Magnetic and structural studies of GeMnSnTe epitaxial layers

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GeMnTe is a multiferroic semiconductor, in which, as demonstrated with ferromagnetic resonance (FMR), ferroelectric and ferromagnetic orders are coupled to each other, leading to ferroelectric domain switching under applied magnetic field [1]. However, since the ferroelectric Curie temperature in GeMnTe turned out to be higher than the ferromagnetic one even up to Mn content of 50%, ferroelectric (rhombohedral) to paraelectric (cubic) phase transition in this system can not be investigated with use of the FMR technique. In order to lower ferroelectric T_C GeMnTe layers co-doped with tin were grown.

The 1µm thick $Ge_{1-x-y}Mn_xSn_yTe$ layers investigated in the present study were grown by MBE on (111) BaF_2 substrates, with Mn content x ranging from 10 to 30% and Sn content y ranging from 2 to 5%. The layers were characterized with use of X-ray diffraction, electron microscopy, and SQUID magnetometry. The magnetic anisotropy was studied with the FMR technique. All the layers were found to be ferromagnetic at low temperatures and rhombohedral, with the distortion axis perpendicular to the layer surface. Only in the case of the highest Sn and Mn content the rhombohedral axis was found to be tilted from the substrate normal.

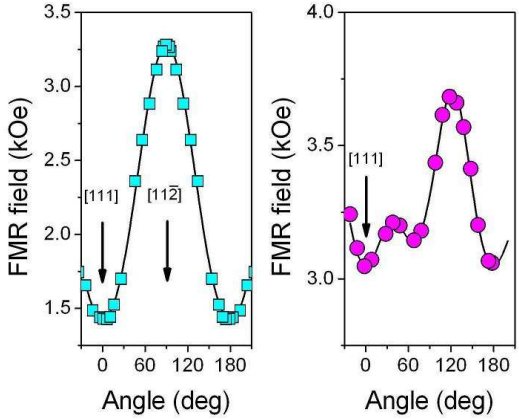

Fig. 1. FMR peak positions in $Ge_{0.85}Mn_{0.15}Te$ (left) and $Ge_{0.88}Mn_{0.1}Sn_{0.02}Te$ (right) layers vs. orientation of the applied magnetic field, at 3 and 10 K, respectively. The angle is measured from the [111] direction (c-axis) perpendicular to the layers.

As shown in Fig. 1 already the addition of 2% Sn changes considerably the magnetocrystalline anisotropy, from purely uniaxial in GeMnTe (with 15% Mn) to distorted cubic in GeMnSnTe (10% Mn). The contribution of cubic anisotropy allows distinction of ferroelectric domains with rotated orientations of crystalographic axes. In contrast to GeMnTe, however, where two such domains were observed for $x_{Mn} \geq 20\%$, in tin codoped layers only one ferroelectric domain is detected up to Mn concentration of 27%. This indicates that domain switching in GeMnTe is probably related to magneto-elastic interactions, which are suppressed in the presence of tin co-doping.

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[1] H. Przybylińska, G. Springholz, R.T. Lechner, M. Hassan, M. Wegscheider, W. Jantsch, and G. Bauer, *Phys.Rev. Lett.* 112, 047202 (2014).