Journal of Magnetism and Magnetic Materials 104–107 (1992) 1341–1343
North-Holland

Magnetic anisotropy and magnetic transitions in $RFe_{10}Mo_2$

X.C. Kou [a], C. Christides [b], R. Grössinger [c], H.R. Kirchmayr [c] and A. Kostikas [b]

[a] *Institute of Metal Research, Academia Sinica, Shenyang 110015, China*
[b] *NCSR "Demokritos", Institute of Materials Science, Athens, Greece*
[c] *Institut für Experimentalphysik, Techn. Univ. Vienna, A-1040 Vienna, Austria*

Compounds of the composition $RFe_{10}Mo_2$ with R = Y, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm and Lu were studied by means of the ac-initial susceptibility (χ) and the singular point detection (SPD) technique in the temperature range from 4.2 to 300 K. Spin reorientation transitions were detected for the compounds $RFe_{10}Mo_2$ with R = Nd and Dy. For the compounds $RFe_{10}Mo_2$ with R = Y, Ho, Er, Tm and Lu the ac-initial susceptibility data indicate a magnetic transition of unidentified nature. For $SmFe_{10}Mo_2$ a first-order magnetization process (FOMP) is observed below 170 K.

The $ThMn_{12}$ structure with RFe_{12} was found to be unstable. However, compounds of the composition $RFe_{12-x}M_x$ (M = Ti, V, Cr, Si, Mo; x = 1 or 2) with $ThMn_{12}$ structure can be formed for various rare earths. Such compounds are interesting for permanent magnet applications because of their high Fe concentration (causing possibly a high saturation magnetization) and their uniaxial crystal structure (causing possibly high magnetocrystalline anisotropy which is basic for a high coercivity). Since 1987, compounds of the type $RFe_{11}Ti$, $RFe_{10}V_2$ have been studied intensively [1–4]. In this contribution experimental investigations on $RFe_{10}Mo_2$ are reported.

Samples of $RFe_{10}Mo_2$ with R = Y, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm and Lu were prepared by arc melting and were subsequently homogenized at 850°C. The homogenized samples have been checked by X-ray diffraction to be single phase with tetragonal structure. In order to detect a possible temperature-induced magnetic transition, all samples were subjected to measurements of the temperature dependence of the ac-initial susceptibility in an ac magnetometer in the temperature range from 4.2 to 300 K using an ac-field of 40 A/m and a frequency of 125 Hz. The spin reorientation transitions, described as a change of the easy direction of magnetization (EDM) from one crystallographic direction to another with varying temperature, were detected for $RFe_{10}Mo_2$ with R = Nd (at 180 K) and R = Dy (at 143 and 63 K). No spin reorientation transition was traced for $TbFe_{10}Mo_2$. Figure 1 shows the temperature dependence of the ac-initial susceptibility (χ) and its first derivative ($d\chi/dT$) for $DyFe_{10}Mo_2$. It follows from this figure that two peaks are evident in the curve of the $d\chi/dT$ versus T. Similar to the case of $DyFe_{11}Ti$ [5], the following explanation can be given for $DyFe_{10}Mo_2$. The peak at the higher temperature (at about 143 K) indicates a change of the EDM from the c-axis to a cone, whereas the

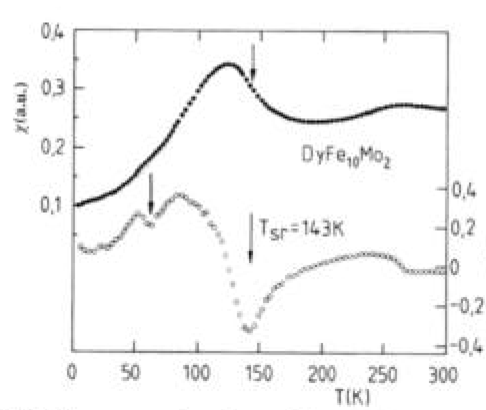

Fig. 1. Temperature dependence of the ac-initial susceptibility χ (solid circles) and its first derivative $d\chi/dT$ (open circles) of $DyFe_{10}Mo_2$.

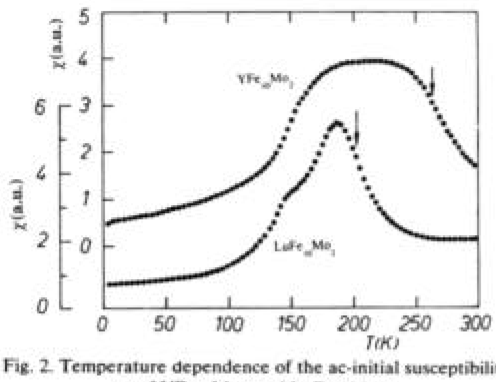

Fig. 2. Temperature dependence of the ac-initial susceptibility χ of $YFe_{10}Mo_2$ and $LuFe_{10}Mo_2$.

0312-8853/92/$05.00

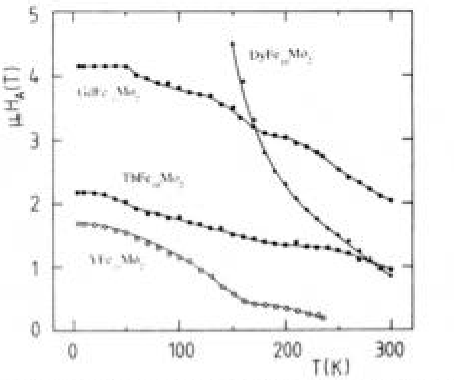

Fig. 3. Temperature dependence of the anisotropy field H_A determined by the SPD technique for $YFe_{10}Mo_2$, $GdFe_{10}Mo_2$, $DyFe_{10}Mo_2$ and $TbFe_{10}Mo_2$.

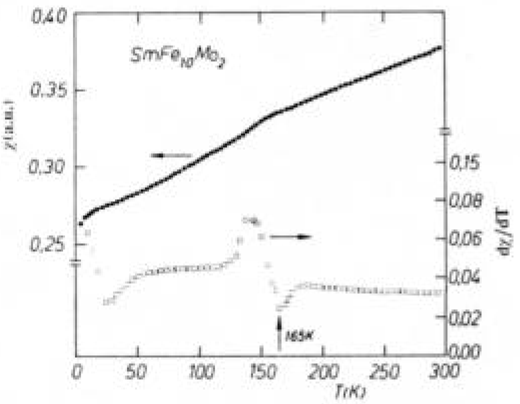

Fig. 4. Temperature dependence of the ac-initial susceptibility χ (solid circles) and its first derivative $d\chi/dT$ (open squares) of $SmFe_{10}Mo_2$.

peak at the lower temperature (at about 63 K) indicates a change of the EDM from the cone to the basal plane. Figure 2 shows the temperature dependence of the ac-initial susceptibility of $YFe_{10}Mo_2$ and $LuFe_{10}Mo_2$. A very pronounced peak can be observed for $YFe_{10}Mo_2$ at 266 K and for $LuFe_{10}Mo_2$ at 204 K. A similar phenomenon was also found for compounds $RFe_{10}Mo_2$ with R = Ho (231 K), Er (219 K) and Tm (204 K). All these experimental facts together with those of the singular point detection (SPD) measurements (see $YFe_{10}Mo_2$ in fig. 3) force us to the conclusion that a temperature-induced magnetic phase transition occurs in the Fe sublattice of $RFe_{10}Mo_2$ compounds. According to this assumption the magnetic transition observed in $HoFe_{10}Mo_2$, $ErFe_{10}Mo_2$ and $TmFe_{10}Mo_2$ can be understood as being due to a competition between the Fe sublattice anisotropy and the very low anisotropy of the Ho-, Er- and Tm sublattice. The nature of this unidentified transition of the Fe sublattice has been explained as the temperature-induced competition of the anisotropy among the different Fe sites.

The SPD theory predicts a singularity in the d^2M/dH^2 versus H curve at $H = H_A$ for an uniaxial compound for which the external field is applied perpendicular to the EDM. Figure 3 shows the temperature dependence of the anisotropy field H_A for $YFe_{10}Mo_2$, $GdFe_{10}Mo_2$, $DyFe_{10}Mo_2$ and $TbFe_{10}Mo_2$. From the results of $YFe_{10}Mo_2$ and $GdFe_{10}Mo_2$, it is concluded that the Fe sublattice anisotropy of $RFe_{10}Mo_2$ is uniaxial. The anisotropy of $TbFe_{10}Mo_2$ is also uniaxial, even down to 4.2 K, whereas the anisotropy of $DyFe_{10}Mo_2$ is uniaxial only above 143 K, which is in agreement with the susceptibility measurement (see fig. 1). Figure 4 shows the temperature dependence of the ac-initial susceptibility χ and its first derivative $d\chi/dT$ for $SmFe_{10}Mo_2$. Due to the large uniaxial anisotropy of the Sm sublattice, no spin reorientation transition is predicted for $SmFe_{10}Mo_2$. However, for $SmFe_{10}Mo_2$ a change of the shape of the $\chi(T)$ curve (resulting in a peak in the curve of the $d\chi/dT$ versus T) is evident (see fig. 4). According to our previously experience on $Nd_2Fe_{14}B$ [6], this change might give an evidence for the onset temperature of a first-order magnetization process. In order to verify this prediction, a direct measurement of the magnetization process at various temperatures from 4.2 to 300 K was performed for $SmFe_{10}Mo_2$ in a pulsed field system by the SPD technique. Figure 5 shows the measured results. From this figure it is evident that, as

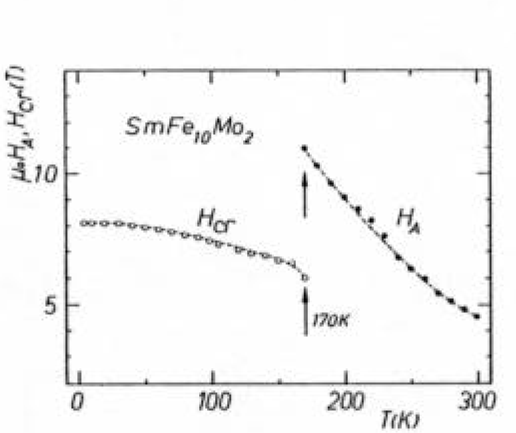

Fig. 5. Temperature dependence of the anisotropy field H_A and critical FOMP field H_{cr} of $SmFe_{10}Mo_2$.

predicted, a type-II FOMP occurs indeed in $SmFe_{10}Mo_2$ below 170 K.

References

[1] B. de Mooij and K.H.J. Buschow, Philips J. Res. 42 (1987) 246.
[2] Bo-Ping Hu, Hong-Shuo Li, J.P. Gavigan and J.M.D. Coey, J. Phys.: Condens. Matter 1 (1989) 755.
[3] W.G. Haije, J. Spijkerman, F.R. de Boer, K. Bakker and K.H.J. Buschow, J. Less-Common Met. 162 (1990) 285.
[4] J.M.D. Coey, J. Magn. Magn. Mater. 80 (1989) 9.
[5] Bo-Ping Hu, Hong-Shuo Li, J.M.D. Coey and J.P. Gavigan, Phys. Rev. B 41 (1990) 2221.
[6] X.C. Kou and R. Grössinger, J. Magn. Magn. Mater. 95 (1991) 184.