Combustion Synthesis of Multiphase Metal Borides and Silicides

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ABSTRACT

Formation of niobium silicides (Nb-Si), niobium borides (Nb-B) and molybdenum silicdes (Mo-Si) was investigated by self-propagating high-temperature synthesis (SHS) in this study. Effects of sample green density, preheating temperature, and starting stoichiometry on the combustion characteristics, as well as on the composition of final products were studies. In the first part of this study, production of niobium silicides (Nb3Si, α-Nb5Si3, β-Nb5Si3, and NbSi2) and Nb5Si3/Nb composites was conducted from elemental powder compacts. XRD analysis showed that the compact with a composition of Nb:Si = 5:3 yielded predominantly α-Nb5Si3, whereas the sample made up of Nb:Si = 3:2 produced largely β-Nb5Si3. The sample of Nb:Si = 1:2 produced NbSi2 with some Nb and Si left unreacted. Experimental observations indicated that except for the sample of Nb:Si = 3:1, upon ignition self-sustained combustion was well established and proceeded throughout the entire sample. Moreover, the reactant compact of Nb:Si = 5:3 had the highest flame-front propagation velocity, followed sequentially by the powder compacts with Nb:Si = 3:2, 1:1, and 1:2. Variation of the combustion temperature with sample initial stoichiometry is in a manner consistent with that of the flame-front velocity. In the synthesis of Nb5Si3/Nb composites, the increase of elemental Nb content in the final composition lowered the combustion temperature and thereby reduced the flame-front velocity. Nb5Si3/Nb composites with the concentration of Nb ranging from 5 to 15 mol.% were produced by SHS in this study. XRD analysis of the Nb5Si3/Nb composite identifies the formation of Nb5Si3 dominated by the α form, along with the existence of elemental Nb. Based upon the data measured combustion temperature and combustion wave velocity, the activation energies associated with combustion synthesis of Nb5Si3 and NbSi2 were determined to be 259.2 and 160.8 kJ/mol, respectively. In the second part of this study, a comparative study on the preparation of specific niobium borides (including Nb3B2, NbB, Nb5B6, Nb3B4, and NbB2) in the Nb-B system was conducted from elemental powder compacts of their corresponding stoichiometries. Reactant compacts of Nb:B = 1:1 and 1:2 were shown to yield single-phase NbB and NbB2, respectively. In contrast, multiphase products consisting of Nb3B4, NbB, and NbB2 were produced from the powder compacts with Nb:B = 3:2, 3:4 and 5:6. However, it was found that two boride phases Nb3B2 and Nb5B6 did not appear in the end products from any of the reactant compacts. Combustion of the samples with Nb:B = 3:2 was characterized by a localized reaction zone propagating along a spiral trajectory, due largely to the low combustion temperatures which further resulted in a poor degree of phase conversion with a significant amount of Nb left unreacted. Based upon the measured combustion temperature and combustion wave velocity, the activation energies associated with combustion synthesis of NbB and NbB2 were determined to be 151.8 and 132.4 kJ/mol, respectively. In the third part of this study, production of molybdenum silicides (Mo3Si, Mo5Si3, and MoSi2) was conducted from elemental powder compacts. Reactant compacts of Mo:Si = 1:2 were shown to yield single-phase MoSi2. However, reactions were extinguished on the compacts of Mo:Si = 3:1 and 5:3. Multiphase products consisting of Mo5Si3, MoSi2 and unreacted Mo were produced from the powder compacts with Mo:Si = 2:3 and 1:1. Measured results showed that the reactant compact of Mo:Si = 1:2 and 2:3 had higher flame-front propagation velocities than that of Mo:Si = 1:1. The activation energy 34.9 kJ/mol was determined for MoSi2.

Keywords : Nb-Si, Nb-B, Mo-Si, Self-propagating High-temperature Synthesis, Activation Energy, Preheating, XRD

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