Magnetic Field-Induced Phase Transformation in NiMnGa and NiMnCoIn Shape Memory Alloys

Ibrahim Karaman
Department of Mechanical Engineering, Texas A&M University, College Station, TX 77845, U.S.A.

Magnetic shape memory alloys (MSMAs) have the ability to exhibit one order of magnitude higher magnetic field induced strain (MFIS) than magnetostrictive materials and few orders of magnitude faster dynamic response than conventional SMAs. Field-induced martensite variant reorientation (MVR) is the main governing mechanism for MFIS which results in low actuation stress levels in NiMnGa alloys. We have recently shown that stress-assisted magnetic field-induced phase transformation (FIPT) is possible in NiMnGa alloys and it can be reversible under low field magnitudes (<1 Tesla) depending on the magnitudes of assisting stress, stress hysteresis, magnetocrystalline anisotropy and saturation magnetization. Utilizing FIPT instead of MVR, more than one order of magnitude increase in stress levels is achieved in NiMnGa under which reversible MFIS can be obtained. Recently, a new family of MSMAs (NiMnIn, NiMnCoIn, NiMnSn) are discovered where FIPT can be triggered from an anti-ferromagnetic martensite to ferromagnetic austenite due to the large difference in their saturation magnetizations (Zeeman Energy). Such mechanism results in large actuation stress and work output, however, the requirement for large magnetic fields (~4T) restricts potential applications. We have conducted an extensive experimental program on NiMnGa and NiMnCoIn single crystals in quest for identifying physical and microstructural parameters critical for FIPT phenomena and how these parameters can be modified to reduce the field requirement. It will be shown that NiMnCoIn single crystals can exhibit actuation stress levels ranging from 20 to 120 MPa with MFIS levels in between 1 to 6%. Certain physical parameters such as orientation dependence of transformation strain and stress and temperature hysteresis are identified as critical in dictating the field requirement in addition to Zeeman energy. We will demonstrate how these parameters can possibly be engineered to decrease the required field magnitude for phase transformation. Possible future directions for research on MSMAs will be presented.

Ibrahim Karaman
VITA

Ibrahim Karaman received his Ph.D. from University of Illinois at Urbana-Champaign in 2000. He joined the faculty of Department of Mechanical Engineering at Texas A&M University in 2000. Currently, he is an Associate Professor in the same department. He is also a member of the Faculty of Materials Science and Engineering Graduate Program. His main research interests are processing-microstructure-mechanical/functional property relationships in metallic materials including 1) ultrafine and nanocrystalline materials, and 2) conventional, high temperature and magnetic shape memory alloys; micro-mechanical constitutive modeling of crystal plasticity; twinning and martensitic phase transformation in metallic materials. Dr. Karaman received several national and international awards including the NSF CAREER Award in 2002, ONR Young Investigator Award in 2005, The Robert Lansing Hardy Award from The Minerals, Metals and Materials Society in 2005, and an Honorable Mention for the Early Career Faculty Fellow Award from The Minerals, Metals and Materials Society in 2007. The Robert Lansing Hardy Award recognizes "outstanding promise for a successful career in the broad field of metallurgy by a metallurgist under the age of 35" and one award is given per year. He is an author or co-author on 80 refereed journal articles.