

## INTERACTION OF THE "FERROSILICON-ZIRCON-ALUMINIUM" MIXTURE WITH NITROGEN DURING SHS

O.G. KRYUKOVA

*Tomsk Scientific Center of the Siberian Branch of the Russian Academy of Sciences, Tomsk, 634055, Russia*

$\text{Si}_3\text{N}_4$  due to its properties (high hardness, heat resistance, mechanical strength) and composite materials based on it ( $\text{Si}_3\text{N}_4\text{-SiC}$ ,  $\text{Si}_3\text{N}_4\text{-TiN}$ ,  $\text{Si}_3\text{N}_4\text{-BN}$ ,  $\text{Si}_3\text{N}_4\text{-MoSi}_2$  etc.) are widely used in tool industry, mechanical engineering, chemistry, electrical and radio engineering [1-3]. Due to the covalent bonds,  $\text{Si}_3\text{N}_4$  is a high-sintering material. Activating oxygen-containing additives (Al, Mg, REM oxides) are used to obtain high-density  $\text{Si}_3\text{N}_4$  - based ceramics. Sintering activators also include  $\text{ZrO}_2$ . In this work, a new approach to the synthesis of  $\text{Si}_3\text{N}_4$ -based composite powders was proposed. It was proposed to nitride ferrosilicon (iron-silicon alloy) with natural oxides (zircon) by self-propagating high-temperature synthesis (SHS). The heat of the nitride formation reaction contributes to an endothermic process of zircon dissociation and the powder  $\text{Si}_3\text{N}_4\text{-ZrO}_2\text{-Si}_2\text{N}_2\text{O-Fe}$  is obtained without additional energy costs.

In [4] the effect of aluminum additives (1-10 wt%) on the phase composition of composite powders was reported using the "40 % ferrosilicon - 30 % nitrated ferrosilicon - 30 % zircon" mixture that was nitrated by SHS. It was found that the addition of 1% Al leads sharply decreases the  $\text{Si}_2\text{N}_2\text{O}$  phase content in the synthesized products, and a further increase in Al leads to the disappearance of  $\text{Si}_2\text{N}_2\text{O}$ . Addition of 6 % and more leads to the formation of  $\text{ZrN}$  phase in the burned samples, which is visually observed as separate areas of golden color. The addition of Al additives to the mixture leads to the formation of a solid solution based on  $\text{Si}_3\text{N}_4$  in the final products. However, the mechanism of interaction of the mixture with nitrogen in the presence of aluminum during combustion remains unclear. This work is an ongoing research and devoted to the study of chemical transformations during nitriding of the mixture with aluminum additives (1 - 10 %) using the methods of isothermal synthesis and differential scanning calorimetry.

To study physicochemical processes occurring during nitriding of the mixture with Al, sample 1 (mixture + 6 % Al) and sample 2 (mixture + 10 % Al) were used. Nitriding of sample 1 under isothermal conditions showed a small amount of nitrogen in the products in the temperature range of 800 - 1000°C with increasing the nitriding time (30 - 180 min). At temperatures above 1000°C, the amount of nitrogen in the products increases. According to XRD data,  $\text{AlN}$  is formed in the products at 800°C. At 900°C,  $\text{Si}_3\text{N}_4$  reflexes are observed in X-ray diffraction patterns, and  $\text{ZrO}_2$  at 1000°C. In the temperature range of 1000 - 1250°C, the phase composition of the products is represented by  $\beta\text{-Si}_3\text{N}_4$ ,  $\text{ZrO}_2$ . With increasing the nitriding time, the intensity of reflexes of these phases slightly increases. The synthesized products contain unreacted components of the mixture ( $\text{FeSi}_2$ , Si,  $\text{Fe}_x\text{Si}_y$ ,  $\text{ZrSiO}_4$ ). A similar pattern is observed during nitriding of sample 2 under isothermal conditions.

### REFERENCES

- [1] F.L. Riley "Silicon nitride and related materials," *J. Am. Ceram. Soc.*, vol. 83, no. 2, pp. 245–265, 2004.
- [2] Z. Gábrišová, P. Švec and A. Brusilová "Microstructure and selected properties of  $\text{Si}_3\text{N}_4$  +  $\text{SiC}$  composite," *Manufact. Technol.*, vol. 20, no. 3, pp. 293–299, 2020.
- [3] A.S. Lysenkov, K.A. Kim, Yu.F. Kargin, M.G. Frolova, D.D. Titov, S.N. Ivicheva, N.A. Ovsyannikov, A.A. Konovalov and S.N. Perevislov "Si<sub>3</sub>N<sub>4</sub>-TiN composites obtained by hot pressing of silicon nitride and titanium powders," *Inorg. Mater.*, vol. 56, pp. 309–320, 2020.
- [4] O. G. Kryukova, K. A. Bolgaru and A. N. Avramchik "Combustion of Ferrosilicon-Zircon Mixtures in Nitrogen Gas: Impact of Aluminum Additives," *Int. J. SHS*, vol. 30, no. 4, pp. 236–240, 2021.