Magnetocaloric properties of Ni-Mn-Sn Heusler alloys

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ABSTRACT

Ni-Mn-Sn off-stoichiometric intermetallic compounds are a subject of intensive research because they show a magnetic field induced reverse martensitic transformation [i,ii]. For the latter they are termed metamagnetic shape memory alloys (MSMA). Along with the magnetic field induced structural transformation these alloys also display a large negative magnetoresistance, occurring around the structural transition temperature (MT), and an inverse magnetocaloric effect. These effects hold promise for magnetic refrigeration and other multifunctional applications [iii,iv]. It has been established that the excess of Mn atoms in off-stoichimoteric alloys brings about a significant change in the different ferromagnetic exchange interactions between the martensite and the parent austenite phase. This then results in a significant contribution to the Zeeman energy $(\mu_0 \Delta M \cdot H)$ across the martensitic transition. The enhanced Zeeman energy is the driving force for the metamagnetic transformation [v,vi]. It has been reported that the austenite phase in the Ni-Mn-Sn systems is a cubic $L2_1$ structure with the Ni atoms located at the corner of the cube, whereas Mn and Sn atoms locate alternating at the body center sites. In contrast the martensite phase is composition sensitive and can feature 10M, 14M, $L1_0$ or 4O structure [vii]. The MT temperatures may be tuned inter alia by changing the valence electron concentration (e/a) or by reducing the unit cell volume [viii,ix]. Simultaneously the T_C^M of martensite is also prone to change with varying composition. The magnetic properties of this phase are strongly dependant on the interatomic Mn-Mn distances, which may change with changing composition [x,xi]. On the other hand the T_C^A shows only slight compositional dependence. In addition multi step martensitic and magnetic transformations has been observed in these alloys. They encompass composition induced first order intermartensitic transitions among different crystallographic variations of martensite and a temperature dependant unique sequence of magnetic states. These entail the material being in a ferromagnetic state at low temperatures, than paramagnetic at intermediate temperatures and then again ferromagnetic upon continued heating until another paramagnetic state appears at elevated temperatures. The smaller than austenite saturation magnetization of the lower temperature martensitic phase is ascribed to the antiferromagnetic coupling of the excess Mn atoms [xii,xiii].

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