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Synthesis and Characterization of Silicon Carbide in the Application of High Temperature Solar Surface Receptors

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Abstract

The use of ceramic surfaces for thermal solar concentrators are not new, but the high costs of fabrication and limited thermal properties have banned the application of such at large scale. Silicon carbide (SiC) is well known due to its high thermo-mechanical properties and spectral absorbance. Because of its capacities to enhance the energy transfer and its resistance to high temperatures silicon carbide have been recognized in our group as a possible improvement to increase the efficiency of electric energy production. At nano-scale SiC shows high surface area and porosity that could be tuned, making it a state-of-the-art material to be used in the application of thermal solar receptors in "Central Tower" power plants. Although the advantages are favorable, the high temperature needs for its synthesis have been an issue for its spread. In the present work, we introduce a novel method to synthesize SiC powders at lower temperature (650°C) we present also its characterization for the potential application in the concentration of thermal solar energy at high temperatures.

Keywords: silicon carbide, solar receptors, central towers.

1. Introduction

Solar receptors transform solar radiation into heat and transfers this energy to the working fluid (1,2); the materials used for its fabrication should be able to withstand high radiative flow, big thermal and mechanical stress, and to work many hours without failure (3). Due to its high absorptance values, superficial area, porosity and high fusion point (4), and its good thermo-mechanical properties (5,6) at high temperatures, SiC presents great advantages for applications in solar receptors used in a central

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tower plant, having a positive impact on the efficiency of the processes of electrical energy production (6-8). The receptors used in central tower plants usually working from 500°C and above 1000°C (2), at this temperature, the required materials must be able to endure not only everyday use but also long periods of time maintaining its properties and characteristics.

SiC's polymorphism is of high importance because it is an influence in its mechanical properties, proving that α-SiC presents a bigger Young module compared to β-SiC (347 to 314 GPa); figure 1 shows the stacking sequence of silicon and carbon atoms in some of SiC polytypes (9).

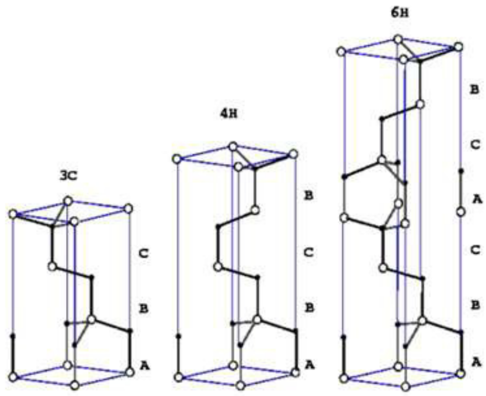

Fig. 1. Stacking sequence of bilayers in polytypes of SiC.

Most common processes to obtain SiC need high temperatures, around 1150-1500°C (10-17), using different techniques as "nanocasting" (10,11), sol-gel (12-13), molten salts (14), carbothermic reduction (15-17) and low temperature processes as magnesiothermic reduction method (18-21); these methods use different materials as silicon precursors: SiO_2 (9,10,16-18), TEOS (12,13); and carbon: polycarbosilane (10,11), phenolic resine (12,13) graphite (17), resorcinol-formaldehyde (18,19).

The present work, presents a technique for synthesis of SiC at low temperature (650°C), via magnesiothermic reduction, from nanocomposite precursor of SiO_2/C. Nanocomposite SiO_2/C was obtained from SiO_2 as a silicon precursor, which was synthesized via sol-gel method from TEOS and sucrose as carbon source. Obtained SiC was characterized via FTIR, XRD, TEM, SEM and thermal analysis (TGA/DSC) with the purpose of further evaluation as a possibility in high temperature solar energy concentration plants.

2. Experiments

2.1. Materials.

Tetraethyl orthosilicate (TEOS, 99.98%), absolute ethanol, HNO_3 4M, H_2SO_4 65% wt, HF 10% wt, sucrose (99.5%), distilled water and magnesium were used. SiO_2 synthesis was via sol-gel method.

The following reagents were mixed and stirred: TEOS-ethanol (1:3) and HNO_3 5%, as a catalyst, to later be dried at room temperature, obtaining SiO_2, which was then milled in an agate mortar.