Anomalous Hall effect in Fe (001) epitaxial thin films over a wide range in conductiviy

S. Sangiao[1], *L. Morellon*[1,2], *G. Simon*[1], *J. M. De Teresa*[2], *J. A. Pardo*[1,3], *J. Arbiol*[4], *M. R. Ibarra*[1,2]

[1]*Instituto de Nanociencia de Aragón and Departamento de Física de la Materia Condensada, Universidad de Zaragoza, Interfacultades II, Zaragoza, 50009, Spain*

[2]*Instituto de Ciencia de Materiales de Aragón and Departamento de Física de la Materia Condensada, Universidad de Zaragoza-CSIC, Facultad de Ciencias, Zaragoza, 50009, Spain*

[3]*Departamento de Ciencia y Tecnología de Materiales y Fluidos, Universidad de Zaragoza, Centro Politécnico Superior, Zaragoza, 50018, Spain*

[4]*TEM-MAT, Serveis Cientifico tècnics, Universitat de Barcelona, Barcelona, 08028, Spain*

sangiao@unizar.es

We report Hall-effect measurements of epitaxial Fe (001) thin films grown on MgO (001). We have focused on the dependence of the anomalous Hall Effect (AHE) in heteroepitaxial structures MgO (001) // Fe(t) / MgO with t = 10, 2.5, 2, 1.8 and 1.3 nm (see Fig. 1). Our results have been interpreted in terms of a recent unified theory of the AHE [1]. We have demonstrated that the thickness and roughness of the Fe layer are control parameters to tune both the longitudinal conductivity σ_{xx} and Hall conductivity σ_{xy}. In this way, we report a crossover from the intrinsic moderately dirty region of conductivities where σ_{xy} = const. to the dirty region of poorly conducting materials ($\sigma_{xx} < 10^4$ S/cm) where we have found that the relation $\sigma_{xy} \propto \sigma_{xx}^n$ with n = 1.66(4) holds, in good agreement, with the expected universal scaling relationship reported in other ferromagnetic compounds.

To our knowledge no single material has been found to span all three regimes proposed in Ref. 1. We show in Fig. 2 that this is possible in pure bcc Fe (001) epitaxial thin films by adequately engineering the conductivity (see Fig. 2). Therefore we provide a comprehensive view and interpretation of the AHE in bcc Fe [4], giving additional support to the unified picture proposed by Onoda et al. [1].

References:

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Figures:

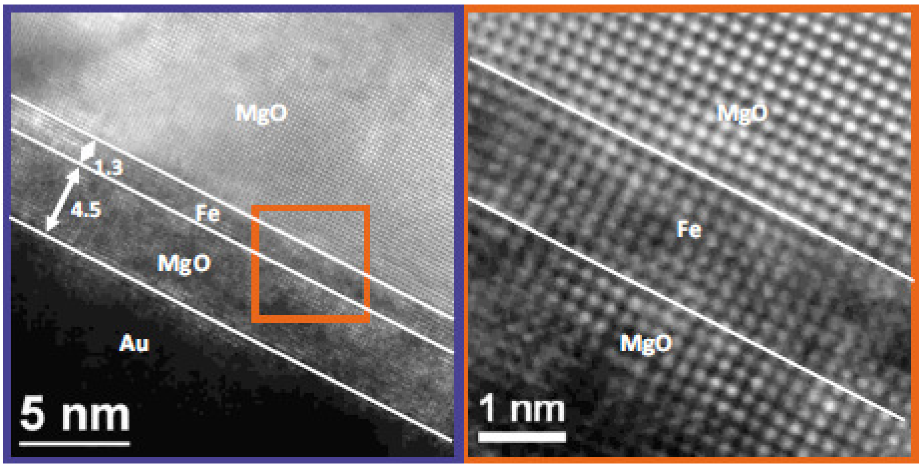

Fig. 1. Cross sectional HRTEM micrograph of a MgO (001) // Fe (t = 1.3 nm) / MgO thin film (left). The interface region marked has been zoomed in (right).

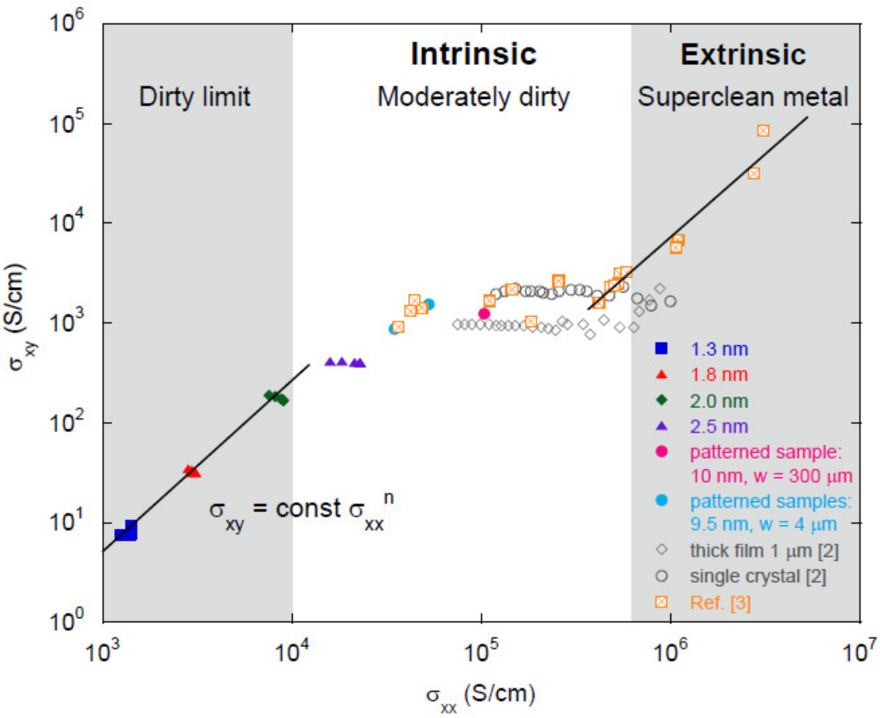

Fig. 2. Anomalous Hall conductivity values $|\sigma_{xy}|$ as a function of longitudinal conductivity σ_{xx} in MgO (001) // Fe (t) / MgO with t = 2.5, 2.0, 1.8, and 1.3 nm, and on patterned samples of t ≅ 10 nm. We have included the results for a 1 μm thick film and single-crystal specimen of Fe from Ref. 2 and that of MBE-grown Fe thin films down to 2 nm (Ref. 3). The solid line in the dirty region of conductivities ($\sigma_{xx} < 10^4$ S/cm) is the fit according to the scaling relationship $\sigma_{xy} = \text{const}\ \sigma_{xx}^n$ with $n = 1.66(4)$.