J Mater Sci (2018) 53:13432–13441

Mechanochemical Synthesis

# Mechanical activation of pre-alloyed $NiTi_2$ and elemental Ni for the synthesis of NiTi alloys

X. Zhao[1], F. Neves[2,*], J. B. Correia[2], K. Liu[1], F. M. Braz Fernades[3], V. Koledov[4], S. von Gratowski[4], S. Xu[5], and J. Huang[1]

[1] School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing 100083, China

[2] Unidade de Energias Renováveis e Integração de Sistemas, Laboratório Nacional de Energia e Geologia, Estrada do Paço do Lumiar 22, 1649-038 Lisbon, Portugal

[3] CENIMAT/i3N, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Lisbon, Portugal

[4] Kotelnikov Institute of Radio Engineering and Electronics of the Russian Academy of Sciences, Moscow, Russia 125009

[5] Departament de Física, Universitat de les Illes Balears, Cra Valldemossa, km. 7.5, Palma de Mallorca, Spain

**Received:** 14 February 2018
**Accepted:** 8 June 2018
**Published online:** 13 June 2018



## ABSTRACT

This work reports on an efficient powder metallurgy method for the synthesis of NiTi alloys, involving mechanical activation of pre-alloyed $NiTi_2$ and elemental Ni powders ($NiTi_2$–Ni) followed by a press-and-sinter step. The idea is to take advantage of the brittle nature of $NiTi_2$ to promote a better efficiency of the mechanical activation process. The conventional mechanical activation route using elemental Ti and Ni powders (Ti–Ni) was also used for comparative purposes. Starting with ($NiTi_2$–Ni) powder mixtures resulted in the formation of a predominant amorphous structure after mechanical activation at 300 rpm for 2 h. A sintered specimen consisting mainly of NiTi phase was obtained after vacuum sintering at 1050 °C for 0.5 h. The produced NiTi phase exhibited the martensitic transformation behavior. Using elemental Ti powders instead of pre-alloyed $NiTi_2$ powders, the structural homogenization of the synthesized NiTi alloys was delayed. Performing the mechanical activation at 300 rpm for the (Ti–Ni) powder mixtures gave rise to the formation of composite particles consisting in dense areas of alternate fine layers of Ni and Ti. However, no significant structural modification was observed even after 16 h of mechanical activation. Only after vacuum sintering at 1050 °C for 6 h, the NiTi phase was observed to be the predominant phase. The higher reactivity of the mechanically activated ($NiTi_2$–Ni) powder particles can explain the different sintering behavior of those powders compared with the mechanically activated (Ti–Ni) powders. It is demonstrated that this innovative approach allows an effective time reduction in the mechanical activation and of the vacuum sintering step.

Address correspondence to E-mail: filipe.neves@lneg.pt



https://doi.org/10.1007/s10853-018-2560-5