SELF-PROPAGATING HIGH-TEMPERATURE SYNTHESIS OF SI3N4-TIC COMPOSITION USING SODIUM AZIDE*

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Silicon nitride is a modern ceramic material with excellent mechanical properties, both at room and at elevated temperatures, and a fibrous microstructure, which is promising for use as a strengthening phase [1]. Adequate fracture toughness, high hardness and good wear resistance are important characteristics of modern ceramics, which find applications in cutting tools and automotive components such as cam rollers and ball bearings of diesel engines [2].

Many efforts have been made to improve the mechanical properties of Si_3N_4 by controlling the microstructure or creating various types of composites. When large β-Si_3N_4 fibers are formed during compaction, the fracture toughness increases significantly as the crack interacts with these fibers, while the strength tends to decrease due to the formation of microcracks around the large grains [3]. Similar improvements are observed when a secondary phase is added to the Si_3N_4 matrix. TiC particles in a Si_3N_4 matrix are used to increase the fracture toughness of composite materials. The effect of changing the crack trajectory was enhanced by the simultaneous presence of TiC particles and β-Si_3N_4 fibers. In addition, pressure sintering reduces the grain size. It was shown in [4] that adding conductive compounds such as (TiN, TiC, TiB_2) to the Si_3N_4 matrix increases the conductivity of the material and improves its machinability. Known approaches to the production of Si_3N_4-TiC composites have some disadvantages, such as complexity, high cost and low productivity, which makes it difficult to organize large-scale production.

The possibility of producing a Si_3N_4-TiC composition in a laboratory SHS reactor in a nitrogen atmosphere at a relatively low pressure of 4 MPa and the bulk density of mixtures of initial powders was experimentally studied. To synthesize a Si_3N_4-TiC composition with a molar ratio of target phases from 1:4 to 4:1, the following equations were used:

$$2Si+Ti+6NaN_3+(NH_4)_2SiF_6+C=Si_3N_4+TiC+6NaF+4H_2+8N_2 \quad (1)$$
$$2Si+2Ti+6NaN_3+(NH_4)_2SiF_6+2C=Si_3N_4+2TiC+6NaF+4H_2+8N_2 \quad (2)$$
$$2Si+4Ti+6NaN_3+(NH_4)_2SiF_6+4C=Si_3N_4+4TiC+6NaF+4H_2+8N_2 \quad (3)$$
$$5Si+Ti+6NaN_3+(NH_4)_2SiF_6+C=2Si_3N_4+TiC+6NaF+4H_2+6N_2 \quad (4)$$
$$11Si+Ti+6NaN_3+(NH_4)_2SiF_6+C=4Si_3N_4+TiC+6NaF+4H_2+2N_2 \quad (5)$$

The results of thermodynamic calculations of these reactions showed that adiabatic temperatures are high enough to implement a self-sustaining combustion regime, and the reaction products correspond to the right-hand sides of equations (1)-(5). During the experimental study, temperatures and combustion rates, structure and phase composition of combustion products were determined.

Thus, the considered application of the azide SHS method made it possible to obtain highly dispersed compositions of Si_3N_4-TiC and Si_3N_4-TiN-TiC ceramic powders with particle sizes from 100 to 400 nm. Further research in this direction is planned with the aim of obtaining a Si_3N_4-TiC nanopowder composition.

REFERENCES

[1] Sungjun Kim, B.G. Park, Tuning tunnel barrier in Si3N4-based resistive memory embedding SiO2, for low-power and high-density cross-point array applications, J. Alloys Compd. 663 (2016) 256-261.

[2] Palmero P. Structural ceramic nanocomposites: a review of properties and powders' synthesis methods.Nanomaterials, Vol. 5, pp. 656-696, 2015.

[3] P.F. Becher, N. Shibata, G.S. Painter, F. Averill, K. van Benthem, H.-T. Lin, S.B. Waters, Observations on the influence of secondary Me oxide additives (Me j Si, Al, Mg) on the microstructural evolution and mechanical behavior of silicon nitride ceramics containing RE2O3 (RE j La, Gd, Lu), J. Am. Ceram. Soc. 93 (2010) 570-580.

[4] D.H. Zheng, X.Q. Li, Y.Y. Li, S.G. Qu, C. Yang, In-situ elongated b- Si3N4 grains toughened WC composites prepared by one/two-step spark plasma sintering, Mater. Sci. Eng. A 561 (2013) 445-451.

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