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Citation style: Drzazga Zofia, Suski W., Wochowski K., Wójcik J., Winiarska Anna. (2000). Magnetic anisotropy of UFe10-xNixSi2 intermetallic alloys. "Acta Physica Polonica A" (Vol. 98, nr 5 (2000), s. 555-559).

Proceedings of the International Conference "Condensed Matter Physics", Jaszowiec 2000

MAGNETIC ANISOTROPY OF $UFe_{10-x}Ni_xSi_2$ INTERMETALLIC ALLOYS

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The magnetic anisotropy in $UF_{10-x}Ni_xSi_2$ series has been studied by torsion magnetometry and initial ac magnetic susceptibility measurements in the temperature range of 77–293 K. The effective anisotropy constant changes with Ni content showing some increase for intermediate concentration. An increase in magnetic anisotropy energy at low temperatures is due to the uranium sublattice ordering. Magnetic anisotropy behaviour in $UFe_2Ni_8Si_2$ is influenced by an additional enhancement of the $3d$ sublattice connected with the ordering Fe magnetic moments.

PACS numbers: 75.30.Gw, 75.20.En, 61.10.Nz

1. Introduction

Considerable attention has been given to the iron-rich alloys $RFe_{12-x}M_x$, where R is a rare earth metal and M = Ti, V, Mo, Cr, Si and their nitrides and carbides. Relatively few investigations have been done on the alloys containing a $5f$ element. The intermetallic alloys $UFe_{12-x}T_xSi_2$, where U is a uranium and T = Co, Ni, Cu, Al, crystallising with the body centred tetragonal $ThMn_{12}$-type structure, show a relatively high Curie temperature ($T_C \approx 600$ K) and a large magnetocrystalline anisotropy [1–3]. To obtain a better insight into the magnetic anisotropy of uranium alloys a series $UFe_{12-x}Ni_xSi_2$ has been studied.

2. Experimental

The magnetic anisotropy was studied by means of ac magnetic susceptibility and torsion measurements in the temperature range of 77–293 K. Torque curves were performed in applied magnetic fields up to 1.8 T. The magnetic anisotropy constants can be determined from measurements of slope of the torque near the easy magnetisation axis and from a maximum torque versus angle.

The anisotropy measurements were performed on the aligned in magnetic field polycrystalline samples with the grain diameters smaller than 10 μm. The easy direction of magnetisation (EMD) at room temperature was determined from the relative intensity of some peaks of the diffraction patterns for the "oriented" and "non-oriented" samples.

3. Results and discussion

All the investigated samples of the series $UF_{10-x}Ni_xSi_2$ have shown the field induced magnetic anisotropy. The experimental results are presented in Figs. 1–3 and the Table.

The X-ray diffraction analyses have shown that the c-axis is the direction of alignment in magnetic field of the Fe-rich alloys with $x \leq 2$. Nevertheless, a small change in the relative intensity of the diffraction peaks for the "oriented" samples of other compositions, i.e. with $x > 2$, suggests that the easy direction of magnetisation lies somewhere between the c-axis and the base plane (Fig. 1).

The torque curves of the sin 2Θ shape were observed for all the compositions in the whole temperature range (see Fig. 2). A field dependence of torque does

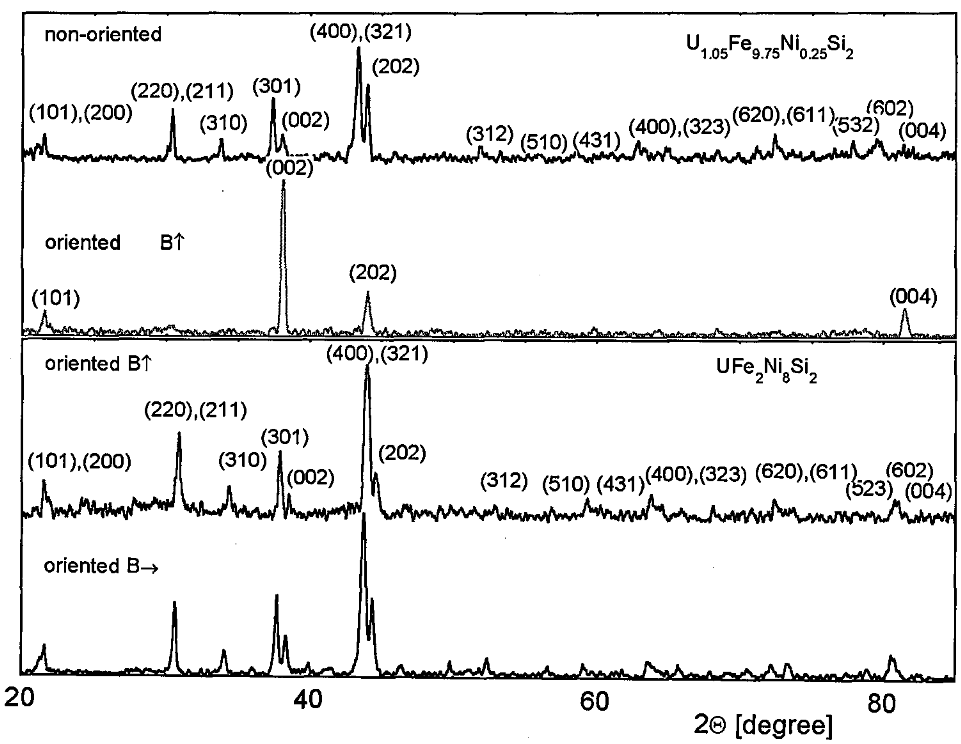

Fig. 1. X-ray diffraction patterns of non-oriented (top) and oriented (bottom) samples of $UFe_{10-x}Ni_xSi_2$.

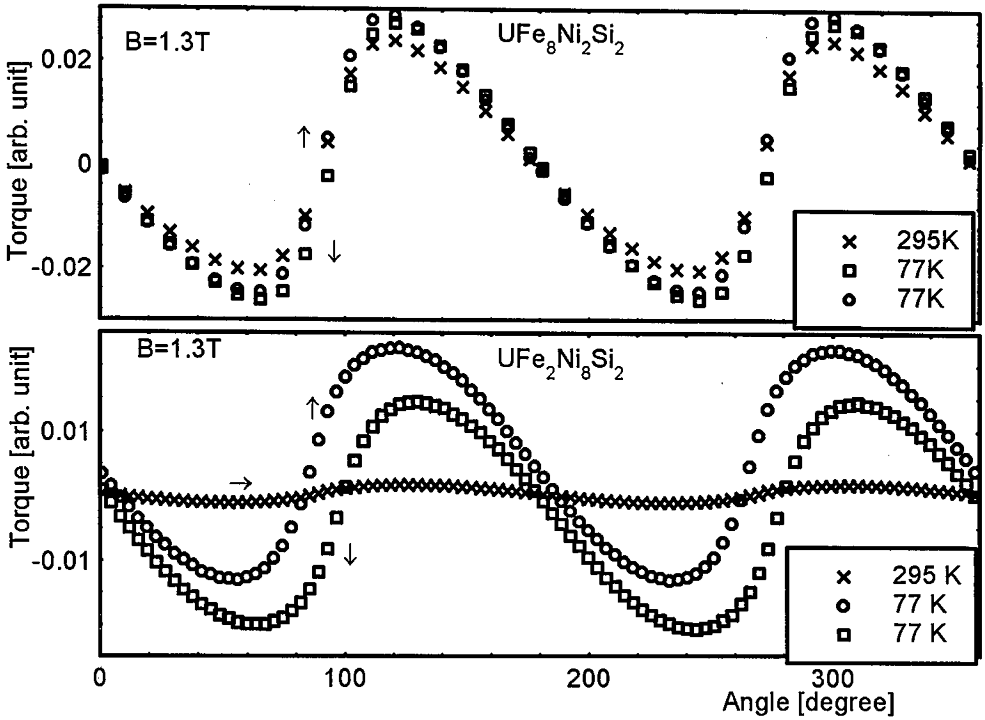

Fig. 2. Torque curves of $UFe_8Ni_2Si_2$ (top) and $UFe_2Ni_8Si_2$ (bottom) obtained at $B = 1.3$ T for $T = 295$ K and 77 K.

TABLE

The easy magnetisation direction (EMD) and the effective anisotropy constant K_{eff} for $UFe_{10-x}Ni_xSi_2$.

x	EMD	K_{eff} [10^3 J/kg] $T = 295$ K	K_{eff} [10^3 J/kg] $T = 77$ K
0.25	c-axis	0.24	0.35
0.5	c-axis	0.30	0.40
2	c-axis	0.39	0.49
4	cone	0.30	0.59
6	cone	0.20	0.45
8	cone	0.01	0.11

not show a tendency for saturation in the applied magnetic fields. It follows that a high magnetic anisotropy is present in the series studied. The effective anisotropy constants listed in the Table for the uranium alloys are comparable with those reported for the intermetallic alloys based on rare earth [4]. The effective anisotropy constant as a function of composition shows an increase for intermediate concentrations of Ni ($0.5 < x < 4$) similar to the remanent magnetisation [2].

At room temperature it seems that the easy direction of magnetisation in the samples studied is determined by the $3d$-metal sublattice, but at low temperatures magnetic anisotropy can be influenced by the $5f$-element sublattice. The temperature dependent torque curves (Fig. 2) reveal an increase in the magnitude of anisotropy energy with decreasing temperature. This enhancement in the anisotropy energy of compounds seems to be connected with the ordering uranium sublattice at low temperatures.

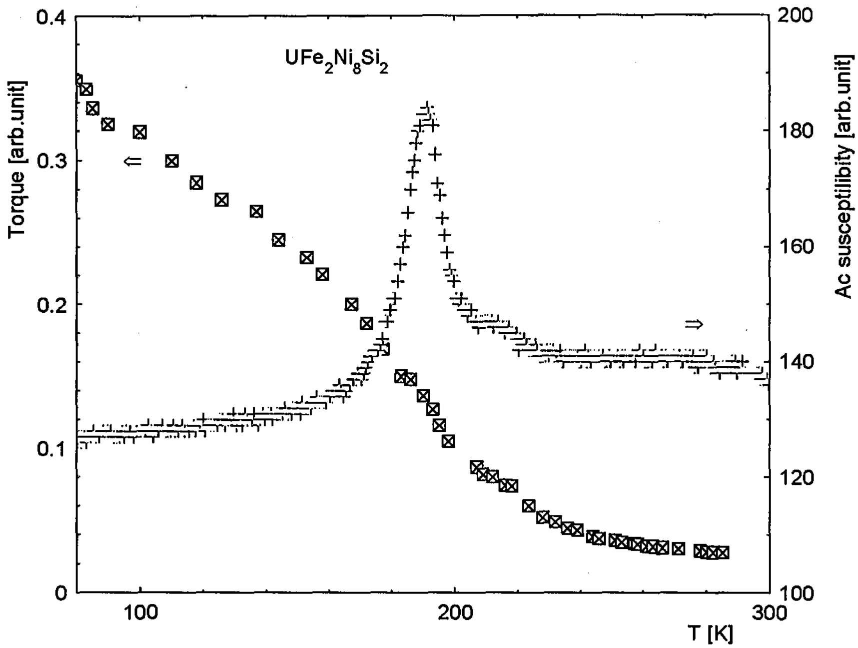

Fig. 3. Change of torque versus temperature (left) and ac magnetic susceptibility versus temperature (right) for $UFe_2Ni_8Si_2$.

The strong increase in the anisotropy energy in $UFe_2Ni_8Si_2$ observed below 200 K is particularly interesting (Figs. 2 and 3). This strengthening of the magnetic anisotropy cannot be explained by the uranium sublattice contribution only. The initial ac magnetic susceptibility versus temperature for $UFe_2Ni_8Si_2$ is illustrated in Fig. 3. This shows a marked anomaly at the corresponding temperatures not observed for other compositions. This anomaly is not associated with a spin reorientation because the $\sin 2\theta$ shaped torque curves are preserved. This is a confirmation of an additional ordering of Fe magnetic moments, observed earlier in the Mössbauer effect [2]. In the torsion measurements a marked increase in the rotational hysteresis with increasing Ni content was found in the sample (Fig. 2). A dilution of the Fe sublattice by the nonmagnetic Ni atoms reduces the resultant magnetic moment and maintains a high T_C. The random distribution of the Fe and Ni atoms may lead to a spin-glass-like behaviour in the 3*d* sublattice. It seems that the partly destroyed long-range magnetic order appears with decreasing temperature, enhancing the magnetic order of the 3*d* sublattice and followed by the uranium sublattice. As a consequence, an increase in magnetic anisotropy is observed. The magnetic anisotropy behaviour in $UFe_2Ni_8Si_2$ originates from the complicated magnetic exchange interactions which have been previous revealed in the magnetisation and Mössbauer effect measurements.

4. Conclusions

All the investigated samples of the series $UF_{10-x}Ni_xSi_2$ show a relatively high magnetocrystalline anisotropy. The effective anisotropy constant changes with Ni content showing some increase for intermediate concentrations. An increase in magnetic anisotropy energy at low temperatures seems to be due to the ordering of the uranium sublattice ($0.5 < x < 4$). Anisotropy behaviour in $UFe_2Ni_8Si_2$ is influenced by the increase in the 3*d* sublattice magnetisation due to the additional ordering of Fe magnetic moments below 200 K.

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