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INTRODUCTION

The history of human exploitation of materials is the history of the advancement and growth of civilizations. With each discovery of a process to transform a natural raw material into a new tool or energy source, humans were better able to control and construct their environment. This is evident by the names of anthropogenic epochs: the Stone Age, the Bronze Age, and the Iron Age.

With each new discovery, the primary components for the process or tool immediately became valuable. These raw materials and other mineral-based wealth have both historical and current significance. Wars have been—and will continue to be—fought over the ownership of metal ores, petroleum, and other resources required to keep modern industrialized society moving. These materials are the basis of all industry, and today we use virtually all of the elements found on the periodic table.

There is no official Ceramic or Glass Age, although objects made of glass and ceramics have long been part of human civilization. Perhaps this omission is related to the historic lack of a relationship between battlefield advantage and glass and ceramics. Nevertheless, these two products have long been invaluable in domestic applications and, therefore, the raw materials to make them have had value.

Until relatively recently, the materials used to make most glass and ceramics have generally been naturally occurring inorganic minerals such as silicates and oxides of metals. Clay and sand perhaps come to mind when one considers the dominant raw materials in these industries. These are examples of relatively crude materials removed from the ground and minimally processed. Although clay and sand continue to be important components, the progressive introduction of complex, rapid fabrication processing of traditional products and the growth of advanced glass and ceramics has forced the business of raw materials to evolve and become more sophisticated. Both the glass and ceramic industry are similar in the need for efficient and economic procurement, beneficiation, and handling of natural and synthesized materials to produce a final product. Modern manufacturing may further require higher purity specifications, the use of waste or recycled materials, and the compliance with environmental and human regulations involved in mining and processing.

For our purposes, we can define a raw material as the precursor ingredients used at the beginning of the manufacturing process for a given ceramic or glass product. Reed (1995) classified ceramic raw materials into the following categories:

- Nonuniform crude from natural deposits
- Refined industrial minerals that have been beneficiated to remove mineral impurities to significantly increase the mineral purity and physical consistency
- High-tonnage industrial inorganic chemicals that have undergone significant chemical processing and refinement to significantly upgrade the chemical purity and improve the physical characteristics

Under each of these categories, a specific mineral or compound can be further classified by mineralogy, chemical composition, and purity, and a variety of physical characteristics, such as particle size distribution and bulk density. Because most raw materials are powders, many of the characteristics pertain to submillimeter-sized particles and granules. As glass and ceramic materials are placed into higher-performance applications, the raw material powders must adhere to higher standards of purity and uniformity. Not only are the initial components of the raw materials important (e.g., the composition of the bauxite used to make alumina), but processes such as grinding, mixing, and classification can also impart properties, both desirable and undesirable (Naito et al., 2003). The desired characteristics of the starting components are defined by the quality and performance of the final manufactured product and these characteristics directly affect the price of the raw material. In general, highly processed materials are more costly due to higher energy and labor requirements needed to produce them.

Because of the inherent link between raw material characteristics and processing behavior, an understanding of raw materials is of utmost importance in economically and efficiently producing glass and ceramic products. In this book we begin with a description of the origin and distribution of elements and minerals in the earth, which, in turn, are related to the discovery of ore deposits and subsequent extraction of material from the ground. By understanding the geological processes that concentrate compounds and minerals, one can better understand the issues specific to each material. In addition, industrial separation and beneficiation techniques often simulate the natural processes that concentrate minerals. For example, heavy minerals such as zircon can be deposited in a river where the water velocity slows, just as an industrial hydrocyclone will separate two minerals based on particle density or size.

The general processing routes that are used to beneficiate, purify, and control particle size are described in the third chapter. Most raw materials are processed to varying degrees, depending on the ore deposit and the desired characteristics and purity levels. Each additional processing step adds to the final cost of the final product; therefore, the manufacturer needs to continually balance purity with cost. Advances in processing have led to the availability of higher purity materials, critical for making high performance products. In addition, better processing has allowed for the exploitation of previously uneconomical ore deposits. As with any industry that relies on natural materials, the extraction and processing activities can result in environmental impacts that, depending on the country, are subject to regulations. Complying with these regulations can be costly and will affect the prices of the product.

In the fourth chapter, we will describe the structure of the raw materials industry. Many of the materials used in glass and ceramics can be classified as industrial minerals while the more refined components can be considered chemicals. The concept of location is presented, as the geography of primary sources (mines) as related to the location of the manufacturer is extremely important, particularly for the low-cost, high-tonnage materials where transportation costs may equal or exceed the cost of the material itself. In other cases, the proximity of a raw material source may even be more important than its composition.

In chapters 5 and 6, we will learn about individual raw materials in terms of mineralogy, distribution, general processing routes, uses, and specifications. First are the naturally occurring minerals, or those that are removed from the ground and processed without substantial alteration to the composition or structure of the material. Some natural materials are feedstocks that are used to produce synthetic materials that are either not found in nature, such as carbides and nitrides, or those that are rare in nature, such as mullite and alumina. Chapter 7 addresses the growing pressure to use materials that do not come from virgin minerals. These include recycled glass cullet and the inorganic slags and ashes that are byproducts of metal smelting and combustion of coal and wood.

The last chapter is dedicated to material characterization and quality control. As with any modern manufacturing process, physical and compositional characteristics of the raw materials need to be consistent. Consistency allows the manufacturer to predict the behavior of the fabrication process and therefore to increase overall efficiency. Another important issue is awareness and compliance with environmental and health issues associated with handling. This is very important because the handling of dry powders and the need for high operating temperatures can release harmful particulate or volatile emissions into the air (from burning fossil fuels or from fine raw materials). The salient problems for each material are discussed in the last part of each specific material section.

Please note that all percentages of components are reported as weight percent unless otherwise stated.

REFERENCES

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