Local probe of disorder-induced magnetism in $Fe_{60}Al_{40}$ thin films by CEMS

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The phenomenon of chemical disorder-induced magnetism in the bulk FeAl system is known for decades [e.g. Ref.1] and has been intensively studied by Mössbauer spectroscopy. The majority of literature reports are dedicated to studies of ball-milled FeAl alloys of different stoichiometry that exhibit a hyperfine field splitting depending on the milling time and temperature. Nowadays it is possible to create such a disorder in a much more controlled and delicate manner also in thin films: the ion beam irradiation technique allows to effectively vary the number of Fe nearest-neighbors and interatomic distances by increasing either the ion energy or the irradiation dose.

$Fe_{60}Al_{40}$ (40nm and 250nm)/SiO_2/Si thin films have been prepared by magnetron sputtering with further annealing and 20 keV Ne^+ irradiation as reported in [2]. XRD scans demonstrate that the irradiation destroys the chemical ordering but preserves the structural integrity. MOKE and VSM magnetometry measurements confirm that chemically disordered films (A2 phase) are clearly ferromagnetic contrary to the annealed ones (B2 phase).

CEMS studies of as-prepared, annealed and irradiated thin films of 40nm were performed at room and low (80K) temperatures in normal or “magic angle” incidence geometry. The evident paramagnetic-ferromagnetic phase transition is shown in Fig.1: the experimental single line from an annealed sample (B2 phase) is replaced by a sextet with a hyperfine field distribution from the irradiated one (A2 phase). Measurements performed at 80K revealed further transformation of the subspectra: the subspectrum related to the paramagnetic phase almost vanishes while the sub-spectrum related to the ferromagnetic phase exhibits an enlarged hyperfine field splitting. Such a behavior may be attributed to the enhanced contribution of ferromagnetic Fe-rich areas in the sample [as in Ref. 3] that could have different Curie temperatures below RT. For 250nm thick samples annealed at 500°C or 1000°C, the parameters of the CEMS subspectra (isomer shifts, quadrupole splitting and doublet intensity ratio) obtained within a model suggested in [4] could be interpreted as an indication of different amounts of thermal vacancies in the samples studied. A comparison of results from CEMS and X-ray element-specific spectroscopy is in progress and will be reported.

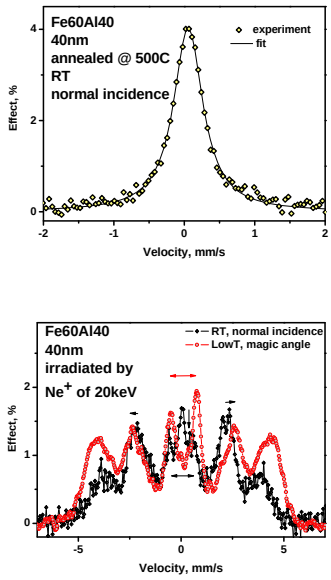

Figure 1: CEMS data from $Fe_{60}Al_{40}$ thin films of 40nm thicknesses:
top – annealed sample measured at RT,
bottom – irradiated sample measured at room and low (80K) temperatures

References

[1] G. P. Huffman et al., J.Appl. Phys. **38**, 735 (1967).
[2] R. Bali et al, Nano Lett. **14**, 435 (2014).
[3] L. Zamora et al., Phys. Rev. B **79**, 094418 (2009).
[4] J. Bogner et al., Phys. Rev. B **58**, 14922 (1998).