Thermal Analysis of Ni-Ti-X Alloys Prepared by Self-propagating High-temperature Synthesis

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In this work, the influence of alloying elements on the transformation temperatures and temperatures of formation of NiTi intermetallic phases were investigated. NiTi alloys are characterized by shape memory effect, pseudoplasticity and superelasticity. These properties strongly depend on the alloy composition in binary Ni-Ti and ternary Ni-Ti-X. Because these alloys are used in various branches of industry, such as aerospace, engineering or medicine, the addition of ternary element can influence their application significantly. Especially, the presence of Ti_2Ni and Ni_3Ti in the NiTi matrix may cause a degradation of the shape memory behaviour and mechanical properties. For this reason, we observed the formation of intermetallics by differential thermal analysis (DTA). Differential scanning calorimetry (DSC) experiments were performed to monitor the evolution of the transformation characteristics. We report new results, which show the strong dependence of the transformation temperatures between austenite and martensite on the alloy composition, and how the alloying elements (Mg, C, Zr) influence the formation of Ni-Ti phases.

Keywords: Ni-Ti-X alloys, DTA, DSC

Acknowledgement

This research was financially supported by Czech Science Foundation, project No. 14-03044S and by MSMT No 20-SVV/2016.

References

[1] OTSUKA, K., REN, X. (2005). Physical metallurgy of Ti-Ni based shape memory alloys. In: *Progress in Materials Science*, Vol. 50, No. 5, pp. 511-678. Elsevier. Netherlands.

[2] NEMAT-NASSER, S., CHOI, J.Y. (2005). Strain rate dependence of deformation mechanisms in a Ni-Ti-Cr shape-memory alloy. In: *Acta Materialia*, Vol. 53, No. 2, pp. 449-454. Elsevier. Netherlands.

[3] VOJTĚCH, D., KUBÁSEK, J., NOVÁK, P. (2013). Corrosion properties of the superelastic shape memory Ni-Ti alloy for medical implants. In: *Manufacturing Technology*, Vol. 13, No. 3, pp. 409-414. UJEP. Czech Republic.

[4] BASU, R., ESKANDARI, M., UPADHAYAY, L., MOHTADI-BONAB, M.A., SZPUNAR, J.A. (2015). A systematic investigation on the role of microstructure on phase transformation behavior in Ni-Ti-Fe shape memory alloys. In: *Journal Alloys and Compounds*, Vol. 645, pp. 213-222. Elsevier. Netherlands.

[5] FRENZEL, J., WIECZOREK, A., OPAHLE, I., MAAß, B., DRAUTZ, R., EGGELER, G. (2015). On the effect of alloy composition on martensite start temperatures and latent heats in Ni-Ti-based shape memory alloys. In: *Acta Materialia*, Vol. 90, pp. 213-231. Elsevier. Netherlands.

[6] NOVÁK, P., MEJZLÍKOVÁ, L., MICHALCOVÁ A., ČAPEK J., BERAN P., VOJTĚCH D. (2013). Effect of SHS conditions on microstructure of NiTi shape memory alloy. In: *Intermetallics*, Vol. 42, pp. 85 – 91. Elsevier. Netherlands.

[7] RESNINA, N., BELAYEV, S., VORONKOV, A. (2013). Influence of chemical composition and pre-heating temperature on the structure and martensitic transformation in porous TiNi-based shape memory alloys, produced by self-propagating high-temperature synthesis. In: *Intermetallics*, Vol. 32, pp. 81-89. Elsevier. Netherlands.

[8] KIM, Y., JEON, K. (2010) Shape memory characteristics of powder metallurgy processed $Ti_{50}Ni_{50}$ alloy. In: *Physics Procedia*, Vol. 10, pp. 17-21. Elsevier. Netherlands.

[9] NAYAN, N., SAIKRISHNA, C.N., RAMAIAH, K.V., BHAUMIK, S.K., NAIR, K.S., MITTAL, M.C. (2007). Vacuum induction melting of NiTi shape memory alloys in graphite crucible. In: *Materials Science and Engineering: A*, Vol. 465, No. 1-2, pp. 44-48. Elsevier. Netherlands.

[10] SADRNEZHAD, S.K, RAZ, S.B. (2005). Interaction between refractory crucible materials and the melted NiTi shape-memory alloy. In: *Metallurgical and Materials Transactions B*, Vol. 36, No. 3, pp. 395-403. Springer. Germany.

[11] WHITNEY, M., CORBIN, S. F., GORBET, R. B. (2008). Investigation of the mechanism of reactive sintering and combustion synthesis of NiTi using differential scanning calorimetry and microstructural analysis. In: *Acta Materialia*, Vol. 56, No. 3,pp. 559 – 570. Elsevier. Netherlands.

[12] NOVÁK, P., MICHALCOVÁ, A., MAREK, I., VODĚROVÁ, M., VOJTĚCH, D. (2012) Possibilities of the observation of chemical reactions during the preparation of intermetallics by reactive sintering. In: *Manufacturing Technology*, Vol. 12. No. 13, pp. 197-201. UJEP. Czech Republic.

[13] NOVÁK, P., POKORNÝ, P., VOJTĚCH, V., KNAISLOVÁ, A., ŠKOLÁKOVÁ, A., ČAPEK, J., KARLÍK, M., KOPEČEK, J. (2015). Formation of Ni – Ti intermetallics during reactive sintering at 500 – 650 °C. In: *Materials Chemistry and Physics*, Vol. 155, pp. 113 – 121. Elsevier. Netherlands.

[14] BISWAS, A. (2005). Porous NiTi by thermal explosion mode of SHS: processing, mechanism and generation of single phase microstructure. In: *Acta Materialia*, Vol. 53, pp. 1415 – 1425. Elsevier. Netherlands.

[15] NOVÁK, P., MICHALCOVÁ, A., ŠKOLÁKOVÁ, A., PRŮŠA, F., KŘÍŽ, J., MAREK, I., KUBATÍK, T. F., KARLÍK, M., HAUŠILD, P., KOPEČEK, J. (2015). Effect of heating rate on the formation of intermetallics during SHS process. In: *Acta Physica Polonica A*, Vol. 128, No. 4, pp. 561 – 564. Instytut Fizyki. Poland.

[16] NOVÁK, P., ŠKOLÁKOVÁ, A., VOJTĚCH, V., KNAISLOVÁ, A., POKORNÝ, P., MORAVEC, H., KOPEČEK, J., KARLÍK, M., KUBATÍK, T. F. (2014). Applications of microscopy and x-ray diffraction in optimization of the production of NiTi alloy by powder metallurgy. In: *Manufacturing Technology*. Vol. 14, No. 3, pp. 387 – 392. UJP. Czech Republic.

[17] SALVETR, P., NOVÁK, P., MORAVEC, H. (2015). Ni-Ti alloys produced by powder metallurgy. In: *Manufacturing technology*, Vol. 15, No. 4, pp. 689 – 694. UJP. Czech Republic.

[18] NEVITT, M. V. (1960). Stabilization of certain amount Ti_2Ni-type phases by oxygen. In: *Transactions of the Metallurgical Society of AIME*, Vol. 218, pp. 327 – 331. American Institute of Mining, Metallurgical and Petroleum Engineers. USA.

Paper number: M2016212