CHAPTER 24

CERAMICS

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CERAMICS

INTRODUCTION

Ceramics\(^1\)\(^2\) are inorganic nonmetallic materials that can be separated into two broad categories—traditional ceramics and structural ceramics. A common characteristic of ceramic materials is that they are manufactured from powders that are formed to a desired shape with a glassy binder and then heated to a high temperature with or without the application of external pressure to achieve a final densified brazement.

Traditional ceramics include clay products and refractories. These materials typically have low densities (because of relatively high porosity content). They are normally used in high-temperature applications for which brazing is not practical.

Structural ceramics include monolithic materials such as aluminum oxide (Al\(_2\)O\(_3\)), zirconium oxide (ZrO\(_2\)), silicon carbide (SiC), aluminum nitride (AlN), silicon nitride (Si\(_3\)N\(_4\)), and silicon-aluminum oxynitrides (SiAlONs) as well as composites made entirely of ceramics like Al\(_2\)O\(_3\) containing SiC whiskers or SiC containing titanium diboride particles. Care is generally taken during the manufacture of structural ceramics to ensure that the chemical composition is controlled and high densities (or relatively low porosity contents) are achieved. The brazing of structural ceramics is possible and widely practiced.

The technological interest in structural ceramics is directly related to their unique properties compared to metals. Many ceramics are characterized by high strength, not only at room temperature but also at elevated temperatures. Silicon carbide, for example, can maintain a tensile strength in excess of 29 × 10\(^3\) pounds per square inch (psi) (200 megapascals [MPa]) at 2786°F (1530°C), the melting point of iron. Other ceramics like Si\(_3\)N\(_4\) and certain ceramic composites also maintain similar strengths at high temperatures.

In addition to high strength, other properties that make ceramics attractive candidates for applications that have usually been reserved for metallic alloys include excellent wear resistance, high hardness, excellent corrosion and oxidation resistance, low thermal expansion, and high electrical resistivity.

Structural ceramics are being used or considered for use as cutting tools, bearings, machine tool components, dies, pump seals, high-temperature heat exchangers, and a variety of internal combustion and turbine engine components. The typical properties of several ceramic materials and metallic alloys are presented in Table 24.1.

Even though there is keen interest in the development of structural ceramics and their use in new and unusual engineering applications, it is in the electronics industry where the largest fraction of ceramics is actually being used. Likewise, while the development of brazing technologies for materials like ZrO\(_2\), Si\(_3\)N\(_4\), and SiC has been pursued vigorously in recent years, Al\(_2\)O\(_3\) is still the most widely used structural ceramic with a sizeable commercial market. For this reason, the brazing of Al\(_2\)O\(_3\) using commercially available practices is emphasized throughout the remainder of this chapter.

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CERAMIC MATERIALS

Ceramics are generally defined as inorganic, nonmetallic materials. Typical examples include alumina, silicon nitride, silicon carbide, aluminum nitride, and zirconia. Most ceramics are based on oxide, carbide, and nitride compounds.