Understanding Silicon Carbide Types Having the Right Tool for the Job!

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By: Martin R. Metzger and Mark L. Witmer, Silicon Carbide Products, Inc.

Silicon carbide is a high performance material selectively used throughout diverse industries for severe applications including conditions of high abrasive wear, high corrosion and high temperatures including thermal shock. Although silicon carbide has been widely used and readily available for decades, misapplications can occur if the best grade for the application is overlooked or simply unknown. Proper material selection best suited to the applications demands is of primary importance and ultimate benefit to the end use customer. When stating "silicon carbide", one is describing a generic material for which many different types or grades with vastly different performance aspects exist. Think of the analogy of specifying stainless steel without detailing the grade you desire. A corrosion resistant grade of stainless steel will not perform as well in a high temperature application as well as one designed for high temperatures. Compounding the end users selection process is the fact that universally accepted conformance standards for the various silicon carbide grades do not exist. Supplier process controls for consistent high performance is paramount therefore, an informed user will lead to a successful and cost effective application of the appropriate silicon carbide for the job.

Generically, silicon carbide is known for its hardness (9.1 Mohs or 2500 Knoop), refractoriness (SiC dissociates at 2815oC), and resistance to corrosion by other materials. Rarely found in nature, silicon carbide is normally synthesized by heating a mixture of silica sand and coke to approximately 2200oC using a method named for its inventor, Edward Acheson.

SILICON NITRIDE BONDED SILICON CARBIDE - (typically abbreviated; SNBSiC, NBSiC or NBSC) commonly called nitride bonded silicon carbide. This material is the most commonly used version of silicon carbide for coal processing applications.

Processing

This material is commonly produced using a mixture of silicon carbide grain and finely divided (typically <325 mesh) elemental silicon. It can be formed into shapes via slip casting, vibratory casting, or by pressing. The formed shapes are furnaced in a nitrogen atmosphere at temperatures below the melting point of silicon (1410oC). Beginning at approximately 1100oC, the nitrogen gas and silicon metal react forming silicon nitride, or Si3N4. Due to the fact that the bond phase grows within existing porosity, there is little to no dimensional change upon firing and a net weight gain occurs.

Properties

Nitride bonded silicon carbide material is characterized by excellent wear properties in severe industrial environments. This material exhibits good resistance to high temperatures even in demanding abrasive applications. This includes better impact resistance than most silicon carbide grades.

Applications

Due to its unique properties and ability to be cast to final shape, this cost-effective grade is widely used as a workhorse throughout the coal industry from mining to power plants. Applications include cyclone apexes, inlet heads, vortexes, centrifuge port liners, power plant burner barrel liners, wear blocks, diffusers, deflectors, transitions, flue gas desulfurization spray nozzles, and slurry pump components. NBSiC is used in non-ferrous molten metal applications because of its non-wetting properties and high temperature corrosion resistant properties. Applications include, thermocouple protection tubes, immersion tubes and molten metal pump components.

REACTION BONDED SILICON CARBIDE - (typically abbreviated; RBSiC, RBSC, SiSiC or SiSC) also commonly called siliconized silicon carbide or high free silicon-silicon carbide.

Processing

This material is formed by preparing a mixture of silicon carbide grain and finely divided carbon usually in the form of graphite. As with SNBSC, fabrication of shapes can be done via casting or pressing. Furnacing of the shapes can be accomplished in vacuum capable or atmosphere controlled furnaces at temperatures between 1500-1650oC, which is above the melting point of silicon metal. Granular silicon metal is placed in contact with the components which upon melting wets or "wicks" into the parts. As this occurs, there is an exothermic liquid-solid reaction between the molten silicon and graphite which forms additional secondary silicon carbide as a bond phase. Also present in the final product is free silicon metal in the amount of approximately 8-12%.

Properties

Reaction Bonded Silicon Carbide is characterized by a high strength, high thermal conductivity, and typically low porosity. RBSC is serviceable to temperatures approaching the melting point of silicon at approximately 1450o C. Due to the excess silicon metal this grade will conduct electricity.

Applications

This grade is used in mechanical seal face applications, radiant heating tubes, cyclone apexes, helix type spray nozzles, burner nozzles, kiln furniture and semi-conductor processing components.

COMPOSITE BONDED SILICON CARBIDE - (abbreviated; CBSiC or CBSC)

Processing

This is a relatively new grade of silicon carbide formed by slip casting. A high purity fine grain silicon carbide is blended with elemental silicon and a binder system. It is formed into shapes via slip casting and is processed in a controlled nitrogen atmosphere at temperatures exceeding 13500 C.

Properties

Composite bonded silicon carbide has relatively high strength for this type material. It performs well in high temperatures especially in contact with non-ferrous molten metals because of its non-wetting characteristics.

Applications

Molten metal pump components, graphite protection liners, thermocouple protection tubes, crucibles, heater tubes.

OXY/NITRIDE BONDED SILICON CARBIDE

Processing, properties, and applications of this material are similar to NBSiC with the exception of a slightly higher porosity, lower density and performance in wear applications.

CLAY BONDED SILICON CARBIDE

Processing

Normally formed via pressing, this low duty material is a mixture of silicon carbide grain and clay. The bond is formed during furnacing where the clay softens and forms a glassy phase. Upon cooling this forms a glass bond.

Properties

This material is prone to oxidation under certain conditions of temperature and atmosphere, and is attacked by most molten compounds.

Applications
Low cost kiln furniture, refractory brick, not widely used for wear resistant applications.

DIRECT SINTERED SILICON CARBIDE - (typically abbreviated; DSSiC, DSSC, alpha and beta bond phases) also commonly called pressure less sintered silicon carbide.

Processing
Preparation of mix into a slurry form consists of sub-micron silicon carbide grain, sintering aides of boron or aluminum, a carbon source of resin and a binder system. The resultant slurry is typically spray dried for agglomeration and powder flowability. Fabrication of shapes can be done via casting or pressing. Furnacing or sintering of the shapes is accomplished in a water-cooled and atmosphere controlled vacuum furnace at temperatures of 2050-2175oC. Densification through sintering causes the formed components to shrink 17-19 % during this operation.

Properties
High strength, good thermal conductivity, and typically low porosity characterize this grade if properly processed. DSSC is serviceable to temperatures approaching 1650o C and gains strength at elevated temperatures. This material is one of the more brittle grades and is prone to chipping. As a result, component design is critical.

Applications
Various applications include mechanical seal faces, sand blast nozzles, semi-conductor process components, specialty kiln furniture, bearings, valve trim, media, thermocouple protection tubes, and chokes. Due to the very fine pure raw materials and high processing temperatures required, this material is expensive.

Typical Material Grade Characteristics

Other Notable SiC Material Systems

Other silicon carbide materials to note include recrystallized, alumina bonded, liquid phase sintered, and hot pressed silicon carbide. These materials are not commonly used in coal applications but rather serve as niche applications in the high temperature and wear markets.

In Summary

Silicon carbide materials are commonly described by the nature of the bonding phase used to hold the material together when formed as a shape. Different bonding methods result in varying end material property differences. Understanding these differences and typical use conditions will enable proper selection of the best material for the particular application.

References are available upon request from the authors.