,000	0.50
Cutting tools	1*	3	—	0.30
Bearing, piston, plungers, etc.	2*	2	—	0.20
Translucent alumina	1*		1 million (1990) 2 million (2000)	20.00 40.00
Zirconia	2*	10	—	0.50

*Claimed to be producing or about to produce.

Sources: B.K. Sarkar and K.K. Bhattacharya, Data Centre, Central Glass and Ceramic Research Institute, Calcutta; Detailed Project Report and 8th Plan Document for CSIR Thrust Area on C. 16—Advanced Ceramics.

Researches have progressed far to produce nitrides (reaction bonded, liquid phase sintered), carbides (both excluded from this book), partially stabilised zirconia, transformation-toughened alumina, plasma coating of oxides, and other innovations.

Most of these areas on advanced ceramics would need several chapters for their detailed treatment and have therefore been discussed in a limited way in this book.

CHAPTER 2

Whiteware

'Whiteware' is a long-used term originally applied to tableware and artware probably because of the white colour, smooth finish, and elegant appearance, sometimes with some translucency, of those wares resulting from the use of purer raw materials and from often firing to a higher temperature giving sufficient maturity and strength. But now similar body, composition and firing are used to make other types of ware and articles and the term can be said to have lost its original enclosures. In other words, it now signifies a much wider field encompassing almost the whole field of ceramic articles excluding only the heavy clayware like bricks, tiles, and sewerpipes which can be made from raw materials easily found in nature and which need minimum or no processing before use.

This wide field is sometimes covered by the term 'fine ceramics', which has been defined by Norton (1970) as 'a ceramic body having a controlled, fine structure which may be glazed or unglazed'.

Some have divided this type of ceramics into two classes: triaxial body, composed mainly of clay, quartz, and feldspar; and non-triaxial body.

Two types of categorisation are usually made for whitewares. One is based on one or two of their vital physical and/or compositional characteristics, and the other on the use or application of the ware.

A classification based on porosity or absorption of the body of the ware is still very much in vogue in order to identify the type of body and its fired maturity. The broad divisions are indicated in Table 2.1. These divisions or classes are sometimes also identified by the commonly adopted nature of firing or the compositions. Table 2.2 gives the nature of firing as well as the compositions that are now covered by those classes.

A common American practice is to classify whitewares broadly into semivit and vit. Ware having absorption down to 2%, like earthenware, some low-absorption stoneware, and some low-absorption china come under the

Table 2.1. Class name according to absorption

Class	% Absorption	Translucency
Earthenware	4–20	None
Stoneware	1–5	Neglibile
China	0.0–2.0	Usually good
Porcelain	0.0–0.5	Moderate to good
Technical ceramics	0.0–0.05	—

semivit category. The French classify as *faience* and *gres* whereas the German names are *Steingut* and *Steinzeug* for earthenware and stoneware. Based on their place of original manufacture different names have also been assigned to china and porcelain ware such as Lenox china from the United States and Belleckware from Ireland.

Table 2.2. Commonly followed nature of firing and composition of classes of ceramicwares

Class	Nature of firing	Usual composition
Earthenware	High bisque, low glost	Single clay, multiple clay, triaxial body, talc body
Stoneware	Mostly single-fired	Same as above, but fired to low porosity
China	High bisque, low glost	Triaxial body, high boneash, glassy flux or frit
Porcelain	Low bisque, high glost; or single-fired	Usually triaxial with special additions, steatite, zircon, alumina
Technical ceramics	Pre-sintered, precalcined, high-fired, fired and annealed; controlled and special firing	Triaxial composition, use of special and synthetic raw materials

Technical ceramics covers such a wide range of articles that its science and technology can form a separate subject for discussion. While some of them are special materials recently developed (mostly in the second half of the 20th century) for use in the field of communication, space exploration, computers, transport, specific engineering materials, and the like, others can be considered to be the results of technical and technological developments on existing techniques of manufacture of ceramicware. Whereas it is not possible to avoid their inclusion in whiteware, it is at the same time not possible to do full justice to this class within the short span of this book. Readers are, therefore, advised to refer to the standard books on the subject for details.