

## HRTEM studies of NiNbZr + Ag amorphous - nanocrystalline composites

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### Abstract

Amorphous powder of composition corresponding to Ni<sub>60</sub>Ti<sub>20</sub>Zr<sub>20</sub> (in at.%) was obtained by ball milling in a high energy mills starting from pure elements. Formation of the amorphous structure was observed already after 10 hours of milling, while complete amorphization occurred after 40 hours. The microhardness of powders increased from about 30 HV for pure elements up to 400 HV after 40 hours of milling. Transmission electron microscopy allowed to identify nanocrystalline inclusions of intermetallic phases of size 2-5 nm. Uniaxial hot pressing was performed at temperature below the crystallization  $T_x$  it is 510°C and pressure of 600 MPa, Mixed amorphous powders and nanocrystalline silver powders allowed to obtain composite, where amorphous phase microhardness is above 1000 HV and 400 HV of nanocrystalline silver. The nano-silver powder was prepared also by ball milling and the resulting grain size was measured using TEM at 20-50 nm. It contain frequent dislocations and stacking faults. Compression strength of the composite measured using testing Instron machine of a high stiffness is equal to 700 MPa and 3 % of plastic strain; it is much better plasticity than for bulk amorphous materials. Both phases have similar values of Young's modulus close to 150 GPa. Microstructure studies show low porosity of composites, less than 1%, uniform distribution of the silver phase and a transition zone between both components, about 150 nm thick, where diffusion of nickel, niobium and zirconium was observed toward silver. High resolution TEM allowed to identify structure of nanocrystalline inclusions in the amorphous matrix after hot pressing as either Ni<sub>3</sub>Zr or Ni<sub>17</sub>Nb<sub>3</sub>. Identification was performed basing on measurements of angles and interatomic distances using inverse Fourier transformed images with upgraded contrast using Gatan program. HRTEM and HRSTEM results allowed to explain behaviour of composites under compression strain conditions.

**Key words:** ball milling, NiNbZr amorphous; vacuum hot pressing, amorphous-nanocrystalline composites, TEM