Carbon arc plasma: characterization and synthesis of nanosized SiC

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Abstract. Silicon carbide SiC is an important ceramic material with many applications. The nanomaterials can posess novel electronic and mechanical properties. Thus, we attempted to produce SiC nanopowder via a fast, one-step direct plasma synthesis. Two experimental systems were tested regarding the efficiency of SiC formation (for comparison): (i) arc plasma and (ii) high-temperature aerosol route. The products were characterized by wet chemical analysis, X-ray diffraction (XRD) and scanning electron microscopy (SEM). Almost total plasma conversion of starting Si-bearing reactants (Si, SiO and SiO_2) was achieved with SiC nanopowder (well below 100 nm) as a main product. From the emission spectroscopy measurements the arc plasma temperatures were evaluated to be within 3500-6000 K.

1. Introduction

Silicon carbide (SiC) and its composites have found wide applications because of its high Young's modulus and hardness, excellent oxidation and corrosion resistance, high strength at elevated temperatures, good thermal shock durability and electronic characteristics [1]. In addition, nano-crystalline SiC attracts considerable attention because of the wide band gap and quantum size effects [2]. Thus, the SiC nano-crystallites can be used to fabricate electronic devices which are durable at high temperature, strong radiation and fierce erosion. Several methods to produce nano-SiC have been proposed, such as combustion synthesis [3], chemical vapour deposition (CVD) [4], ion implantation [5], heat synthesis [6] and electrochemical etching [7]. Those routes usually suffer, however, from low productivity and long reaction duration. In this paper, we compare two different novel approaches to prepare SiC nanocrystallites. Not only we study the overall process efficiency, but also the oxygen presence in the reaction zone has been tested since in our earlier work we found [8] its profound influence on the formation of β-SiC nanowires synthesized via a combustion route (SHS). The on-line emission spectroscopy was carried out for a carbon plasma diagnostics, too.

2. Experimental

The plasma runs were carried out in the experimental system shown in figure 1 and described in details elsewhere [9]. The arc gap and its position against the optical axis was controlled automatically. The system allowed for holding the electrode gap between 1 and 2 mm for at least 5 minutes of arc operation, during which the radiation emission was measured. The home-made sintered anodes were prepared using the powdered mixtures of carbon black with either Si elemental, SiO or with SiO_2. Arc sublimation/reduction of reactants were performed under He-O_2 low pressure (300 hPa) at the arc current within 10-50 A. The gas-phase condensed products were collected for the

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