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Ceramic Matrix Composites with Nano Technology–An Overview

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Abstract

Ceramic matrix composites (CMCs) are promising materials for use in high temperature structural applications. This class of materials offers high strength to density ratios. Also, their higher temperature capability over conventional super alloys may allow for components that require little or no cooling. This benefit can lead to simpler component designs and weight savings. These materials can also contribute in increasing the operating efficiency due to higher operating temperatures being achieved. Using carbon/carbon composites with the help of Nanotechnology is more beneficial in structural engineering and can decrease the production cost. They can withstand high stresses and temperatures than the traditional alumina, silicon carbide which fracture easily under mechanical loads Fundamental work in processing, characterization and analysis is important before the structural properties of this new class of Nano composites can be optimized. The fields of the Nano composite materials have received a lot of attention to scientists and engineers in recent years. The fabrication of such composites using Nano technology can make a revolution in the field of material science engineering and can make the composites able to be used in long lasting applications.

1. Introduction

As we know that Composite materials are the type of materials that are formed by combining two or more materials of different physical and chemical properties. The material formed has totally different characterstics from the individual materials. Ceramic materials in general have high strength and can withstand very high temperatures. Also their chemical inertness and low density increases their application in many fields like in aerospace shuttle designing, material casting, etc. But they are prone to failure in case of thermal shock and are easily damaged during fabrication or service. Therefore, it is necessary now to make these composites overcome this problem. Nano composites are the ceramics materials composed by the use of Nano technology. Our main focus is on this part of Ceramic matrix composite.

Ceramic Matrix Composites are a subgroup of composite material. They consist of ceramic fibers embedded in a ceramic matrix forming Ceramic fiber reinforced ceramic. Nowadays CMC's are mainly used in the field that require reliability at high temperature (beyond the capibility of metals) and resistance to corrosion.This include heat shield system of space vehicles,for manufacturing the components of high temperaure gas turbines and components for burners and flame holders.

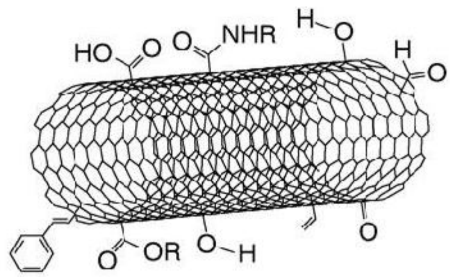
There are some basic differences in ceramic composites and other composites. In non- ceramic matrix composites the fibers bear a greater proportion of the applied load. This load partitioning depends on the ratio of fiber and matrix elastic moduli. In non-ceramic matrix composites, this ratio can be very high, while in CMCs, it can be as low as unity. Another distinctive point regarding CMCs is that because of limited matrix ductility and generally high fabrication temperature, thermal mismatch between components has a very important bearing on CMC performance.

1.1 What ARE Nano Composites

The area of Nano composite material has received a lot of attention from scientists and engineers in recent years. Nano composite is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nanometres (nm), or structures having Nano-scale repeat distances between the different phases that make up the material. The mechanical, electrical, thermal, optical, electrochemical, catalytic properties of the Nano composite will differ markedly from that of the component materials. Size limits for these effects have been proposed, <5 nm for catalytic activity, <20 nm for making a hard magnetic material soft, <50 nm for refractive index hanges, and <100 nm for achieving super paramagnetism, mechanical strengthening or restricting matrix dislocation movement.

Nano composites are found in nature in biological form such as in plants and bones. These materials consist of an inorganic (host) solid containing an organic phase or vice versa. Or they can be consisting of two or more organic or inorganic phases in some combinatorial form with the constraint that at least one of the phases or features is in the nanometre size. Important examples of Nano composites can be porous media, colloids, gels and copolymers.

High performance ceramics are being developed that can withstand high temperature, wear and chemical attack as required in applications like highly efficient gas turbines, automobiles and aerospace materials. Mostly ceramic materials face problems like low fracture toughness and strength, degradation of mechanical properties at high temperatures, fatigue and thermal shock. The problems have been solved by incorporating second phase such as platelets, particulates, and fibres in the micro level at the matrix grain boundaries. But micro-sized fillers cannot solve these problems. The most promising solution researched currently is the dispersion of Nano particles specially carbon Nano tubes in the ceramics matrix.



1.2 Applications in Past

Boron carbide has found application in lightweight armour because of its high hardness and low density. Silicon carbide is also being reinforced with shape-modified SiC fibres for armour, as well as tungsten carbide with diamond Research at the German Aerospace Centre has improved these discs by applying a coating based on Si-SiC called SiCraleen during fabrication. The discs are made by hot pressing half shell C/C preforms, pyrolysis at 900-1600°C, joining the two halves and then infiltrating them with liquid Si. In situ joining via reaction bonding during siliconizing also allows production of complex parts. The improved discs have almost no wear and are expected to last a lifetime or 300,000 km for a car and reduce costs by 75-80% compared to C/C disks. No distortion or corrosion has been observed.

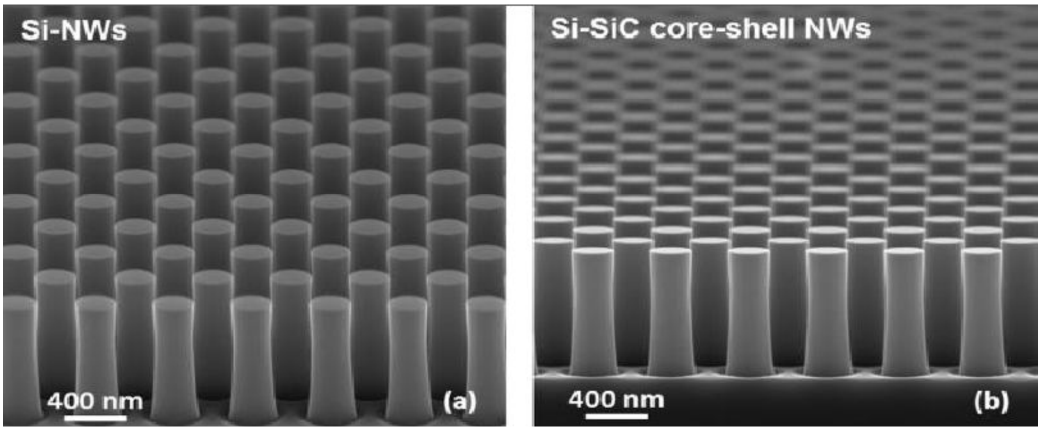
In 2002 a new production plant for these disks was built, which currently can produce 35,000 disks per year. By 2004-2005, production is expected to increase to 300,000 disks per year. However, process costs still need to be reduced since the discs are quite expensive. If costs come down the discs may have application as service brakes for cars/planes and emergency brakes for trains. In addition to gas turbines, SiC/SiC composites are being considered for advanced nuclear applications such as fusion blanket/first wall structures and fission core structures/liners. These materials are promising because of the radiation resistance of the SiC beta phase and their excellent high-temperature fracture, creep, corrosion and thermal shock resistance.

2. Current Overview

Current performance limits are: a maximum temperature 1000°C, a resistivity of 10-15 W/m-K, and a strength of 100-200 MPa as irradiated. Creep limits are unknown and because lifetime depends on creep strain, these limits must be determined. Other issues include production cost, impurity control, joining, and chemical compatibility.

3. Future Aspect

Silicon Carbide is a material now a days used in high temperature or high voltage applications. Now we can synthesize SiC at Nano level, in form of a coating. At Nano level, Silicon Carbide becomes stronger and its tensile strength increases. The heat bearing strength also increases at this level. Silicon Carbide of 12 micrometre size is converted into Nano powder by using high energy ball milling technology. As we increase the time of ball milling the surface area increases, size decreases, makes it more strong and rough. It can be used in the spacecraft sheets which require bearing heat radiated by the Sun. We can also use it in the making of satellites which are continuously in the space and require such materials with such properties. It can also be used in building up of space stations. The heat shield system based on ceramic matrix composite have advantages like reduced weight, reusability, better steering during re-entry into the earth's atmosphere. Figure below depicts the crystal structure of Silicon Carbide at 400 nm. The silicon carbide roughness increases on decreasing the size but it becomes stronger and stronger if we heat it for a more time.



4. Conclusion

Production of ceramic matrix composite using Nano technology can be made more powerful, cost effective and high ending in the service conditions. It's future is very vast and can be used in various applications such as paints in homes, automobile paints, metal paints or coatings to prevent corrosion, aircraft and space shuttle sheets. The roughness of silicon carbide can be used in abrasive metal coatings where the soft metals are corroded by wind action. It can be a cost effective and long lasting matrix in future. The relationship between the Nano composite structure, the properties, and the active toughening mechanisms remains to be established

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