Effects of Reaction Modes and Melting Point of Reactants on Combustion Synthesis of Metal Nitrides

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ABSTRACT

An experimental study on different reaction modes of self-propagating high temperature synthesis (SHS) was investigated to prepare metal nitrides, carbides, and carbonitrides. Three different modes of SHS reactions were studied, including solid/gas, solid/solid, and simultaneous solid/solid/gas synthesis reactions. In this study, the propagation of the self-sustained flame front was observed and the flame front velocity and combustion temperature were measured. Different experimental variables were examined and discussed for different SHS reactions. In the solid/gas combustion reactions, tantalum nitride (TaN) was prepared from tantalum (Ta) powder compacts in gaseous nitrogen, and the result showed that sample density and nitrogen pressure were important parameters. Lower density and higher pressure can increase the degree of conversion. Besides, the melting point of reactant was also important to solid/gas combustion reactions. In order to demonstrate the influence of melting point on the reaction, aluminum (Al) powder compacts was used to synthesize aluminum nitride in nitrogen to compare with the case of tantalum which has a high melting point of 2996 oC. Because the melting point of aluminum (660oC) was lower than combustion temperature (1600~1800 oC), the addition of diluent was required in order to prevent the melting of samples and to achieve a high extent of conversion. In the solid/solid combustion reactions, tantalum carbides were prepared from tantalum/carbon powder compacts in argon. Results indicated that the different molar ratios of Ta:C = 1:1 and 2:1 produced two kinds of carbides TaC and Ta2C, and an increase in the sample density enhanced the degree of conversion of the product. The activation energies of SHS processes associated with TaC and Ta2C systems were determined to be 187.42 and 298.97 kJ/mole, respectively, based upon the measurement of flame-front velocity and combustion temperature. Simultaneous solid/solid/gas combustion reactions conducted in this study produced tantalum carbonitrides Ta(C,N) from the compacts of tantalum and carbon powder mixtures under nitrogen pressures. Results indicated that the carbon content and nitrogen pressure were important parameters. Higher nitrogen pressure can increase the degree of conversion. X-ray diffraction (XRD) analysis indicated the existence of a small amount of unreacted Ta in the final products, and the presence of negligible Ta2N under the condition with a low content of carbon.

Keywords : Self-propagating high temperature synthesis (SHS) ; Reaction mode ; Solid/gas SHS ; Solid/solid SHS ; Simultaneous solid/solid /gas SHS

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