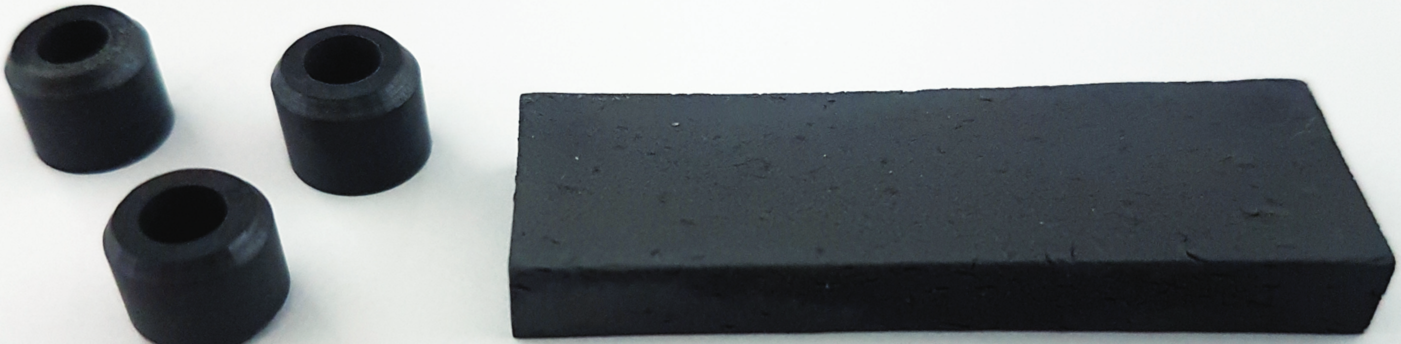

Samples of the new oxidation-resistant silicon carbide ceramic developed by Functional Materials Manufacturing Inc.

High-temperature advancements: New class of oxidation-resistant silicon carbide

By Vladimir Krstic

With advances in transportation technologies and energy systems, today's electrical, structural, and electronic ceramics are increasingly expected to perform well at higher and higher temperatures. Silicon carbide (SiC), with its high thermal conductivity and high-temperature mechanical strength, may offer a solution to this market need.[1]

However, standard, commercially available silicon carbide ceramics are known to be unstable when exposed to air due to the affinity of carbon and silicon for oxygen. The oxidation process starts at the surface of the silicon carbide, forming the oxide layer (SiO_2) through the following reaction:

$$SiC(s) + 3/2O_2(gas) = SiO_2(s) + 2CO(gas)$$

Due to differences in thermoelastic properties between the SiO_2 layer and SiC, cracking and delamination occurs, leading to a progression in oxidation. This oxidation reaction is a rate-controlled process. Initially, at lower temperatures, the reaction rate is slow. But as the temperature increases, the oxidation rate becomes rapid.

To prevent oxidation, SiC ceramics must be coated or packaged with protective materials, such as oxide ceramics, to avoid air exposure. This requirement can add time and cost to the processing of SiC ceramics.

Recently, scientists and engineers at Functional Materials Manufacturing Inc., or FMM (Kingston, Canada), developed the first generation of SiC ceramics that are stable in the presence of air at temperatures up to 1,500°C.

To suppress oxidation, FMM modified the lattice structure such that oxygen ions are incorporated into the SiC lattice, thus bonding the neighboring carbon and silicon ions to oxygen (Figure 1). Under such conditions, instead of reacting with

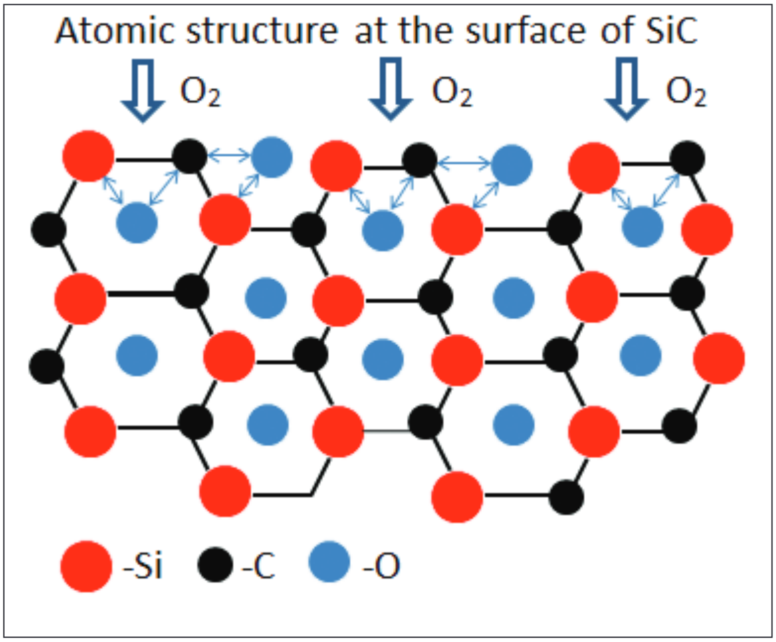

Figure 1. Distribution of oxygen ions in the lattice of SiC. The arrows indicate bonds created between oxygen, carbon, and silicon ions.

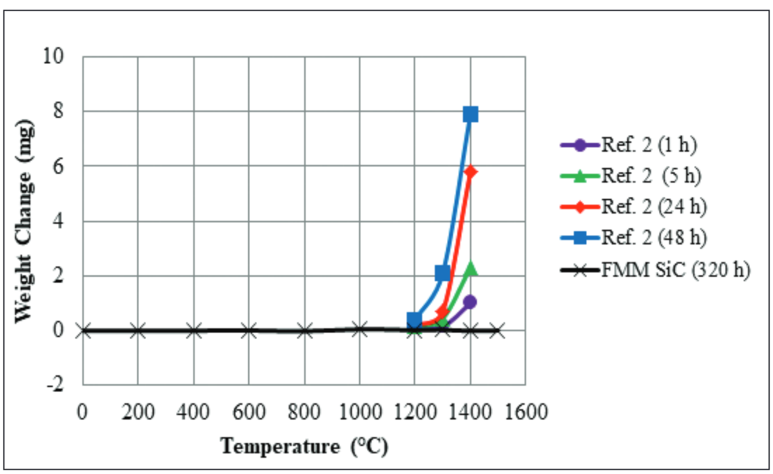

Figure 2. Change of weight with temperature for classical SiC (data from Reference 2) and SiC produced by FMM.

oxygen from air and thereby leaving the surface in the form of carbon monoxide, the carbon atoms remain bonded to oxygen at and beneath the surface of SiC, thus protecting the surface against oxidation.

While standard SiC exhibits continuous build up of silicon dioxide at its surface, as seen in Figure 2,[2] FMM's new SiC exhibits no oxidation up to 1,500°C.

The significance of this development is that we now have a class of SiC ceramics capable of withstanding temperatures far exceeding those of currently commercially available SiC ceramics without significantly changing other key physical properties. In practice, this material opens the door to the creation of SiC components and devices that do not require coating or additional packaging, which could be used in applications ranging from aerospace (spark plugs), nuclear, automotive (diesel spark ignitors), and electronics, to list a few. In addition, it is feasible that the same technology used to develop oxidation-resistant SiC can be applied to other carbides and possibly some nitrides and borides.

About the author

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