Magnetic properties of Eu-Codoped $Sn_{1-x}Cr_xTe$ crystals: the role of magnetic inhomogeneities

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Chromium doped IV-VI diluted magnetic semiconductors attracted a large attention in the last few years due to the observations of carrier mediated ferromagnetism with the Curie temperature T_C as high as 180 K in $Ge_{0.94}Cr_{0.06}Te$ [1]. Addition of rare earth ions at small quantities is expected to improve the magnetic properties of IV-VI materials. SnTe shows interesting perspectives for understanding the magnetism of both Cr and Eu ions in IV-VI semiconductor matrix.

The main aim of our work was to study magnetic and transport properties of bulk $Sn_{1-x-y}Cr_xEu_yTe$ mixed crystals with $0.006 \leq x \leq 0.025$ and $0.01 \leq y \leq 0.02$ grown using a modified Bridgman method. The structural characterization of the samples indicated the presence of only a single NaCl phase related to a solid solution of Cr and Eu in SnTe. All our samples show p-type conductivity with high carrier concentration $p > 10^{20}$ cm^{-3} and mobility $\mu > 70$ cm^2/(V·s). Metallic conductivity of the samples is observed together with a small, but visible decrease of p with increasing temperature, T. The physical mechanisms of this decrease will be discussed as well as the scattering mechanisms responsible for the decrease of μ with increasing temperature.

The ac magnetic susceptibility as a function of temperature, $\chi_{ac}(T)$, measured in the $Sn_{1-x-y}Cr_xEu_yTe$ crystals, indicated the presence of a well defined magnetic transition. The transition temperature increased as a function of Cr and Eu content, x and y, from about 120 K to 150 K. The frequency shift of the peak in the $\chi_{ac}(T)$ dependence indicated the superparamagnetic nature of the magnetic order. The high field magnetization curves, $M(B)$, were different in the samples containing Cr only (Brillouin like) and the samples with both Cr and Eu (nonsaturating curves), indicating an increasing magnetic disorder with addition of Eu to the alloy. Moreover, the magnetization measurements showed a presence of a well defined hysteresis loop with a coercive field of about 0.3 T, indicating that the magnetic state observed in this alloy is most probably a cluster-glass state. The scanning electron microscope coupled with energy dispersive x-ray spectrometer allowed us to detect the presence of CrTe nano-bars in our samples. CrTe-related magnetic clusters are responsible for the observed high temperature cluster-glass state in our samples.

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[1] Y. Fukuma et al., *Appl. Phys. Lett.* **91**, 092501 (2007).