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Extraction and Synthesis of SiC Nano Particulate to Enhance Matrix Composites

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Abstract- The eminent properties of SiC such as hardness, strength, chemical and thermal stability, high melting point, oxidation resistance, high erosion resistance of these high qualities makes this material as a prime candidate to make composites and alloys which ensures high strength, high temperature electronic devices as well as abrasion and cutting applications in manufacturing. In this connection nano based particulates, wires, tubes, films and bulk materials based on silicon carbide in nanocrystalline/amorphous condition to make polymer matrix composite, metal matrix composite and ceramic matrix composite. Their structure, physical, chemical and mechanical properties of the composite are discussed in connection with the influence of size effects and other features in detail to make high end materials.

Key words*:* Synt hesis, Polytypes, Nonocomposite, Characterization

1. INTRODUCTION

Number of works were done for synthesis of SiC since the manufacturing process initiated by Acheson in 1892(author). Different varieties of crystal structures and fabrication routes the SiC starting from the traditional Acheson process which led to a large extent into commercialization. In earlier times conventional method like carbothermal reduction is used to synthesis SiC powders, which is costly and time consumes hence alternative methods have been adopted for sintering SiC particulate to meet the present demand.

In the recent days technological improvement drives the synthesis of SiC. In that view physical vapour deposition (PVT), chemical vapour deposition (CVD), sol-gel, liquid phase sintering (LPS) and Mechanical alloying (MA) are the prime methods. Which are makes better mechanical, structural and electrical properties of the fabricated SiC based products

Now scientists introduce nanotechnology for synthesis of silicon carbide particles, wires, tubes, films and bulk materials which are in crystalline/amorphous structure for various related application. The main attention is taken to prepare nanosized SiC inclusions, which are improve structure behavior , physical properties, chemical properties and mechanical properties.

2. HISTORY OF SiC

Many articles related with nanotechnology are discussed in connection with the influence of size effects and other features. From the new findings, the properties like hardness, high plasticity, substantial increase of photoluminescence spectra intensity, biocompatibility, good resistance to amorphization under irradiation and so on, are all described.

Silicon carbide (SiC) was observed in nature for the first time in 1824 by the Swedish scientist Berzelius (Houyem Abderrazak1 ,1-29).Now this semiconductor took the vital role in mechanical and electronic device applications due to its straightforward physical and electronic properties.

Silicon carbide (SiC) compound is constituted by silicon and carbon atoms, with a 1:1 stoichiometric relationship. Each Si and C atoms are bonded to form four atoms of the other element, in a tetrahedral arrangement. The chemical bond between Si and C atoms are “polar covalent”, constituted by sp3 hybrid orbital, with a bond distance of 1.89 A which is shown in the figure 1.1

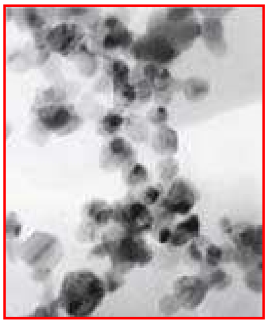

Figure 1.1

2.1 Formation of SiC

To obtain high-performance SiC product, fine powder with narrow particles-size distribution as well as high purity are required. For this purpose, many effective methods have been developed. The simplest manufacturing process of SiC is to combine silica sand and carbon in an Acheson graphite electric resistance furnace at temperatures more than 2500 °C. Crystallinity refers to the degree of structural order in a solid. Crystallinity is usually specified as a percentage of the volume of the material that is crystalline. A perfect crystal would extend in all directions to infinity, so no crystal is perfect due to its finite size. (Model: 2036E201; Rigaku, Ultima IV, Japan). In these connections more than 200 SiC polytypes have been found up to date (Pensl, Choyke, 1993).

Many authors proved that these polytypes were dependent on the seed orientation. For a long time, (Stein et al, 1992; Stein, Lanig, 1993) had attributed this phenomenon to the different surface energies of Si and C faces which influenced the formation of different polytypes nuclei. A listing of the most common polytypes includes 3C, 2H, 4H, 6H, 8H, 9R, 10H, 14H, 15R,19R, 2OH, 21H, and 24R, where (C), (H) and (R) are the three basic cubic, hexagonal and rhombohedral crystallographic categories. In the cubic zinc-blende structure, labelled as 3C-SiC or β-SiC, Si and C occupy ordered sites in a diamond framework. In hexagonal polytypes *n*H-SiC and rhombohedral polytypes *n*R-SiC, generally referred to as α-SiC, *n*-SiC bilayers consisting of C and Si layers stack in the primitive unit cell (Houyem Abderrazak ,1-29).

2.2 Commencement of Nano Silicon Carbide in recent times

Varieties of methods used used to synthesis nanosized particles, which are broadly classified into two categories.

i. Bottom up method and
ii. Top down method.

For example, PlasmaChem GmbH (Germany) delivers the SiC nanopowder with the average size of particles 20±7 nm and purity> 95%. Among new works on the SiC nanopowder synthesis it seems to be interesting to mark out the following most interesting investigations (R.A.Andrievski, 1-20).

Synthesis of β-SiC nanoparticles using the low pressure microwave plasma. Synthesis α-SiC nanocrystals by carbothermic reduction. The amorphous SiC particles were synthesized from the decomposition of tetramethylsilane precursor in a plasma operated at room temperature and low precursor partial pressure (0.001-0.02 Torr) using argon as carrier gas (3 Torr).

The nanoparticles with reasonable monodispersity are studied with transmission electron microscopy (TEM) characterization. The high organic content and excess carbon presented in the synthesized particles were identified by X-ray photoelectron spectroscopy (XPS) and Fourier-Transformed Infrared (FTIR) spectroscopy related with purity of matters (Babu Rao, 1-7)

Further studies for commercial scale production of SiC nanoparticles smaller than 10 nm are continuing. Further investigations are now in progress in order to obtain a pure β-SiC.

3 APPLICATION OF NANO SiC IN COMPOSITES

A common reason for adding filler in matrixes are to increase the modulus or stiffness via reinforcement mechanisms which is described by theories for composites (Lorenzo H.Mancini , 1-282).

Properly dispersed and aligned platelets have proven to be very effective for increasing stiffness. For example increasing the modulus by a factor of two relative materials. A neat nylon requires approximately three times more mass of glass fibers than that of montmorillonite, MMT, platelets. Thus, the nanocomposite has a weight advantage over the conventional glass fiber composite.

Furthermore, if the platelets are aligned in the plane of the sample, the same reinforcement should be seen in all directions within the plane, whereas fibers reinforce only along a single axis in the direction of their alignment.

In addition, the surface finish of the nanocomposite is much better than that of the glass fiber composite. The greater efficiency of the SiC has anything to do with its nanometric dimensions, i.e., a ‘‘nano-effect’. However, the short answer is that we can explain essentially all of the experimental trends using composite theory without invoking any ‘‘nano-effects’’ may not give fulfillment.

Exfoliation Nanocomposites can, in principle, be formed from clays and organoclays in a number of ways including various in situ polymerization, solution, and latex methods. The melt processing is generally considered more economical, more flexible for formulation, and involves compounding and fabrication facilities and commonly used in commercial practice.

While far from a complete accurate or descriptive nomenclature, the literature commonly refers to three types of morphology: immiscible (conventional or microcomposite), intercalated, and miscible or exfoliated.

Placing polymer chains in such a confined space would involve a significant entropy penalty that presumably must be driven by an energetic attraction between the polymer and the organoclay. It is possible that the gallery expansion may in some cases be caused by intercalation of oligomers or low molecular weight polymer chains.

However, no matter how well these process considerations are optimized, it is clear that complete exfoliation, or nearly so. It cannot be achieved unless there is a good thermodynamic affinity between the SiC and the polymer matrix. This affinity can be affected to a very significant extent by optimizing the structure of the surfactant used to form the SiC composite, as this effect the density of surfactant molecules over the matrix. A key factor in the polymer–SiC interaction is the affinity polymer segments. (Lorenzo H.Mancini , 1-282).

4 APPLICATIONS

Grain refinement is one of the effective ways to improve performance of materials. Some of the applications are listed in the table 1.1

Table 1.1

S.NO	Composite Matrix	IMPROVEMENT
1	Silver alloy	Gives high-intensity and high-conductivity and tensile strength- 391MPa, relative conductivity will be 60.2% and abrasion resistance improved
2	Copper compound material	The SiC nano powder dispersion improves strength of the copper matrix material
3	SiC nano powder in rubber tyre	By adding certain proportion of SiC nanoparticles in rubber, we can improve the abrasion resistance by 15%~30% .
4	Engineering plastic & nano magnetic metals	The content of silicon carbide nanopowders, which is treated by coupling agent in plastic materials comprehensively improve the abrasion resistance, thermal conductivity, insulation, tensile elasticity, impact resistance and high temperature resistance.
5	Ceramic matrix compound	The improved properties of tenacity and reliability have been applied to tools, sliding components, engineer parts, energy components and so on.
6	Coating and Special material	The coating can improve the abrasion resistance, corrosion resistance and oxidative stability. Silicon Carbide nanoparticle to metal matrix (aluminium, copper, silver, steel and ferroalloy), to make the new-type metal material for light weight, high intensity and excellent heat resistance.

5 CONCLUSION

Silicon carbide can occur in more than 250 crystalline forms called polytypes. Silicon carbide has attracted much attention for few decades ago because it has a good match of chemical, mechanical and thermal properties.

These applications include high radiation exposure, operation in high temperature and corrosive media. Mechanical alloying is a solid state process capable to obtain nanocrystalline silicon carbide. Moreover this process has a potential for industrial applications.

In fact, as the main factors affecting the improvements of the mechanical properties in super alloys by SiC, depends on the type and amount of sintering aids to be chosen.

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