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Original Research Paper

Carbothermal formation and microstrutural evolution of α′-Sialon–AlN–BN powders from boron-rich blast furnace slag

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ABSTRACT

Boron-rich blast furnace slag of low activity is one of the major products created during the separation of iron and boron from ludwigite in a blast furnace process, and the high-efficiency utilisation of its is of great importance to the Chinese boron industry. This paper proposes one new application process to synthesize α′-Sialon–AlN–BN powders by a carbothermal reduction–nitridation method using boron-rich blast furnace slag as the staring material and describes a series of experimental studies that were performed to elucidate the mechanism of phase formation and microstructure evolution during CRN. The experimental results revealed that the phase compositions and microstructures of the synthesized products were greatly affected by the initial compositions ($(Ca,Mg)_xSi_{12-3x}Al_{3x}O_xN_{16-x}$), $x = 0.3–1.8$), temperature and holding time. With the compositions shifting from values of x of 0.3–1.8, the relative amount of α′-Sialon, AlN and BN increased gradually, and the amount of α′-Sialon reached a maximum at a value of x of 1.4. The optimal condition for powder synthesis was a temperature of 1480 °C with a holding time of 8 h, under which the crystalline phases included α′-Sialon, AlN, BN and less SiC. More elongated α′-Sialon grains were observed at higher x values and temperatures. During the CRN process, $MgAl_2O_4$, Mg_2SiO_4, $Ca_2Al_2SiO_7$, $MgSiN_2$, β′-Sialon and 27R appeared sequentially as intermediate products. The volatilisation of SiO gas and magnesium vapour resulted in additional weight loss of the samples, which was aggravated with increases in the synthesis temperature and holding time.

1. Introduction

Boron resources are relatively rich in China, with demonstrated B_2O_3 reserves of up to 50.4 million tons, which ranks fourth in the world. These boron resources exist mainly in the form of ascharite and ludwigite. The former tends to be used, and the latter is the paragenetic ore of boron, magnesium and iron and is mainly composed of magnetite, camsellite, paigeite and serpentine minerals. The demonstrated reserves of ludwigite in China consist of 0.28 billion tons, accounting for 58.0% of the total boron reserves in China. As one of major products created during the separation of iron and boron from ludwigite in a blast furnace process, boron-rich blast furnace slag primarily contains SiO_2, Al_2O_3, MgO, CaO and B_2O_3 along with a smaller amount of iron oxide and other materials. Because of the low activity (approximately 50%) and low boron grade (B_2O_3 content of approximately 12 wt.%), it is difficult to use boron-rich blast furnace slag to directly produce boric acid and borax. Thus, the high-efficiency utilisation of boron-rich blast furnace slag is of great importance in the Chinese boron industry.

Based on this background, one innovative process to recycle the boron-rich blast furnace slag in the synthesis of (Ca,Mg)α′-Sialon using the carbothermal reduction–nitridation (CRN) method has been proposed in this study. In this process, B_2O_3 is converted into hexagonal boron nitride (h-BN), which has a high melting point and thermal conductivity, excellent corrosion and thermal shock resistance, and good electric insulativity and lubricity [1–4], which can improve the properties of α′-Sialon matrix composites. The α′-Sialon–BN composite can be used as break rings in the horizontal continuous casting of steel, as a nozzle refractory or in new structural ceramics.

α′-Sialon is represented by general formula $M_x^{v+}Si_{12-(m+n)}Al_{(m+n)}O_nN_{16-n}$ (where M represents Li, Ca, Mg, Y and most of the lanthanide elements; x is given by m/v and v is the valency of the cation) [5,6]. Presently, the general α′-Sialon synthesis methods include reaction sintering, self-propagating high-temperature synthesis and the CRN method. The CRN method can be used to synthesize α′-Sialon powders by using pure SiO_2 and Al_2O_3 [7],

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