Fe *K*-EDGE XMCD STUDY IN R_6Fe_{23} COMPOUNDS NEAR COMPENSATION TEMPERATURE

In recent years, a large body of research has been devoted to the study of the magnetic properties of several rare-earth transition-metal (R-M) compounds by means of X-ray magnetic circular dichroism (XMCD) technique. Special interest has been focused on the XMCD spectra at the R $L_{2,3}$-edges, probing the R-5*d* states, as they mediate the magnetic interaction between the R and M sublattices. However, the interpretation of XMCD spectra at these edges is a matter of debate because they do not follow simple sum rules. In a previous work, we proposed an alternative way to overcome this problem by studying the XMCD at the transition-metal *K*-edge [1]. Experimental findings have shown that the Fe *K*-edge XMCD signals of R-M intermetallics are rare-earth dependent and directly related to the Fe(4*p* ,3*d*)-R(5*d*) hybridized band. Thus, it would be possible to monitor the magnetism of the R-5*d* states by studying the Fe *K*-edge magnetic absorption [1].

To further clarify the applicability of this method, we have studied the Fe *K*-edge XMCD in the R_6Fe_{23} series showing the compensation phenomenon. In these systems, the antiferromagnetic coupling between R and Fe moments implies that the total magnetization starts to decrease at a point somewhat below the Curie temperature due to increasing ordering of 4*f* moments. As a result, the total magnetization may vanish at a given temperature (T_{CP}) and at temperatures below T_{CP} the magnetization of the R sublattice prevails. This is shown in Fig. 1, in which the temperature dependence of the magnetization of Y_6Fe_{23} and Ho_6Fe_{23} measured under an applied field of 10 kOe are compared. While the Y_6Fe_{23} magnetization shows a slight increase as the temperature decreases, corresponding to the enhancement of the Fe magnetic moment at low temperatures, the magnetization of Ho_6Fe_{23} decreases upon cooling down from room temperature, reaches a minimum at about T_{CP} = 195 K and then increases with further cooling. This behavior is due to the fact that the total Ho moment is coupled antiparallel to the Fe moment.

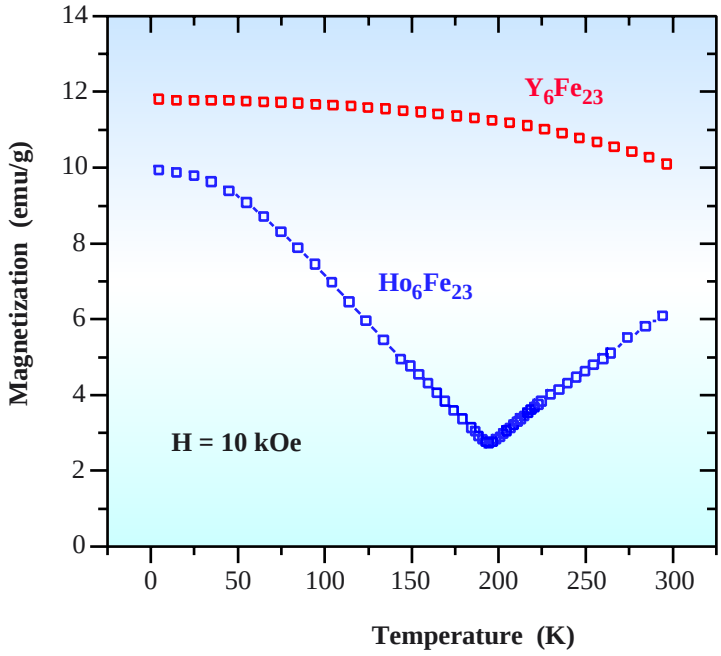

Fig. 1. Thermal dependence of the magnetization of Y_6Fe_{23} and Ho_6Fe_{23} under an applied field of 10 kOe.

Therefore, the Fe sublattice magnetization dominates at high temperatures, but as the temperature decreases, the increase of the Ho magnetic moment becomes large enough to compensate for the Fe magnetization and the total magnetization vanishes. Below this compensation temperature, the magnetization of the Ho sublattice dominates [2].

XMCD experiments were performed at the Fe *K*-edge and at the Ho $L_{2,3}$-edges on polycristalline Y_6Fe_{23} and Ho_6Fe_{23} samples at the X-ray undulator beamline **BL39XU** [3]. The XMCD spectra were recorded in the transmission mode using the helicity modulation technique [4] at different fixed temperatures from room temperature down to 50 K using a closed-cycle He cryostat under the influence of an applied 0.6 T magnetic field. Typical XMCD spectra are shown in Fig. 2, showing a change of sign at T_{CP} that is associated with the modification of the relative orientation of the Fe and Ho sublattices magnetizations with respect to the total magnetization of the sample, which is fixed by the external applied field.

The shape of the Fe *K*-edge XMCD signal of Y_6Fe_{23} is closely similar to that of Fe metal, while that of Ho_6Fe_{23} shows an additional positive feature just on the negative dip of the Y_6Fe_{23}. Our previous findings indicate that it is due to the Holmium sublattice [1]. The intensity of Fe- and Ho- derived peaks centered at E= 7.112 keV and E= 7.118 keV, respectively, was compared to the magnitude of μ_{Fe} and μ_{Ho} derived from our magnetization data [5] following a simple two-sublattices model. If our assignments [5] are correct, a remarkable increase in the intensity of the second peak as temperature decreases, in correspondence with the huge enhancement of the Ho magnetic moment needed to compensate Fe sublattice magnetization, should be seen. This comparison is shown in Fig.3, which clearly demonstrates how the intensity of the two peaks identified on the Fe *K*-edge XMCD spectrum follows the temperature dependence of the Fe and Ho magnetic moments.

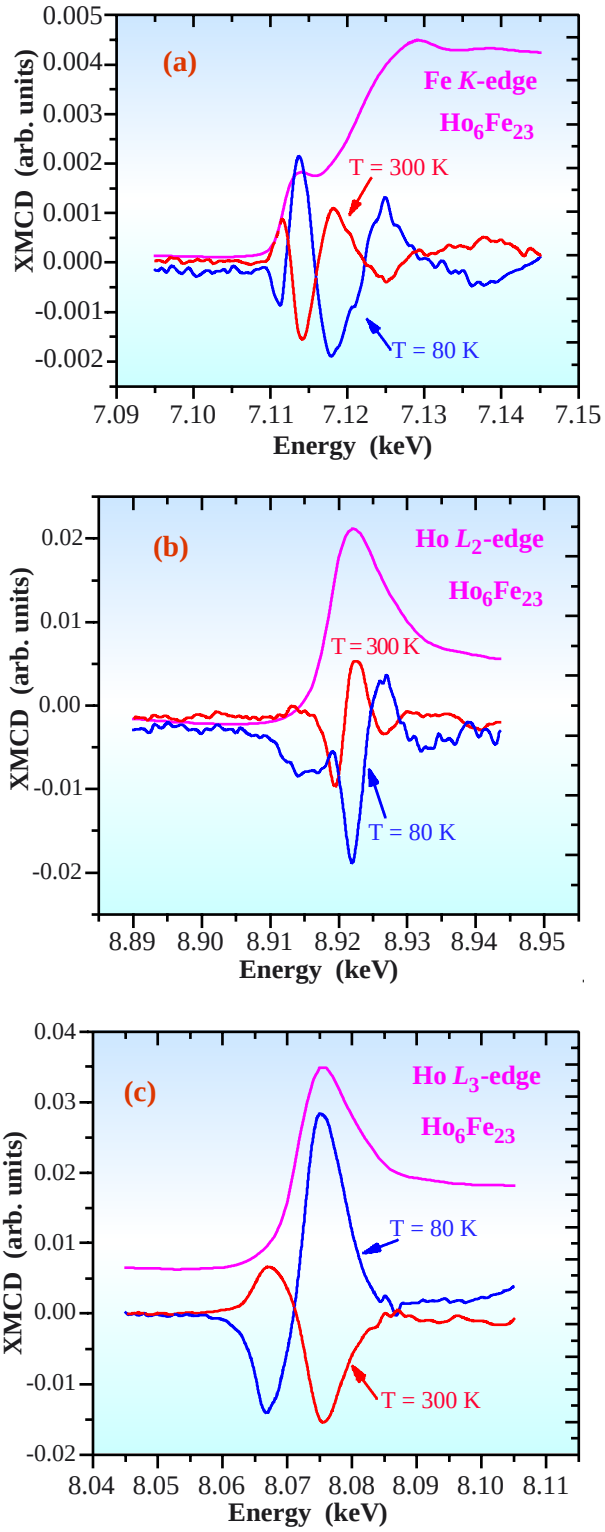

*Fig. 2. Comparison of the XMCD spectra recorded on Ho_6Fe_{23} at room temperature and T = 80 K : **(a)** Fe K-edge, **(b)** Ho L_2-edge and **(c)** Ho L_3-edge.*

In this work we have presented an X-ray magnetic circular dichroism (XMCD) study at the Fe *K*-edge in the R_6Fe_{23} series. This study identifies the influence of the rare-earth magnetic state on Fe *K*-edge XMCD signals. Our results demonstrate that the contribution of both Fe and R to the Fe*K*-edge XMCD spectra can be easily isolated by following their temperature-dependent behavior through T_{CP}, and that they can be directly correlated with the Fe and R magnetic moments. These results provide a new way to magnetically characterize the R-5*d* states in R-M intermetallic compounds.

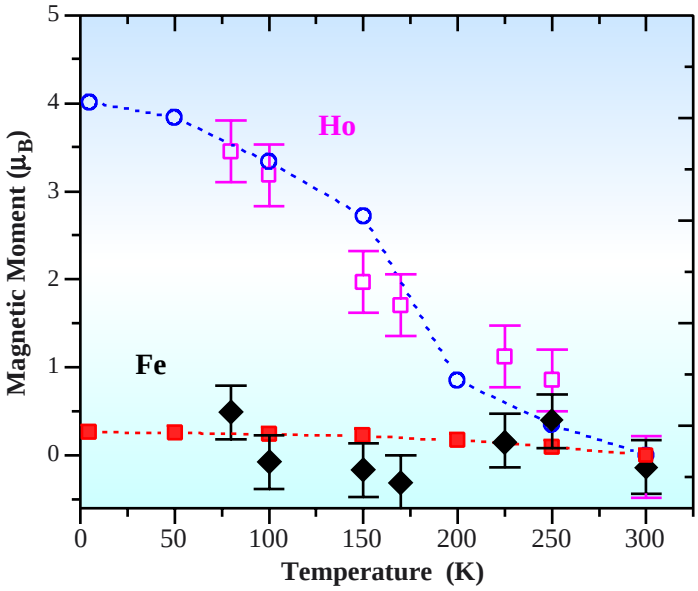

Fig. 3. Comparison between the thermal dependence of μ_{Ho} (open circles) and μ_{Fe} (solid squares) derived from magnetization data and from the intensity of Ho (open squares) and Fe (solid diamonds) contributions to the Fe K-edge XMCD spectrum normalized in both cases to the room temperature values.

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