Synthesis of nano-sized SiC and Si/SiC from silicon and carbon powders by non-transferred arc thermal plasma

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Abstract

SiC is widely used as refractory materials, disc brakes, filter materials, cutting tools, catalyst support, and heater materials because of its superior properties, which include high fracture strength, excellent creep and wear resistances, high hardness, heat resistance at high temperatures, corrosion resistance at high temperatures, and abrasion resistance. Recently, SiC has been used both in high-temperature heating and in the fabrication process of silicon wafers, which are critical to the semiconductor industry, and is being actively studied with the aim of achieving high-purity and large-scale production [1-3].

However, the problems being difficult to sinter and the poor fracture toughness can restrict the effective use of SiC in engineering. It is highly required for SiC-based materials to enhance the fracture toughness, high temperature creep strengths, and swelling resistance, especially for fusion applications. To improve the mechanical properties of SiC, high quality nanopowders have been used. Many methods could be used to produce SiC powders, such as sol–gel methods, gas-phase reaction method, solid state synthesis of silicon with carbon and so on. Among these methods, solid state synthesis of silicon with carbon was considered to be an attractive method due to its proven advantages: lower energy requirement, simpler and cheaper equipment, higher product purity, and finer and well-sintered starting powders [4]. Thermal arc plasma has a high temperature and is rapidly cooled in the tail flame region. The high temperature region can provide enough energy for the melting and evaporation of the sintered SiC powder and the rapidly cooled tail can aids a rapid solidification produced nano-sized sic.

In the present work, nano-sized sic powder was synthesized by solid state reaction and thermal arc plasma process from silicon powder with particle size of 6 μm and carbon black with particle size of 60 μm. In addition, for preparing nano-sized Si/SiC composite powder, the composition of silicon and carbon black powders was changed from Si:C = 1:1 to Si:C= 1:2 in mole ratio. The silicon and carbon black was mixed together by ball mill for 15h. The mixture was calcined in an electric furnace at 1200 ^{o}C for 6h. The calcined SiC or Si/SiC powder was nano-sized by non-transferred arc thermal plasma at pressure of 220 Torr. The Phase and crystalline structural analysis were carried out by X-ray diffraction (XRD).The crystalline structure of nano-sized SiC powder was ß-phase (Fig.1). The morphology was observed by transmission electron microscopy (TEM) & Scanning electron microscopy (SEM). The particle size of synthesized Si and Si/SiC nano-powder was in the range of 40 ~ 100nm as shown in Fig.2.

References

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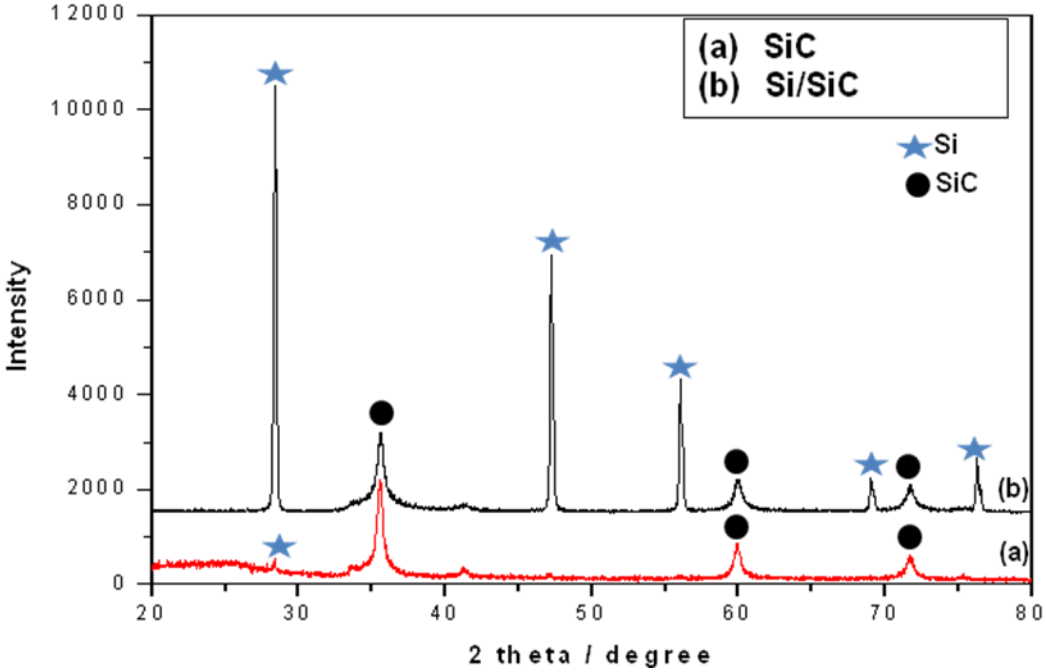

Fig. 1. X-ray diffraction patterns of nano-sized (a) SiC powder and (b) Si/SiC composite powder.

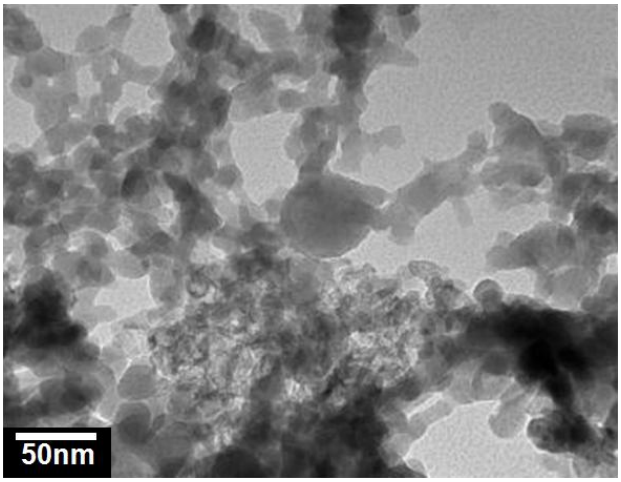

Fig. 2. TEM image of nano-sized SiC powder (mixture composition, Si:C=1:2).

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