Experimental study of the thermal behavior and magneto-electric response of $Ni_{45}Co_5Mn_{36.7}In_{13.3-x}Ge_x$ melt-spun ribbons

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The Heusler-type system $Ni_{45}Co_5Mn_{36.7}In_{13.3-x}Ge_x$ with x = 0, 1, 2, 3 (at. %) is studied by thermogravimetric method, under small DC applied magnetic field (H ~ 2 Oe), and magneto-capacitance, magneto-impedance and Hall effect measurements. The thermogravimetric study indicates the exchange interaction weakens with increasing Ge content. At low and moderate frequencies ($500 \leq f \leq 10$ MHz), our magneto-capacitance and magneto-impedance results support, respectively, a ferro-electric behavior and a longitudinal giant magneto-impedance effect (L-GMI) with a moderate change of the impedance up to around 40% relative. The Hall effect curve exhibits a quasi-linear dependence on the magnetic field.

Keywords: Heusler alloys; thermal behaviour; magneto-electric behaviour.

1. Introduction

The Heuler-type Ni-Mn-(In, Sn, Sb) metamagnetic shape memory alloys, *MetaMSMAs*, with martensitic transformation have high potential to be integrated to magnetic solid-state refrigeration technology based on the magneto-caloric effect, *MCE* [1]. It is the main purpose of this work to explore the effect of Ge substitution for In on the thermal behavior and magneto-electric response of the Heuler type alloy ribbons $Ni_{45}Co_5Mn_{36.7}In_{13.3-x}Ge_x$ which were labeled as $In_{13}Ge_0$, $In_{12}Ge_1$, $In_{11}Ge_2$, and $In_{10}Ge_3$ for x = 0, 1, 2, 3, respectively. These physical characteristics are still largely unexplored. The thermal behavior was studied using a thermogravimetry analyzer (TGA Q500 TA Instruments). The magneto-capacitance and magneto-impedance experiments were carried out at room temperature in the presence of a *dc* magnetic field, H_{dc}, using a small coil as described by Wang et. al., in [2]. The Hall effect measurements were carried out in the *dc* field range $-10 < H < 10$ kOe for several *dc* electrical currents applied to the samples, using a homemade Hall effect system.

2. Results and discussion

The Curie temperature values in the austenite phase of $In_{13}Ge_0$, $In_{12}Ge_1$, $In_{11}Ge_2$, and $In_{10}Ge_3$ are (111.6 ± 0.4 °C; 67.0 ± 0.3; 66.5 ± 0.4 °C and; 62.4 ± 0.4 °C), respectively. This result indicates that the exchange interaction weakens with increasing Ge content. Fig. 1 reports magneto-capacitance (top row) and Hall effect (bottom row) data, respectively, for the $In_{13}Ge_0$ sample. The fact that the magneto-capacitance response assumes negative values is suggestive of a ferro-electric behavior. Furthermore, the magneto-capacitance curve exhibits a single-peak (SP) behavior followed of a hysteretic behavior reflected by two peaks (see Fig. 1). The samples exhibit a L-GMI effect with a moderate change of the impedance up to around 40% relative, and L-GMI single-peak (SP) behavior. The Hall effect curve shows a quasi-linear dependence on the magnetic field in the field range of the present experiments, as seen in Fig. 1 (bottom row). Furthermore, the positive dependence of the Hall effect with the magnetic field indicates that this sample deviate from the nearly free electron model prediction of simple metals that it should always be negative. A similar behavior was observed in the other samples.

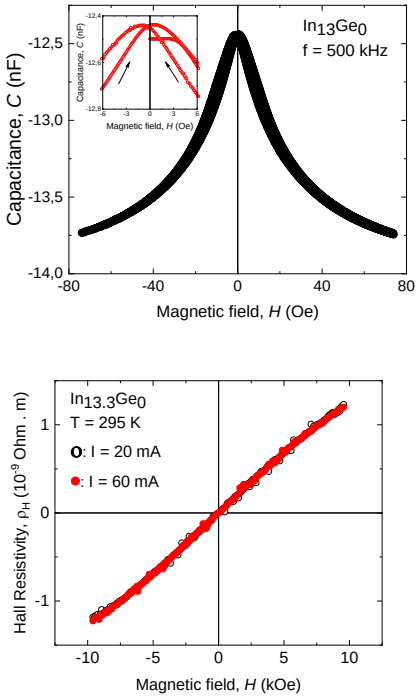

Figure 1: Top row: magneto-capacitance *vs.* H response measured on $In_{13}Ge_0$. Inset shows in detail the emergence of single-peak (SP) behavior followed of some hysteretic behavior reflected by two peaks in the magneto-capacitance response.
Bottom row: Hall effect curve for DC currents, I_{DC} = 20 and 60 mA, and a T = 295 for the $In_{13}Ge_0$ sample.

References

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