EFFECT OF SELF-FLUIDIZATION OF REACTION MEDIUM AND ITS APPLICATION TO THE COMBUSTION SYNTHESIS OF Ni–Al INTERMETALLICS

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Abstract: The paper studies the mechanism of self-propagating high-temperature synthesis in powder mixtures of $\mathrm{Ni + Al + CaCO_3}$. Using $\mathrm{CaCO_3}$ makes it possible to form a fluidized state of the reaction mixture in the preheat zone of the combustion wave and synthesize highly permeable intermetallic alloys. The mechanism was studied using high-speed imaging, dynamic temperature measurements, and reaction quenching. It was found that highly mobile microdroplets of reacting Ni and Al melts ($\sim$ 0.1–0.2 mm in diameter) participate in the structural transformation of the reaction medium in the combustion wave zone. A wide range of capillary processes accompanies the synthesis: (i) formation of droplets in the process of reaction coalescence of melts; (ii) intake of melting powder by moving droplets; (iii) wrapping a rolling droplet with a thin layer of newly-formed melt; and ($i\nu$) thermocapillary drift of droplets in a fluidizing powder medium. The effect of self-fluidization of the reaction mixture on the structure of the synthesized alloys has been discussed.

Keywords: combustion synthesis; intermetallics; Ni–Al; self-fluidization; structure

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Figure Captions

Figure 1 Schematic diagrams of experimental apparatus (*a*), optical path of the spectrometer (*b*), and the technique for hardening the combustion wave (*c*)

Figure 2 Video stills of the reaction zone in $\mathrm{Ni + Al + 2\%\, CaCO_3}$ powder mixture illustrating local melt flow dynamics: merging of droplets (*a*), intake of melting powder by a moving droplet (*b*), and wrapping a rolling droplet with a thin layer of newly-formed melt (*c*)

Figure 3 Position–time histories of the propagating combustion waves for Ni + Al (*a*) and $\mathrm{Ni + Al + 2\%\, CaCO_3}$ (*b*) reaction mixtures: round markers — the boundary between the preheat zone and the reaction mixture; and square markers — the boundary between the preheat zone and the reaction zone. The coordinates of the boundaries were determined within sighting strips 0.5 mm wide oriented in the direction of propagation of the combustion wave X

Figure 4 Typical temperature–time histories of the $\mathrm{Ni + Al + 2\%\, CaCO_3}$ combustion

Figure 5 Typical temperature–time history of the $\mathrm{Ni + Al + 2\%\, CaCO_3}$ combustion. Pyrometric data

Figure 6 The peak temperature of the largest reactive droplets and the average temperature in the combustion wave vs. the $\mathrm{CaCO_3}$ concentration (*a*) and the porosity (*b*), pyrometric data: (*a*) the porosity is fixed to 50%; and (*b*) the $\mathrm{CaCO_3}$ concentration is fixed to 2%

Figure 7 The maximal diameter of strut elements $d_{\max}$ (*1*) and the average duration of temperature pulses t_{imp} (*2*) (pyrometric data) vs. the $\mathrm{CaCO_3}$ concentration β (*a*) and the porosity ε (*b*): (*a*) the porosity is fixed to $\varepsilon = 50\%$; and (*b*) the $\mathrm{CaCO_3}$ concentration is fixed to $\beta = 2\%$

Figure 8 The SEM (scanning electron microscope) images of quenched combustion wave for Ni + Al (*a*) and $\mathrm{Ni + Al + 2\%\, CaCO_3}$ (*b* and *c*) powder mixtures; (*a*)–(*c*) transverse fracture surfaces of the hardened layer; and (*d*) internal structure of Ni–Al microsphere

Figure 9 Schematic illustration of thermocapillary-driven motion of a microdroplet through the $\mathrm{Ni + Al + CaCO_3}$ powder mixture

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