ESRF	Experiment title: **Hard x-ray XMCD study of metal-capped Co nanoparticles with enhanced magnetic anisotropy**	Experiment number: HE-2238
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GRANULAR Co thin film multilayer constitute a family of nanoparticle systems which have been very useful for understanding size effects in magnetism. We have studied Co clusters of a nearly spherical shape can be produced by sputtering of Co on amorphous alumina, previously deposited on a Si substrate. Capping with a noble metal allows us to modify the matrix that surrounds the particle, thus modifying its magnetic properties. When capping with Cu or Au the particles behave as superparamagnetic with anisotropy constants that depend on the metal capping [1]. Instead, capping with Pt has a completely different effect, as Co particles are strongly coupled via the polarized Pt [2]. Metallic Ag is in this respect intermediate between Au and Cu. In the proposal of experiment HE-2238 we proposed to continue the experiment HE-1880 by measuring Ag- and W-capped multilayers to complete the study. We expected that a comparison of these two cases would allow to understand the role played by RKKY in the observed phenomena, which is a key question on the subject.
We prepared several $(Al_2O_3/Co/Ag)_N$ samples, but the XMCD signal in Ag was extremely small, partly due to the intrinsic size of the signal and partly due to the reduced circular polarisation degree of the radiation offered by ID12 at the $L_{2,3}$ Ag energies and the 16 bunch mode which was allocated. Therefore, very long counting time was needed to obtain a usable result. We only had time to study one Ag-capped sample, with a Co particle size and the Ag thickness which had been measured with every other metal capping in order to allow comparisons. Our preliminar results obtained on several $(Al_2O_3/Co/Ag)_{20}$ are shown in Figure 1. We also measured K-Co XMCD.

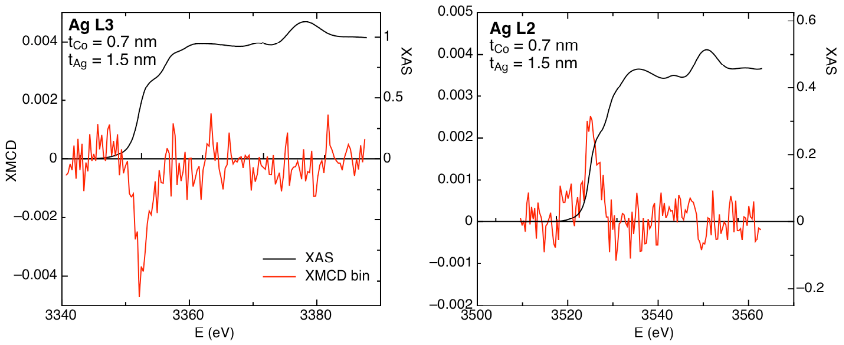

Figure 1. Normalized Ag *L*2,3-edge XAS (top)and XMCD (bottom) spectra of $(Al_2O_3/Co/Ag)_{20}$

From the data we have shown that the Ag capping is magnetically polarized by Co. Further analysis will allow to extract the size of the Ag magnetic moment, and, if possible, to apply sum rules to give orbital and spin moments. However, our objective is to relate the Co orbital moment and the Ag induced magnetic polarization with the sample anisotropy.

When the capping metal is W, which has a less than half filled $5d^4$ band, gives rise to completely different trends in the dependence of their magnetic properties with the configuration of the multilayers. We have magnetometry results on samples with t_{Co}=0.4, 0.7 and 1 nm, and a W capping film of t_W= 0.6, 1.5 and 4.5 nm, (N=20 repetitions). As much of the allocated time was gone measuring the Ag sample, we only measured XMCD at the K Co edges and W $L_{2,3}$ in one W sample: t_{Co}=0.7 and t_W= 1.5 nm (P2806 in Figs. 2, 3 and 4).

In good agreement with magnetometric results, the magnetism of the Co particles is strongly affected by W capping, in the sense of **strong decreasing of the saturation magnetic moment and effective anisotropy**.

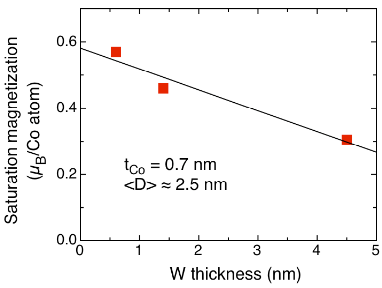

Fig. 1: Saturation magnetization of W-capped Co particles (t_{Co}=0.7nm) as a function of the thickness of the W layer. (for t_W=0, M ~ 1.5 μ_B / Co atom).

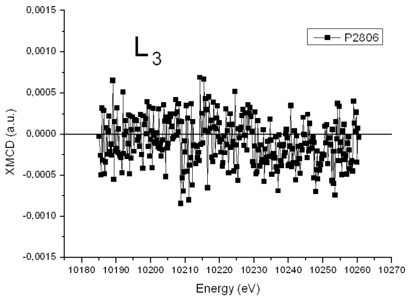

Fig. 2: XMCD at the W L_2 edge measured on the P2806 sample (t_{Co}=0.7nm)

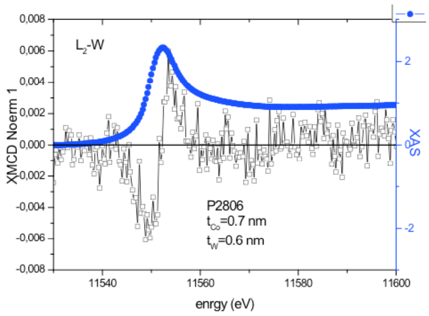

Fig. 3: XAS and XMCD at the W L_2 edge measured on the P2806 sample (t_{Co}=0.7nm)

Magnetization and susceptibility measurements on the W-capped samples show superparamagnetic behavior above a blocking temperature T_B which increases with t_{Co}, just as with the noble metal capping. However, in stark contrast with them, the saturation magnetization per atom decreases strongly with decreasing t_{Co}, and it also decreases with increasing width of the capping W below T_B. These results are consistent with the formation of a magnetic dead shell around the Co core of the nanocluster, of CoW alloys. The amount of W and the effective surface of the particle surface modulate the thickness of the dead shell, thereby, modifying the mean Co moment and particle anisotropy.

It is important to disentangle the question whether the decreasing of the magnetic moment of the samples is originated by an homogeneous decrease of the Co moment per atom, or by the formation of the magnetically death shell in the particles, or by ferrimagnetic polarisation of the Wpolarized layer. We expect that this can be deduced from the combination of static and dynamic magnetic measurements as a function of H and T, together with XMCD measurements on Co and W in several samples.

We have asked for a continuation on experiment HE-2238, to measure XMCD at the $L_{2,3}$-W and K-Co edges in a series of Co clusters (4 samples) capped with a tungsten thin film. In particular we plan to study other two W thickness (t_W=0.6, 4.5 nm) for t_{Co} = 0.7 nm and other two Co particle sizes (t_{Co}=0.4, 1 nm) for t_W = 1.5 nm.

References

[1] F. Luis, F. Bartolomé, F. Petroff, J. Bartolomé, L.M. García, C. Deranlot, H. Jaffres;M.J. Martínez, P. Bencok, F. Wilhelm, A. Rogalev and N.B. Brookes. Europhys. Lett. 76, 1 (2006)

[2] J. Bartolomé, L.M. García, F. Bartolomé, F. Luis, F. Petroff, C. Deranlot, F. Wilhelm, A. Rogalev. J. Magn. & Magn. Mat. 316, e9 (2007).