ESRF	**Experiment title:** MCD in the $L_{2,3}$ fluorescence of 4d transition metals: alloys and multilayers	**Experiment number:** **HE19**
Beamline: **ID12A**	**Date of experiment:** from: Nov. 14 1996 to: Nov. 22	**Date of report:** Feb. 8 1997
Shifts:	**Local contact(s):** José Goulon	***received at ESRF:*** 04 MAR 1997

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Report:

In our first experiment on beamline ID12A (March 1996) we were able to observe magnetic circular dichroism in the Rh 4d→2p x-ray **fluorescence** (XFMCD) spectrum from a $Co_{75}Rh_{25}$ alloy. Somewhat surprisingly, the shape of the dichroic signal did not match that of the Co 3d→2p XFMCD, which we had previously measured for bulk cobalt and Fe/Co multilayers [1]. This was not the first time that an element-selective technique had been used to single out magnetic moments in an alloyed 4d element since, shortly before, Harp et al. [2] had observed dichroism in the Rh $M_{2,3}$ x-ray absorption spectrum from a coevaporated Co-Rh film. It was the first time, however, that XFMCD had been observed in a 4d element.

Our main purpose is to measure spin polarization of **occupied** conduction states (valence electrons) in complex magnetic materials and to determine whether or not XFMCD may be related to ground state properties. XAMCD is founded on atomic theory and concerns an "impurity" core-hole excited atom but the MCD ***intensity*** is proportional to the difference in the majority and minority spin conduction holes. XFMCD, it has been suggested [3], may be identified with the energy ***resolved*** spin polarization of the valence densities of states. In the one-electron approach only a dipole matrix element separates the experiment from the ground state. (The dipole matrix element is only slowly energy dependent). Here we report on our second experiment using the 97% circularly polarized Helios II undulator peak, tuned to the Rh L3 threshold without further monochromatization (ΔE -140 eV).

A confrontation with a spin polarized fully relativistic FLAPW calculation performed by Singh [4] for the hcp Co_3Rh intermetallic compound looked promising.

The experimental results and the calculated spin polarization are shown in Figs. I and 2 [4]. The next step was to estimate the sensitivity of the method. Figure 3 shows our magnetization curves for Co-Rh alloys in which a 3d or 4d element has been introduced as a substitute for Rh. Partially replacing Rh with Ni has little impact, however use of Pd or Ru has the effect of increasing or reducing magnetization respectively. No simple intuitive explanation can be given for this, even though a number of empirical laws based on charge transfer, rigid band models, or, more recently, on "magnetic valence"[5] have been devised. According to the latter, adding Pd reduces the average magnetic valence and should therefore decrease the magnetic moment per atom in the alloy. On the other hand the Co-Pd, Co-Rh, and Co-Ru systems do have decreasing moments per atom, in that order, and the moment decreases as the 4d element concentration increases[6]. We were able to ascertain that the intensity of the dichroism at the Rh site increased in $Fe_{75}Rh_{25}$ compared to $Co_{75}Rh_{25}$. This is what one might expect simply from the lowering of the Fermi level. Next we observe that the dichroic intensity at Rh sites is reduced when Ru is substituted for Rh, but increases when the substitute is Pd (figure 4).

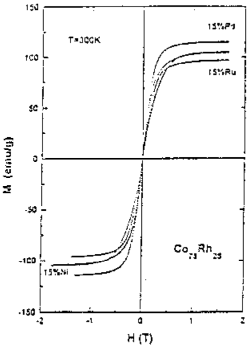

Fig. 3

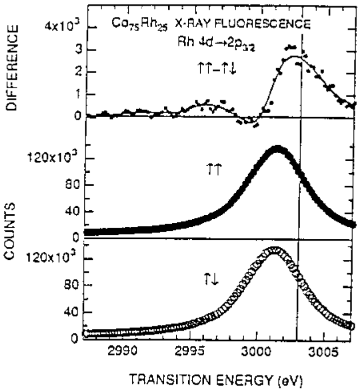

Figure 1

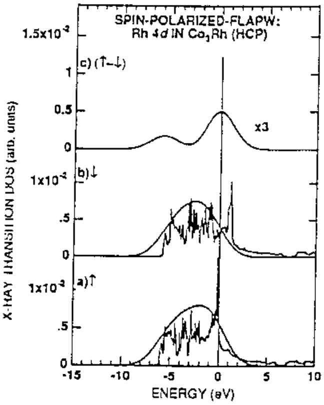

Figure 2

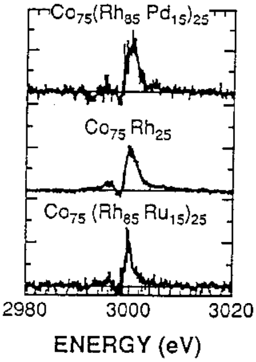

Fig. 4

[1] J.-M. Mariot and C. F. Hague, J. Physique IV 4–C9, 453 (1994); C. F. Hague and J.-M. Mariot, Nucl. Instr. and Meth. in Phys. Res. B 97, 449 (1995); J.-J. Gallet et al., Proceedings XAFS IX, J. Physique IV (to be published)
[2] G. R. Harp et al., Phys. Rev. B 51, 12037 (1995)
[3] P. Strange et al., Phys. Rev. Lett. 67, 3590 (1991)
[4] J.-J. Gallet et al. (to be submitted for publication)
[5] A. R. Williams et al., J. Appl. Phys. 55, 2353 (1984)
[6] J. Crangle and D. Parsons, Proc. Royal Soc. London Ser. A 255, 509 (1960)