An Experimental Research on Solid-phase Combustion Synthesis of TiNi and Ni3Al Intermetallics

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ABSTRACT

The self-propagating high-temperature synthesis (SHS) of three NiTi, Ni3Al and Ni3Al+B intermetallic compounds was studied. Effects of initial sample density, preheating temperature, and particle size of the reactants on the flame-front velocity, combustion temperature and composition of combustion products were investigated. The influence of preheating the sample prior to ignition on the synthesis process was also discussed. It was found that all these three kinds of SHS processes were characterized by the steady propagation of the flame front. The combustion process indicated the melting and shrinkage of test samples except for the compacts with low initial densities in the synthesis of Ni3Al, in which the volume expansion was observed. The flame-front propagation velocities increased with initial sample density and preheating temperature. The increase in boron concentration led to a noticeable increase in flame-front propagation velocity. The flame-front propagation velocities in this study were in the region between 5.5 and 121 mm/s. Based upon the measurement of flame-front velocity and combustion temperature, the activation energies of SHS processes associated with Ni3Al and Ni3Al+B systems were calculated to be 92.06~97.78 kJ/mole and 86.4 kJ/mole, respectively. The composition of combustion products was affected by the initial sample density, preheating temperature, and particle size of reactants. Results of X-Ray Diffraction (XRD) analysis indicated that in addition to the NiTi phase, the existence of NiTi2, Ni3Ti, and unreacted metal in the final products of the Ni-Ti system was detected. However, fully-reacted products madeup of the Ni3Al phase were obtained in the Ni3Al and Ni3Al+B systems. The microstructures of synthesized products illustrated by Scanning Electron Microscope (SEM) photographs indicated the formation of high-density and porous NiTi compounds. In the synthesis of Ni3Al, the addition of boron resulted in the formation of denser products when compared with the condition without boron.

Keywords : NiTi ; Ni3Al ; Self-propagating High-temperature Synthesis ; Flame-Front ; Activation Energy ; Preheating

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REFERENCES

1. Otsuka, K., and Ren, X.,“ Recent developments in the research of shape me -mory alloys, ”Intermetallics, Vol. 7, pp.511-528, 1999. 2.

Funakubo, H, editor., Shape memory alloys, New York: Gorden & Breach, 1987. 3. Starosvetsky, D., and Gotman, I., “ Corrosion behavior of titanium nitride - coated Ni-Ti shape memory surgical alloy, ” Biomaterials, Vol. 22, pp. 1 -853-1859, 2001. 4. Kapanen, A., Ryhanen, J., Danilov, A., and Tuukkanen, J., “ Effect of Nicke -l-titanium shape memory metal alloy on bone formation, ” Biomaterials, Vo -l. 22, pp. 2475-2480, 2001. 5. Li, B,Y., Rong, L, J., Li, Y, Y., and Gjunter, V, E., “ Synthesis of porous - Ni-Ti shape-memory alloys by self-propagating High-temperature synthesi -s: reaction mechanism and anisotropy in pore structure, ” Acta Materiali -a, Vol. 48, pp. 3895-3904, 2000. 6. Li, B, Y., Rong, L, J., Li, Y, Y., and Gjunter, V, E., “ A recent developmen -t in producing porous Ni-Ti shape memory alloys, ” Intermetallics, Vol. 8, p -p. 881-884, 2000. 7. Bram, M., Ahmad-Khanlou, A., Heckmann, A., Fuchs, B., Buchkremer, H, P., an -d Stover, D., “ Powder metallurgical fabrication processes for NiTi shape m -emory alloy parts, ” Materials Science and Engineering, Vol. A337, pp. 254- -263, 2002. 8. 楊聰賢, ” 以Ni3Al作為鑽石刀具基材之製程研究, ” 碩士論文, 國立臺灣大學材料科 學與工程學研究所, 2000. 9. Dey, G, K., “ Micropyretic synthesis of NiTi in propagation mode, ” Acta Ma -terialis, Vol. 51, pp. 2549-2568, 2003. 10. Yi, HC., Moore, JJ., Journal of Materials Science, Vol. 24, pp. 3449, 1989. 11. Yi, HC., Moore, JJ., Journal of Materials Science, Vol. 25, pp. 1159, 1990. 12. Lee, S-H., Lee, J-H., Lee, Y-H., Shin, D, H., and Kim, Y-S., “ Effect of he -ating rate on the combustion synthesis of intermetallics, ” Materials Scie -nce and Engineering, Vol. A281, pp. 275-285, 2000. 13. 莊賀傑, 葉俊良, 宋文義, “ 固相燃燒合成氮化鈦之實驗研究, ” 中華民國第二十六屆 全國力學會議, 雲林縣國立虎尾技術學院, 2002. 14. 莊賀傑, 葉俊良, 宋文義, “ 自持傳遞高溫合成氮化鈮之實驗研究, ” 中華民國燃燒學 會第十三屆學術研討會, 台北市, 2003. 15. 莊賀傑, “ 固相燃燒合成金屬氮化物之研究, ” 碩士論文, 大葉大學機械工程學系, 2003. 16. Merzhanov, A, G., “ History and recent developments in SHS, ” Ceramics Interm -ational, Vol. 21, pp. 371-379, 1995. 17. Moore, J, J., and Feng, H, J., “ Combustion synthesis of advanced materials: p -art I. Reaction parameters, ” Materials Science, Vol. 39, pp. 243-273, 1995. 18. Moore, J. J., and Feng, H. J., “ Combustion Synthesis of Advanced Materials: P -art I. Reaction Parameters, ” Progress in Materials Science, Vol. 39, pp. 243 -273, 1995. 19. Moore, J. J., and Feng, H. J., “ Combustion Synthesis of Advanced Materials: P -art II. Classification, Applications and Modeling, ” Progress in Materials Sci -ence, Vol. 39, pp. 275-316, 1995. 20. Makino, A., “ Fundamental Aspects of the Heterogeneous Flame in the Self-propag -ating High-temperature Synthesis (SHS) Process, ” Progress in Energy and Combus -tion Science, Vol. 27, pp. 1-74, 2001. 21. Locci, A, M., Orru, R., Cao, G., and Munir, Z, A., “ Field-activated pressure-a -ssisted synthesis of NiTi, ” Intermetallics, Vol. 11, pp. 555-571, 2003. 22. Hibino, A., Matsuoka, S., and Kiuchi, M., “ synthesis and sintering of Ni3Al in -termetallic compound by combustion synthesis process, ” Journal of Materials P -rocessing Techology, Vol. 112, pp. 127-135, 2001. 23. Dounand, D, C., Mater. Manufacturing Proc., Vol. 10, pp. 373, 1995. 24. Zhu, P., Li, J, C, M., and Liu, C, T., “ Adiabatic temperature of combustion sy -nthesis of Al-Ni systems, ” Materials Science and Engineering, Vol. A357, pp. 2 -48-257, 1995. 25. William, C., Stangle, W., and Stangle, G, C., J. Mater. Res., Vol. 10, pp. 1763, - 1995. 26. Miura, S., and Liu, C, T., Intermetallics, Vol. 2, pp. 297, 1994. 27. Maslov, V, M., Borovinskaya, I, P., and Merzhanov, A, G., Combust. Explos. Shoc -k Waves, Vol. 12, pp. 631, 1976. 28. Barin, I., Knacke, O., and Kubaschewski, O., “ Thermochemical Properties of Ino -rganic Substances:Supplement, ” Springer-Verlag, New York, pp. 490, 1977. 29. Wang, Weimin., Fu, Zhengyi., and Yuan, Runzhang., J.Wuhan Univ. Technol, Vol. 9, - pp. 10, 1994. 30. Anselmi-Tamburini, U., and Munir, Z, A., J. Appl. Phys., Vol. 66, pp. 5039, 1989. 31. Matsuura, K., Kitamura, T., and Kudoh, M., J. Jpn. Inst. Light Met, Vol. 46, pp. 383, 1996. 32. Itin, Vi., Bratchikov, AD., Dronin, VN., Pribytkov GA, Soviet Physics Journal, V -ol. 24, pp. 1134, 1981. 33. Eslamloo-Grami, M., and Munir, Z., “ Effect of Nitrogen Pressure and Diluent Cont -ent on the Combustion Synthesis of Titanium Nitride, ” Journal of American Cera -mic Society, Vol. 73, No. 5, pp. 2222-2227, 1990. 34. Zhang, S., and Munir, Z, A., “ The Combustion Synthesis of Refractory Nitrides, P -art II The Synthesis of Niobium Nitride, ” Journal of Materials Science, Vol. 2 -6, pp. 3380-3385, 1991. 35. Zhu, Ping., Li, J, C.M., and Liu, C.T., “ Combustion reaction in multilayered nic -kel and Aluminum foils ” Materials Science and Engineering, pp. 532-539, 1997.