An Exprimental Study on Synthesis of Metal Carbonitrides by SHS

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ABSTRACT

An experimental investigation of direct formation of titanium carbonitride Ti(CN), niobium carbonitride Nb(CN), and vanadium carbonitride V(CN) by self-propagating high-temperature synthesis (SHS) was conducted using compacted samples made up of transition metal and carbon powders ignited in gaseous nitrogen. Effects of sample green density, nitrogen pressure (0.274~1.653 MPa), and diluent content on the degree of conversion and flame-front velocity were studied. It was found that SHS processes of all these three kinds of samples were characterized the propagation of the self-sustained flame front, which was followed by afterburning reaction. The combustion process indicated melting in the Ti(CN) system. The pulsating phenomenon was observed in the synthesis of Nb(CN). Combustion wave temperatures measured in this study under different systems were ranged from 1250 to 1750 oC for the formation of Nb(CN), and were approximately between 1350 and 1570 oC in the V(CN) system. For the systems of Nb(CN) and V(CN), after the passage of the combustion front the reaction continues lengthily in an afterburning stage, thus resulting in the nitridation percentage between 53% and 80% that is nearly unaffected by the variation of nitrogen pressure. In the synthesis of Ti(CN), a low degree of nitrogen uptake was obtained for the undiluted samples, primarily due to the excessive melting of titanium during the reaction. Results indicated that the addition of diluent TiN was required in order to achieve the complete conversion. This implies that the formation of carbonitrides was substantially affected by the dilution with product nitride in the powder reactants. Results of X-ray diffraction (XRD) analysis indicated the - viii - existence of unreacted metal in the final products while samples were undiluted. It also found the presence of Ti2N, Nb2N and V2N in the final products of Ti(CN), Nb(CN) and V(CN) systems, respectively. The burned samples with diluent were composed mainly of stoichiometric carbonitrides. Microstructures of synthesized products examined by a scanning electron microscope (SEM) showed the formation of liquid phase in the Ti(CN) system. However, the Nb(CN) and V(CN) samples remained in solid phase during the SHS process.

Keywords : Titanium Carbonitride, Niobium Carbonitride, Vanadium Carbonitride, Afterburning, Pulsating Combustion, Self-propagating High-temperature Synthesis, Flame Front, Diluent

Table of Contents

REFERENCES

[1] W. Lengauer, “ Transition metal carbides, nitrides and carbonitrides, in: R. Riedel (Ed.), ” Handbook of Ceramic Hard Materials, 1, Wiley-VCH, Weinheim, pp. 202-252 (2000).
[2] S. Zhang, “ Material development of titanium carbonitride-based cermets for machining application, ” Key Eng. Mater, 138-140, pp. 521-543 (1998).
[3] S. Bolognini, G. Feusier, D. Mari, T. Viatte, W. Benoit, “ High temperature mechanical behavior of Ti(C,N)-Mo-Co cermets, ” Int. J. Refract. Metals Hard Mater, 16, pp. 257-268 (1998).
[4] P. Ettmayer, H. Kolaska, W. Lengauer, K. Dreyer, “ Ti(C,N) cermets-metall-urgy and properties, ” Int. J. Refract. Metals Hard Mater., 13, pp. 343-351 (1995).
[5] T. Francavilla, S. Wolf, E. Skelton, “ Superconducting properties of reactively sputtered NbCN tjin films, ” IEEE Transactions on Magnetics, 17(1), pp. 569-572 (2000).
[6] M. Ohmer, J. Wollan, J. Ho, “ Improved superconducting properties of multifilamentary niobium carbonitride wire, “ IEEE Transactions on Magnetics, 11(2), pp. 159-162 (1975).
[7] W. Smith, R. Lin, J. Coppola, J. Economy, “ Preparation and properties of multifilament niobium carbonitride superconductor, ” IEEE Transactions on Mangnetics, 11(2), pp. 182-184 (1975).
[8] J. R. Gavaler, M. A. Janocko, C. K. Jones, “ Superconducting Properties of Niobum Carbonitride Thin Films, ” J. App. Phy., 19(8), pp. 305-307 (1971).
[9] A. G. Merzhanov, “ Solid Flames : Discoveries, Concepts, and Horizons of Cognition, ” Comb. Sci. Technol., 98, pp. 307-336 (1994).
[10] J. J. Moore, H. J. Feng, “ Combustion Syntheis of Advanced Materials : Part I. Reaction Parameters, ” Prog. Mater. Sci., 39, pp. 243-273 (1995).
[11] J. J. Moore, H. J. Feng, “ Combustion Syntheris of Advanced Materials : Part Π . Classification, Applications and Modeling, ” Prog. Mater. Sci., 39, pp. 275-316 (1995).
[12] A. Makino, “ Fundamental Aspects of the Heterogeneous Flame in the Self-propagating High-temperature Synthesis (SHS) Process, ” Progr. Energy Combust. Sci., 27, pp. 1-74 (2001).
[13] H. Kudo, O. Odawara, “ Characteristics of Self-Propagating Reaction in TiN Combustion Synthesis, ” J. Mater. Sci., 24, pp. 4030-4033 (1989).
[14] S. Kang, “ Some issues in Ti(CN)-WC-TaC cermets, ” Mater. Sci. Eng., A209, pp. 306-312 (1996).
[15] A. Bellosi, V. Medri, F. Monteverde, “ Processing and properties of Ti(C,N)-WC-based materials, ” J. Am. Ceram. Soc., 84(11), pp. 2669-2676 (2001).
[16] F. Monteverde, V. Medri, A. Bellosi, “ Microstructure of hot-pressed Ti(C,N)-based cermets, ” J. Am. Ceram. Soc., 22, pp. 2587-2593 (2002).
[17] A. Jha, S.J. Yoon, “ Formation of titanium carbonitride phases via the reducetion of TiO2 with carbon in the presence of nitrogen, ” J. Mater. Sci., 34(2), pp. 307-322 (1999).
[18] J. Xiang, Z. Xie, Y. Huang, H. Xiao, “ Synthesis of Ti(C,N) ultrafine powders by carbothermal reduction of TiO2 derived form solgel process, ” J. Eur. Ceram. Soc., 20, pp. 933-938 (2000).
[19] L. M. Berger, W. Gruner, E. Langholf, S. Stolle, “ On the mechanism of carbothermal reduction process of TiO2 and ZrO2, ” Int. J. Refract. Metals Hard Mater., 17, pp. 235-243(1999).
[20] H. Pastor, “ Titanium carbonitride-based hard alloys for cutting tools, ” Mater. Sci. Eng., A105/106, pp. 401-409 (1988).
[21] L. Ma, H. Bian, G.. Liu, “ Influence of CH4/N2 ratio on microstructure and mechanical properties of PCVD- Ti(CxN1-x) coating, ” Int. J. Refract. Metals Hard Mater, 13, pp. 369-374 (1995).
[22] P. Huber, D. Manova, S. B. Mandl, ” Rauschenbach, Formation of TiN, TiC and TiCN by metal plasma immersion ion implantation and deposition, ” Surf. Coatings Technol., 174-175, pp. 1243-1247 (2003).
[23] J. B. Holt, Z. A. Munir, “ Combustion synthesis of titanium carbide : theory and experiment, ” J. Mater. Sci., 21, pp. 251-259 (1986).
[24] M. Eslamloo-Grami, Z. Munir, “ Effect of Porosity on the Combustion Synthesis of Titanium Nitride, ” J. Am. Ceram. Soc., 73(5), pp. 1235-1239 (1990).
[25] M. Eslamloo-Grami, Z.A. Munir, “ Effect of Nitrogen Pressure and Diluent Content on the Combustion Synthesis of Titanium Nitride, ” J. Am. Ceram. Soc., 73, No. 5 , pp. 2222-2227 (1990).
[26] C. C. Agrafiotis, J. A. Puszynski and V. Hlavacek, “ Experimental Study on the Synthesis of Titanium and Tantalum Nitrides in the Self-Propagation Regime ” Comb. Sci. Technol., Vol. 76, pp. 187-218 (1991).
[27] M. Eslamloo-Grami, Z.A. Munir, “ The mechanism of combustion synthesis of titanium carbonitride, ” J. Mater. Res., 9(2), pp. 431-435 (1994).
[28] Ranjan, G.S. Upadhyaya, “ Effect of copper and VCN additions on sintering of low alloy steel, ” Mater. Design, 22, pp. 359-367 (2001).
[29] S. Abisset, F. Maury, L. Pelletier, J. M. Carretas, A. Pires De Matos, “ Depot Chimique En Phase Vapeur A Basse Temperature De Revetements Dans Le Systeme [30] V-C-N A Partir De Bis(Arene) Vanadium. ” Ann. Chim. Sci. Mat, 23, pp. 695-706 (1998).