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Effects of composition differences on the performance and properties of NiMnGa magnetic shape memory alloys

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Magnetic shape memory alloys are promising candidates as sensor and actuator materials with high actuation frequency, energy density and strain. Magnetic shape memory effect allows even 50 times greater strains than in previous magnetically controlled materials (magnetostrictives). The large strains occur due to the magnetic field induced reorientation via twin boundary motion driven by mechanical stresses and/or magnetic fields. NiMnGa alloys, with their ability to develop large strokes under precise and rapid control, offer a great potential as magnetic shape memory materials. In addition to the magnetic shape memory phenomenon, NiMnGa alloys have shown conventional shape memory effect, traditional and magnetic-field-assisted superelasticity, magnetocaloric, and special transport properties. One of the major problems with the NiMnGa alloys is that even a slight change in the alloy's composition causes significant changes in the martensitic transformation temperature. Magnetic shape memory effect is only possible in the martensitic region, so those shifts may result in a no-strain situation. Also, brittleness is a major obstacle for the applications of NiMnGa alloys. These two factors make it imperative to analyze the effect of composition on the transformation temperatures and investigate the microstructures of various alloys. In this study, effect of alloy composition and heat treatment on the microstructure, local composition, and thermal and dilatometric properties of Ni_2MnGa alloys were investigated. The results of the characterization tests of various NiMnGa alloy crystals, with and without post-crystal growth heat treatment, were analyzed by differential scanning calorimetry, dilatometry, optical metallography and scanning electron microscopy. In addition, the study includes results about the effect of composition on the martensite transformation temperature. The results showed that as solidified, off-stoichiometric, alloys had three distinct microstructural features—a Heusler phase, a Mn-rich phase and a eutectic or eutectoid region. Various heat treatment procedures were applied to successfully remove the last phase. Heat treatment was also essential for the production of a distinct martensite transformation in differential scanning calorimetry and dilatometry traces and a magnetic shape memory effect. Composition variations from Bridgman growth were large enough that a shift in martensite start temperature might occur in some parts of the alloy, based on literature data for the dependence of martensite start temperature on composition.

Biography

Gursev Pirge is Associate Professor of Mechanical Engineering, Department of Aerospace Engineering at the Turkish Air Force Academy, where he teaches courses in materials science and mechanical properties of materials. He has published peer-reviewed papers and technical reports.

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