AL-09AO61A

High Temperature Shape Memory Alloys for Improved Efficiency in Aeronautic Turbomachinery

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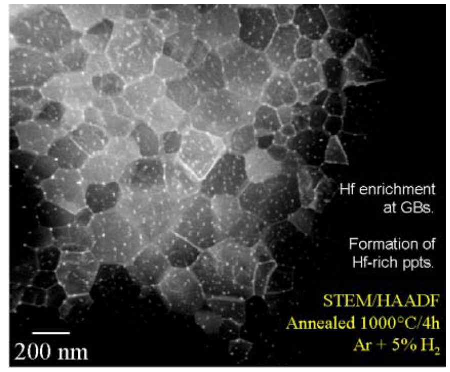
Start Date: September 12, 2009



STEM-HAADF image of a high temperature NiAl-Hf intermetallic showing Hf segregation to grain boundaries and the formation of Hf richprecipitates.

Research: Shape memory alloys (SMA) are a unique class of materials which can recover deformation induced at some lower temperature by heating through a given transformation temperature. This deformation recovery can act as a source of work by having the material recover against an applied load and act as compact, low profile, solid-state actuator. To date, the exploitation of SMA is limited because the recovery phenomenon occurs at low temperatures (<100 deg. C). By increasing the transformation temperature, SMA would have immediate usage in several higher temperature aerospace applications. This research program will facilitate the development of a new class of NiTi high temperature SMA. By macro-alloying NiTi with Pt, Pd, Zr and Au, the transformation temperature has been shown to increase upwards of 1000 deg. C for particular elements and amounts. This macroalloying facilitates the precipitation of several metastable nanometer-sized secondary phases. The influence of these macroalloy elements and the thermomechanical fabrication process of the alloys on the elevated temperature shape memory effect are not well understood. To fully exploit these materials and optimize the processing-properties-microstructure relationships, a careful microscopy-based study is required. The team will utilize atom probe tomography for atomic scale partitioning quantification, advanced electron microscopy techniques to determine the crystallographic and deformation stability of these alloys, and Orientation Imaging Microscopy for global grain and phase identification as they relate to alloy chemistry and thermomechanical process history. The program provides for a concentrated effort to link nearly six-orders of magnitude length scales to elucidate the behavior and materials development of these alloys. The results of which will bring to fruition optimal materials engineering necessary for the development and application of high temperature SMA in aerospace and related technologies.

Potential Impact: The rather limited microstructural characterization of HTSMAs provides this program an optimal opportunity to have a large impact on the development of macroalloyed HTSMAs. This will be accomplished by providing an enhanced understanding of microstructural development and evolution, and improved processing methods for these materials. The correlation of atomistic-level partitioning related to the sequence of phase transformations in secondary precipitation events in near stoichiometric and ternary NiTi alloys will provide desperately needed information required to optimize the processing-properties-microstructure triad and increase the fidelity of modeling efforts at NASA-GRC. The atom probe efforts will directly be feed into TEM defect analysis for rationalizing how macroalloying alters the deformation and crystallographic behavior. Finally, the linkage to OIM, in particular the 3D serial sectioning initiative, provides the global understanding of how these alloys' microstructures evolve. The collective effort between UA and NASA-GRC will help bring to maturation this emerging class of materials for advanced actuator applications in the aerospace, automotive and energy exploration industries.

http://www.uah.edu/ASGC/EPSCoR.php