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Synthesis of SiC powder by RF plasma technique

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ABSTRACT

Continuous synthesis of SiC nanoparticles by RF thermal plasma method has been studied. Precursor mixtures comprised commercial silica powder and various types of carbon source including graphite, char, carbon black as well as the carbonaceous residue of tire pyrolyses. The obtained SiC consisted of nanosized particles that were crystallized mainly in β phase with traces of α. The conversion rate of the silica precursor to SiC varied between 60% and 73% depending on the type of carbonaceous material and on the carbon excess. The main obstacle to achieve higher conversion is the rapid cooling of reactive species that can also be attributed to formation of nanosized particles.

1. Introduction

Silicon carbide (SiC) is the most widely used non-oxide ceramics for many industrial applications because of its attractive mechanical and thermal properties such as high mechanical strength and hardness, high thermal conductivity, excellent corrosion and thermal shock resistance, semiconductivity, etc. [1–6]. SiC finds application as free-standing parts, as thin layer depositions as well as in composites as filler material. Since nanoparticulate materials exhibit unique properties and nanocomposites are reported to have superior mechanical properties too over their conventional counterparts [7–11], over the last decade attempts have been directed to the synthesis of nanosized SiC powders.

The main method of SiC production is the Acheson process, which is the carbothermal reduction of SiO_2 by coke at 2200–2500 °C [12]. Due to the high reaction temperatures and long reaction time of the process, the product has large grain size and invariably contaminated with more or less oxygen. For the synthesis of nanosized SiC powder numerous synthesis routes have been developed, although most of them remained only in laboratory scale. Among these processes the most studied include mechanical milling [13,14], rapid carbothermal synthesis [15–17], SHS processes [18], microwave synthesis [19], polymer pyrolisis [20], sol–gel processes [21], CVD [22] and laser synthesis [23]. All the mentioned processes have their merits and limitations over the others such as the cheaper precursors they use or the lower reaction temperature, the higher purity of the obtained product, and so on. It's beyond the scope of this article to make detailed comparison of these processes and judge them in terms of feasibility. Instead, in the present article the authors report on a plasmathermal process also for the synthesis of nanometer-sized SiC powder which combine the benefits of low cost precursors with continuous processing.

Thermal plasmas have been mainly utilized in such processes where the extremely high temperature that can reach several thousand degrees provides advantage to establish a more economical processing route [24–29]. In addition, it makes possible a continuous process. The main question is whether or not the residence times of solid precursors in the plasma were enough for an in-flight reaction. In respect of residence time RF plasma has an advantage over arc plasma due to the more extended plasma flames that result in longer mean residence time of reactive species in the hot plasma region [30].

In the present paper attempt has been made to synthesize nanosized SiC powder from low cost raw materials using RF thermal plasma. We investigated the feasibility of an in-flight reaction when reactants are fed in solid form and the effect of the carbon excess on the SiC yield. Various types of carbon sources were compared in terms of efficiency of the reduction and subsequent carburization. Beyond economic point of view, environmental aspects were also considered when carbon powder that remained from the pyrolytic destruction of waste car tires was also involved in the tests.

2. Experimental

Starting powders were of commercial fine silica (C600, Sifraco) and different carbon powders as well as char residue from tire pyrolysis. Powder mixtures were prepared and processed by milling and thermal plasma processing. Not only the type and source of carbon powders

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