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Dr. Jannis Lemke

Managing Director

BioActiveMetals S.r.l.

Ni-Ti-Hf-Nb SMAs for High-Temperature Actuation

In the field of high-temperature shape memory alloys (HTSMA) for actuators operating above 100 °C, alloy development has not yet fully met industrial requirements. The most promising and extensively studied system is Ni-Ti-Hf. However, its development remains far from widespread commercialization, primarily due to the limited processability of these alloys. More recently, the addition of Nb to the ternary Ni-Ti-Hf system has been shown to significantly improve the workability without compromising functional properties. The increase in ductility enables cold drawing of the alloys, facilitating the production of thin wires suitable for actuation at temperatures beyond the working range of conventional NiTi.
In this work, further advancements in the quaternary Ni-Ti-Hf-Nb system are presented. Alloys with varying compositions were prepared by vacuum arc remelting (VAR) for screening and vacuum induction melting (VIM) for simulating industrial processes, followed by hot and cold deformation. The ingots were subjected to various heat treatment conditions, including homogenization, solution treatment, and aging. The samples were characterized using differential scanning calorimetry (DSC), X-ray diffraction (XRD), scanning electron microscopy (SEM), and by mechanical testing methods. The influence of composition on both functional properties and workability is discussed. Finally, case study results on thin wires are presented to demonstrate the potential and limitations of this class of HTSMA materials, along with an assessment of their feasibility for industrial applications.

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