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Experimental probing of the emergence of magnetic order at the insulator-to-metal transition in (Ga,Mn)As

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The question whether the Anderson-Mott localization enhances or reduces magnetic correlations is central to the physics of magnetic alloys. Particularly intriguing is the case of (Ga,Mn)As the canonical diluted magnetic semiconductors in which the spin-spin coupling is mediated by holes. In order to find out how magnetism evolves when the carrier density is diminished, magnetisation changes induced by an electric field in metal/insulator/(Ga,Mn)As structures were probed directly by SQUID magnetometry [1]. Our findings show that the channel depletion results in a monotonic decrease of the Curie temperature and spontaneous magnetic moment, with no evidence for the maximum expected within the impurity-band models but explained theoretically in terms of the appropriately modified p-d Zener model [1]. We have found that this transformation proceeds via the emergence of a hitherto non-revealed superparamagnetic-like spin arrangement, which points to a fragmentation of long range spin order into ferromagnetic and nonmagnetic regions, which are driven by critical fluctuations in the local density of states, specific to the Anderson-Mott quantum transition. Finally, our studies provide a direct magnetic evidence for spontaneous 90 deg switching of the in-plane uniaxial easy axis upon gate-voltage-induced reduction of the hole density in the channel [2]. The work was done in collaboration with D. Chiba, Y. Nishitani, F. Matsukura, and H. Ohno in Sendai and with A. Korbecka, J.A. Majewski, and T. Dietl in Warsaw. The support from Japanese: Grant-in-Aids from MEXT/JSPS, the GCOE program, the Research and Development for Next-Generation Information Technology Program (MEXT), and EU: FunDMS Advanced Grant of ERC and InTechFun (POIG.01.03.01-00-159/08) is gratefully acknowledged.

[1] M. Sawicki, D.Chiba, A. Korbecka, Y. Nishitani, J.A. Majewski, F. Matsukura, T. Dietl, H. Ohno, Nature Phys., DOI: 10.1038/NPHYS1455.
[2] D. Chiba, M. Sawicki, Y. Nishitani, Y. Nakatani, F. Matsukura, and H. Ohno, Nature **455**, 515 (2008).