Silicon carbide ceramics reinforced SiC fibers

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Silicon carbide ceramics reinforced SiC fibers

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Abstract. Ceramic materials based on silicon carbide, SiC fibers reinforced were densely obtained by hot pressed at 1850°C. SiC fibers were obtained by siliconizing. Yttrium aluminum garnet (YAG) was used as an activating additive in an amount of 8 wt.%. The highest level of physical and mechanical properties was achieved ρ = 3,19±0,01 g/cm^3; δ = 571±33 MPa; K_1C = 5,7±0,1 MPa·m$^{1/2}$ in the material reinforced with 5 wt.% SiC fibers.

1. Introduction

Silicon carbide (SiC) is an interesting material that has found application in a variety of industries. Carbides are a class of ceramic materials that has drawn great interest to the scientific community due to their exceptional mechanical, physical, chemical, and even biological properties. Therefore, carbides are the basis of advanced ceramics with numerous applications and a future prospect. Although they have been known for over one hundred years and being important materials in many technological fields such as industry tools, mechanical engineering, engine industry, optic, electronic, catalytic, nuclear technology, and chemical industry, most of their applications are recent.

There are two best known applications of this material an abrasive material and more recent use as a wide band gap semiconductor for high power and high temperature electronic devices. It is well-known for many years that SiC has a high hardness, so it is used as tools in machining and other structural applications [1].

There is the need for creating fundamentally new materials with a complex of high physicomechanical properties, capable of working under harsh conditions in connection with the development of science and technology. Attempts to create such materials have led to the emergence of composite ceramic materials reinforced with fibers and threadlike crystals. Ceramic composites are actively used for the manufacture of high-temperature protective structures, elements of gas turbines and engines, elements of optical measuring systems, sliding and rolling bearings, cutting tools, elements of armor, nozzles, friction units, etc. [5, 6]. However, their creation is associated with a number of problems, the most important are achieving uniform distribution of reinforcing additives, creating the necessary interface between components in composition and structure, and achieving a high density of material. [7]. The composite properties are derived from the combination of two or more materials properties. The composite components are not independent and can reveal strong interfacial interactions that might influence the composite's properties significantly. Specifically, mechanical characteristics depend on stress transfer from the matrix to the inclusions through the interface. Thus, the properties of the composite are affected by the compatibility of the two or more components. In some instances, the composite components can be incompatible, causing agglomerations, weak interfacial bonding, voids, or other possible defects in the composite material [2, 3].

It is therefore understandable that an overriding consideration in ceramic matrix composites (CMCs) is to toughen the ceramics by incorporating fibers in them and thus exploit the attractive high temperature strength and environmental resistance of ceramic materials without risking a catastrophic failure.

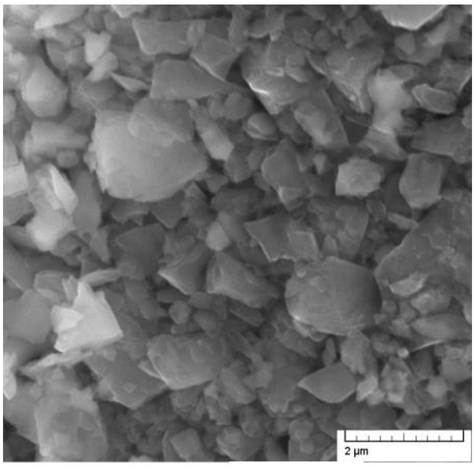
A ceramic composite is a ceramic material (matrix) carried out by introducing into its volume ultrafine micro- and nano-sized particles: whiskers, fibers, nanotubes, fullerenes, microspheres, powders of a different nature ceramic materials, etc. Al_2O_3, mullite, cordierite, Si3N4, AlN, SiC, carbon, etc. are used as the matrix material. Oxide, carbide, nitride, and boron fibers are used as the reinforcing phase. Fibers improve the physical and mechanical properties more than powders. However, if we are talking about a high temperature zone, then fibers have limitations up to 1500°C. SiC and carbon fibers are of greatest interest to developers [5-7].

Together with boron filaments and carbon fibers, SiC fibers are important continuous inorganic reinforcement materials with high modulus. Owing to their high-temperature properties and the resistance to oxidation they are particularly well suited for structural parts where high stiffness at high temperatures is required.

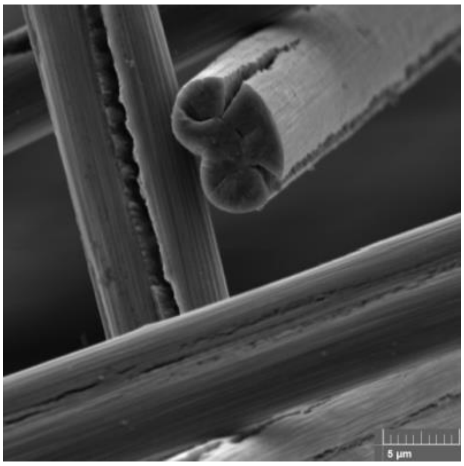
2. Materials and Method

The main aim of the research is to obtain a composite based on silicon carbide reinforced with SiC fiber, that has a combination of physicomechanical properties, namely, high strength and hardness, low thermal expansion coefficient and wear resistance.

The raw materials used in the work were granulated industrial silicon carbide powder (by Saint Gobain), an average particle size was 1 μm (Figure 1a), and silicon carbide fibers obtained by siliconizing SiO vapor (Figure 1b) in accordance the procedure [8].



(a)



(b)

Figure 1. SEM (a) nitrogen carbide powder; (b) fiber-reinforced nitrogen carbide, obtained by siliconizing carbon fibers (the fibers are fully siliconized)

The mixture of silicon carbide powder and reinforcing fiber SiC (5 wt.%) with a sintering additive (8 wt.% yttrium-aluminum garnet), was obtained in an isopropanol environment in a planetary mill for

60 min. The resulting mixture was dried at the next stage. The blanks were molded by cold uniaxial two-sided pressing in a steel mold at 100 MPa pressure with the 3 wt.% addition of 10 % aqueous solution of polyvinylpyrrolidone. Sintering was carried out by hot pressing (Thermal Technology Inc. HP20-3560-20) in a graphite mold at 1850°C in an argon atmosphere. The pressure was 30 MPa.

The obtained samples in the form of tablets were and cut into beams polished in order to study the physicomechanical properties. The density and open porosity of the samples was measured according to GOST 15139-69. Flexural strength was determined on an Instron 5581 testing machine. Crack resistance measurements were carried out according to the indentation method on a TP-7p-1 testing machine. The method does not involve study of propagating cracks, which is typical of all other crack resistance testing methods. It is based on the study of stopped cracks after the introduction of the Vickers indenter into the sample surface.

3. Results and discussion

In this work, the microstructure and some physicochemical properties of hot-pressed silicon carbide-reinforced silicon carbide materials were studied (Figure 2). SEM analysis of the obtained ceramic samples showed no interaction between the matrix material and the reinforcing component. It may indicate the obtained ceramics is a composite material.

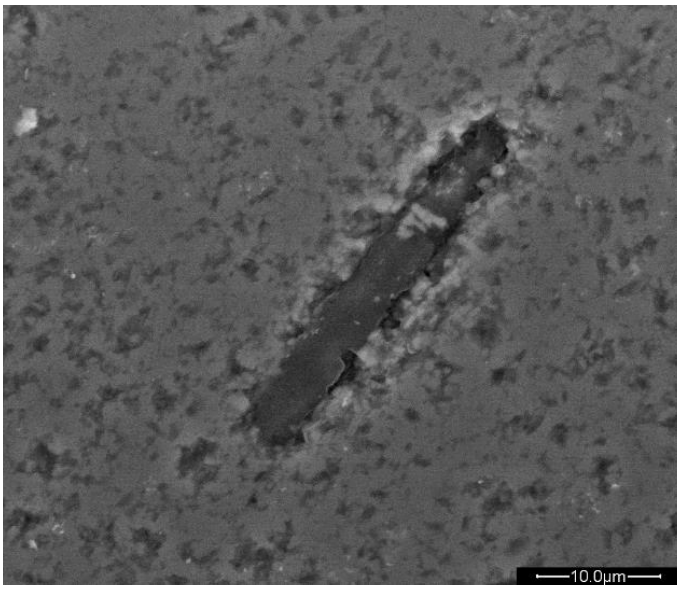


Figure 2. SEM ceramics reinforced with SiC fibers

The fibers concentration increases in SiC matrix leads to an increase in the mechanical properties of the composite. The maximum physicomechanical properties of ceramics based on silicon carbide, reinforced with SiC fibers, were the following. The samples density was obtained 3.17 g/cm^3, strength 430 MPa.

4. Conclusion

The possibility of using silicon carbide fibers as a reinforcing material causes a combination of properties such as high strength and electrical conductivity, low density, implementation of stiffness control, corrosion resistance and high-temperature creep, heat resistance, the ability to create intelligent materials, etc., as well as their compatibility with matrices of different chemical nature [1-3, 5]. In view of the listed features above, composite materials reinforced with SiC fibers can work for a long time in conditions of high temperatures and corrosive environments, while maintaining a high level of operational characteristics.

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