



Experiment title: Spin Structure of Pulsed Laser Deposited Fe/Cu(100) Films

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Report:

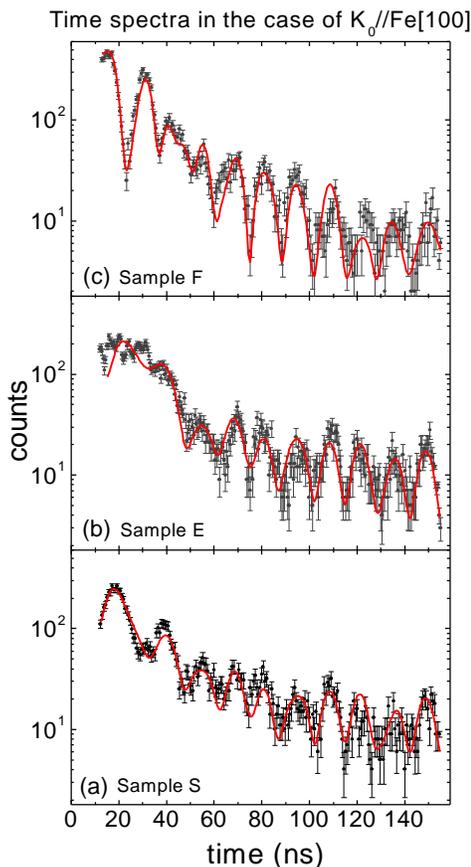


Fig.1: measured time spectra (symbols) at 60 K and best simulations (lines).

We have measured nuclear forward scattering (NFS) spectra of 6 ML Fe-films grown on Cu(001) by pulsed laser deposited (PLD). Using ^{57}Fe probe layers at different depth of the Fe-film we studied the layer dependent spin orientation.

Recently, PLD has been used to prepare magnetic metal films [1], e.g., Fe on Cu. Good layer-by-layer growth and an almost ideal fcc structure in the thickness range below 10 monolayers (ML) have been found. The PLD-grown Fe/Cu(100) films show a spin reorientation from in-plane observed in the coverage range between 2 and 5 ML to perpendicular above 7 ML coverage [2]. The purpose of this experiment was to explore the spin structure of PLD-Fe films in the transition region between 5 and 7 ML.

Three Fe/Cu(001) samples were prepared. The total thickness of the Fe-films is 6 ML, while a 2 ML ^{57}Fe probe layer was inserted into different positions: at the bottom of stack (sample S: Cu(001) / 2ML ^{57}Fe / 4ML ^{56}Fe / 20ML Au), at the center (sample E: Cu(001) / 2ML ^{56}Fe / 2ML ^{57}Fe / 2ML ^{56}Fe / 20 ML Au) and at the top (sample F: Cu(001) / 4ML ^{56}Fe / 2ML ^{57}Fe / 20ML Au). The remainder of the films is composed of natural Fe with only 2% ^{57}Fe . After PLD the samples were coated with about 20ML Au by thermal deposition to prevent contamination. Using MOKE, hysteresis loops were observed both in polar and longitudinal configuration, indicating the simultaneous presence of perpendicular and in-plane components of the remanent magnetization M_R .

The samples were magnetized by an external field of 0.2 T oriented parallel to [100]. The measurements were carried out in remanence in grating incidence geometry and with k_0 parallel to [100] and [010]. The figure (1) shows the time spectra measured for k_0 parallel to [100]. High quality fits characterized by χ^2 values in the order of 2 to 4 could be achieved. The fits are shown as solid lines superimposed on the time spectra. The layer resolved spin-orientation as obtained from the analysis is shown in figure (2a). While we find $\theta=90^\circ$ for the bottommost layers (i.e. \mathbf{B}_{hf} within both ^{57}Fe ML is perpendicular to the sample surface) for the upper layers θ decreases to an average value of 75° (sample E, layers #3,4) and to 41° (sample F, layers#5,6). Similar results are obtained for the $k_0 \parallel [010]$ geometry, suggesting the presence of a cone like spin arrangement, where the cone opens from bottom to the top of the sample.

On the basis of the MOKE measurements [2] we estimated the angle \bar{q} (averaged over the entire film) by using the coverage dependent ratio between the (normalized) perpendicular $(M_R/M_{R(\text{max})})_\perp$ and the in-plane $(M_R/M_{R(\text{max})})_\parallel$ (see inset in figure 2a). Here, M_R and $M_{R(\text{max})}$ are the remanent magnetization and the maximum M_R measured for pure in- or out of plane magnetization, respectively. We find $\bar{q} \approx 50^\circ$ in comparison with 68° when taking the average value from the NRS experiment [$1/3 \times (90^\circ + 75^\circ + 41^\circ)$].

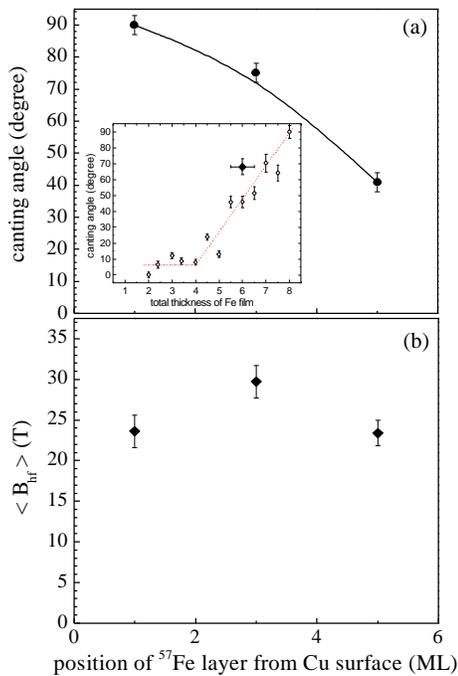


Fig.2: Layer resolved variation of the angle θ between the spin direction and the surface (a) and the weighted mean hyperfine field (b). The inset shows the average values of θ derived from MOKE (open symbol) and NRS (solid symbol).

In summary we have carried out NFS experiments on 6ML Fe/Cu(001) deposited by PLD. The analysis indicates a layer-dependent spin orientation within the Fe-films. From our analysis we can conclude that the two layers next to the Cu surface already show full out of plane orientation, while the spin orientation of higher layers are gradually oriented to the in-plane direction. The average value (68°) is in reasonable agreement with MOKE data (50°). From the similarity of the time spectra measured with k_0 parallel to [100] and [010] the existence of a cone like spin structure is suggested.

References:

- [1] J. Shen et al., *Phys. Rev. Lett.* **80**, 1980(1998)
- [2] J. Shen et al., *Europhys. Lett.* **43**, 349 (1998); H. Jeniches et al., *Phys. Rev. B* **59**, 1196(1999)
- [3] G. V. Smirnov, *Hyperfine Interactions* **123/124**, 31(1999)