Effects of BN and Si3N4 on Combustion Synthesis of Composite Materials Containing Metal Nitrides

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ABSTRACT

Preparation of three composite materials TiN/TiB2 (titanium nitride/titanium diboride) , TaN/TaB (tantalum nitride/tantalum boron), and TiN/Ti5Si3 (titanium nitride/titanium silicon) was studied by self-propagating high-temperature synthesis (SHS). In this study, boron nitride (BN) and silicon nitride (Si3N4) powders were employed as the solid source of nitrogen to enhance the formation of metal nitrides. In the first part of this study, formation of TiN-TiB2 composites was conducted in two reaction systems. Combustion of sample compacts made up of titanium (Ti) and boron nitride (BN) powders was initiated under nitrogen pressure for the synthesis of composites with TiN contents of 75-87.5 mol.%. Experiments with reactant compacts from the Ti-BN-B powder blends were performed in argon (Ar) for the preparation of composites with 50-75 mol.% of TiB2. Due to the involvement of solid and gaseous reagents in the former reaction system, sample porosity and dilution by TiN made a significant impact on the degree of nitridation. On the contrary, combustion synthesis in the latter test configuration was essentially governed by the reaction between solid constituents. Experimental results show complete conversion was observed on a 1.5Ti+BN compact which yielded the composite with a molar ratio TiN/TiB2 = 67/33 in Ar, verifying the contribution of BN to the formation of TiN and TiB2. Direct formation of a composite with 75 mol.% TiN in nitrogen of 1.48 MPa was achieved by an undiluted compact of 2Ti+BN at 60% TMD. For the preparation of composites with TiN contents as high as 83 and 87.5 mol.%, complete conversion was achieved by 60% TMD TiN-diluted samples. In the second part of this study, formation of TiN/Ti5Si3 composites was conducted in two reaction systems. One adopted silicon nitride (Si3N4) as the solid source of nitrogen in a solid-state combustion system. The other employed both solid and gaseous reagents and performed the reactions of the Ti-Si powder compact under nitrogen pressures. TiN/Ti5Si3 composites containing Ti5Si3 from 20 to 80 mol% were effectively produced by solid-state combustion synthesis of Ti-Si3N4 and Ti-Si3N4-Si powder compacts. This result verifies the contribution of Si3N4 to the formation of TiN and Ti5Si3. However, the solid/gas reaction of Ti-Si compacts with gaseous nitrogen was proved to be an inappropriate route in terms of product composition. For the production of a TiN-rich composite such as 80 mol% TiN, it was found that the nitrogen uptake by the Ti-Si sample compact was inadequate. On the contrary, when preparing the TiN-Ti5Si3 composite with a low TiN content like 20 mol% or even 50 mol%, Ti-Si powder compacts in gaseous nitrogen were subjected to excessive Ti nitridation and yielded a Si-rich silicide phase TiSi2 in addition to TiN and Ti5Si3. In the third part of this study, preparation of TaN-TaB composites was attempted. It was found that the decomposition of BN in the reactant compacts was not complete under low nitrogen pressures. Therefore, formation of Ta2N and presence of residual BN were observed in the final product. As suggested by the observations of this study, the role played by BN in the synthesis of TaN/TaB is not as beneficial as that in the formation of TiN/TiB2.

Keywords : Self-propagating High-temperature Synthesis (SHS), TiN/TiB2, TaN/TaB, TiN/Ti5Si3, Afterburning, Diluent.

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