Quantitative Studies of Magnetic Anisotropy in Insulating Dilute Ferromagnet (Ga,Mn)N

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The recent technological and characterization efforts [1,2] have shown a great potential of (Ga,Mn)N to reach the status of the model (dilute) ferromagnetic insulator. These prospects have increased considerably after very recent realization that in (Ga,Mn)N two fields of research developed so far independently: piezoelectricity of wurtzite semiconductors and electrical control of magnetization in hybrid and composite magnetic structures can be successfully combined [3]. It is therefore timely and important to assess the magnetic anisotropy of (Ga,Mn)N in the ferromagnetic (FM) state which is realized in this insulating compound owing to the superexchange mechanism [2].

To this end a set of $Ga_{1-x}Mn_xN$ layers with $1 < x < 10\%$ has been grown by molecular beam epitaxy on GaN templated *c*-plane Al_2O_3 [4]. The in-plane/out-of-plane (easy/hard axis, respectively) magnetic anisotropy of these layers have been investigated in a SQUID magnetometer between 2 and 300 K and up to 7 T. The magnetic anisotropy of $Ga_{1-x}Mn_xN$ samples with a low $x \cong 1\%$, in which FM Mn-Mn coupling at $T > 2$ K is very weak, is compared with $x > 6\%$ samples in which FM superexchange drives the material into the FM state below 7 K. We find that the single ion magnetic anisotropy is visibly reduced in the FM state, and that the anisotropy center of gravity is shifted towards the near-zero field region. This is the general feature which distinguishes the low-*x* paramagnetic (PM) layers in which close Mn pairs are rare from those in which near neighbor pairs and triples dominate. To quantified the magnetic anisotropy we integrate area between the easy and hard axis $m(H)$ and find that it does not show any critical behavior on crossing FM – PM transition. Neither its magnitude shows any systematic dependency on *x*. Whereas the latter can be attributed to various concentration of Mn in 2+ state, which exhibits no magnetic anisotropy, the former observation further confirms the percolating character of the transition in this diluted insulating ferromagnet.

This work has been supported by the National Science Centre (Poland) through grants FUGA (DEC-2014/12/S/ST3/00549) and OPUS (DEC-2013/09/B/ST3/04175), by the EU 7th Framework Programme "EAgLE" (REGPOT-CT-2013-316014), and by Wroclaw Research Center EIT+ within the NanoMat project (P2IG.01.01.02-02-002/08) co-financed by the European Regional Development Fund (operational Programme Innovative Economy, 1.1.2).

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