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Dynamics in FePt Thin Films Studied by Grazing Incidence Synchrotron Reflexion on Isotopic Multilayers

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1. Introduction

We used a new method, see [1], for grazing incidence nuclear resonant scattering of synchrotron radiation to determine the self-diffusion coefficient of Fe in FePt thin films with high accuracy.

Up to now the radiotracer technique has been used to study mesoscopic and macroscopic diffusion dynamics. On the atomic scale scattering methods as quasielastic Mössbauer spectroscopy (QMS), nuclear resonant scattering of synchrotron radiation (NRS) and quasielastic neutron scattering (QNS) are state of the art [2].
Isotopically enriched ^{57}FePt/ ^{56}FePt multilayers are epitaxially grown on MgO substrates. The bilayer structure is chemically homogeneous, i.e. all FePt layers are of the stoichiometric composition. Please note that the bilayer structure only corresponds to the use of pure ^{57}Fe and natural Fe for each second layer, respectively. The isotopic superstructure, however, can be observed via grazing incidence nuclear resonant scattering of synchrotron radiation. Self-diffusion of Fe in the FePt thin film will cause the isotopic superstructure to vanish, and thus the nuclear Bragg Peaks corresponding to resonant scattered gamma quanta to disappear.

2. Experiment

The samples were deposited using MBE at 350°C. Multilayers of Pt (20Å) / [^{57}FePt (20Å) / FePt (30Å)]x10 / MgO. The films were crystalline $L1_0$ ordered with c-axis perpendicular to the film plane. Spectra were taken at the beamline ID22 of ESRF. The setup is like a conventional setup for nuclear resonant scattering in grazing incidence geometry, see [3] for details. In figure 1, nuclear Bragg peaks can be seen at

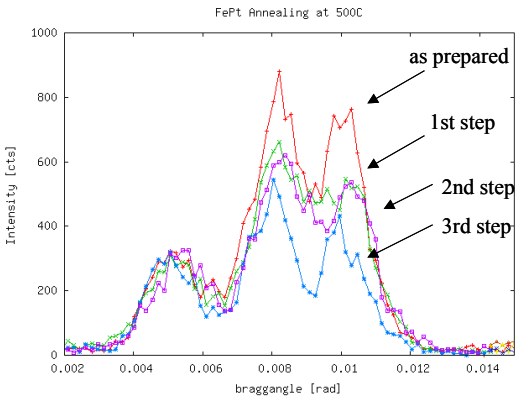

Fig.1.: Nuclear reflectivity of FePt isotopic multilayer. Each curve corresponds to an annealing step at 500°C. See text for details.

angular positions corresponding to the bilayer period. The peak at the lowest angle corresponds to the total reflection for FePt. The double-peak structure of the nuclear Bragg peak is caused by a disturbance in the bilayer periodicity, but does not influence the result. As self-diffusion of iron atoms occurs during the annealing for a certain time at temperature T, the bilayer structure is smeared out. As a result, the spectra show a decrease of the nuclear Bragg peaks. The curves in figure 1 show this decrease for three annealing steps each at 500°C, indicated by the arrows. Please note that the annealing time was the same of about 1h for each step.

The samples were annealed at temperatures of 500°C, 550°C, 575°C and 600°C for times between 3600s and 7200s, respectively. The macroscopic or tracer diffusion coefficient for a certain annealing temperature $D(T)$ can be directly calculated from the intensity loss of the peaks as shown in [4]. The diffusion coefficients of several different temperatures follow an Arrhenius behaviour. The corresponding plot for the activation energy is shown in figure 2. The slope of the Arrhenius plot corresponds to an activation energy of $Q = (1.65 \pm 0.29)$eV and the constant $D_0 = (3.45 \pm 0.44)*10^{-13}$ m^2s^{-1}.

3. Conclusion

Our studies show that very slow iron diffusion in thin films can be investigated with NRS. The method has very high accuracy and sensitivity. Investigations are non-destructive, i.e. non-contaminating and it is possible to measure very low rates of diffusion of about 10^{-23} m^2s^{-1} to 10^{-25} m^2s^{-1}. The sensitivity can be controlled by increasing the annealing time at low temperatures.

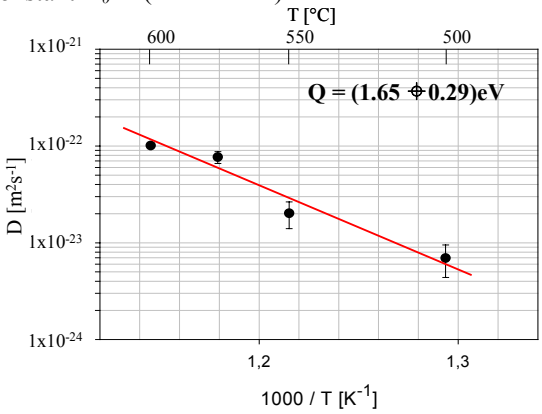

Fig. 2: Arrhenius plot for diffusion of Fe in FePt multilayer, the line indicates the fit of the data.

4. Acknowledgements

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