Magnetic anisotropy and magnetic transitions in RFe$_{10}$Mo$_2$

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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 ($\chi$) 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 La 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 Th$_{1-x}$M$_x$Fe$_{12}$ ($M = Ti, V, Cr, Si, Mo$; $x = 1$ 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 uraliaial crystal structure (causing possibly high magnetocrystalline anisotropy which is basic for a high coercivity). Since 1987, compounds of the type RFe$_{11}Ti$, RFe$_{10}V$, 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 ($\chi$) 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...
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 $\chi_{Fe}$ for $YFe_{2}Mo_{3}$, $LuFe_{2}Mo_{3}$, and $YFe_{2}Mo_{3}$. A very pronounced peak can be observed for $YFe_{2}Mo_{3}$ at 266 K and for $LuFe_{2}Mo_{3}$ at 204 K. A similar phenomenon was also found for compounds $RF_{2}Mo_{3}$ 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 $YFe_{2}Mo_{3}$ in fig. 3) force us to the conclusion that a temperature-induced magnetic phase transition occurs in the Fe sublattice of $RF_{2}Mo_{3}$ compounds. According to this assumption the magnetic transition observed in $HoFe_{2}Mo_{3}$, $ErFe_{2}Mo_{3}$ and $TmFe_{2}Mo_{3}$ 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 $dM/dH$ curve at $H = H_{s}$ for an external field applied perpendicular to the EDM. Figure 3 shows the temperature dependence of the anisotropy field $H_{s}$ for $YFe_{2}Mo_{3}$, $GdFe_{2}Mo_{3}$, $DyFe_{2}Mo_{3}$ and $TbFe_{2}Mo_{3}$. From the results of $YFe_{2}Mo_{3}$ and $GdFe_{2}Mo_{3}$, it is concluded that the Fe sublattice anisotropy of $RF_{2}Mo_{3}$ is uniaxial. The anisotropy of $TbFe_{2}Mo_{3}$ is also uniaxial, even down to 4.2 K, whereas the anisotropy of $DyFe_{2}Mo_{3}$ is uniaxial only above 140 K, which is in agreement with the susceptibility measurement (see fig. 1). Figure 4 shows the temperature dependence of the ac-initial susceptibility $\chi$ and its first derivative $\phi / dT$ 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 $\phi / dT$ versus $T$) is evident (see fig. 4). According to our previous experience on $Nd_{2}Fe_{14}B$, 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
predicted, a type-II FOMP occurs indeed in SmFe$_{10}$Mo$_2$ below 170 K.

References