

Magnetic properties of $Y(\text{Co}_x\text{Ni}_{1-x})_3$ compounds

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The crystal structure and magnetic properties of $Y(\text{Co}_x\text{Ni}_{1-x})_3$ compounds are reported. Some metamagnetic transitions involving nickel atoms were shown. These were correlated with the combined effects of exchange and external fields.

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1. Introduction

The $Y\text{Co}_3$ and $Y\text{Ni}_3$ compounds crystallize in a PuNi_3 -type structure, having space group $R\bar{3}m$. In this lattice, the 3d transition metals occupy 3b, 6c and 18h sites [1]. The cobalt, M_{Co} , and nickel, M_{Ni} , moments are dependent on their local environments. By neutron diffraction studies values $M_{\text{Co}} = 0.55 \mu_B$ (3b), 0.79(6c) and 0.04 μ_B (18h) [2] and $M_{\text{Ni}} = 0.057 \mu_B$ (3b), 0.073 μ_B (6c) and 0.065 μ_B (18 h) [3] were determined. From magnetic measurements only their mean values can be obtained. The Co magnetic instability is at the origin of the two metamagnetic transitions, at 60 T and 82 T, which were evidenced in magnetization curves of $Y\text{Co}_3$, at 4.2 K. At 60 T, the Co subsystem goes from a low magnetic state to an intermediate one and then, at the second transition, to a strong magnetic state [4]. This transition can be also observed under the action of molecular field in $(\text{Gd}_x\text{Y}_{1-x})\text{Co}_3$ system [5] or in $(\text{Gd}_x\text{Y}_{1-x})_2\text{Co}_7\text{B}_3$ [6] one. A transition of nickel from non-magnetic to magnetic state, in $(\text{Gd}_x\text{Y}_{1-x})\text{Ni}_3$, was shown to occur at ≈ 35 T [7].

Previous study on $Y(\text{Co}_x\text{Ni}_{1-x})_3$ system showed an interesting behaviour [8]. The magnetizations decrease both from rich cobalt and rich nickel regions and have a minimum for $x = 0.2$. This compound was suggested to be nonmagnetic. In the following we report some metamagnetic transitions in $Y(\text{Co}_x\text{Ni}_{1-x})_3$ system in rather lower fields and we discuss the reason for their appearance.

2. Experimental

The $Y(\text{Co}_x\text{Ni}_{1-x})_3$ compounds were prepared by arc melting the constituent elements in a purified argon atmosphere. A small excess of yttrium was used to compensate the loss of weight during melting. The samples were remelted several times in order to ensure a good homogeneity. The alloys were then heat treated at 950 °C for 10 days.

The X-ray analyses show that the compounds are single phases and crystallize in a PuNi_3 -type structure,

having $R\bar{3}m$ space group, in all the composition range. The lattice parameters are only little dependent on composition – Fig.1. This behaviour may be correlated with close radius of transition metal atoms.

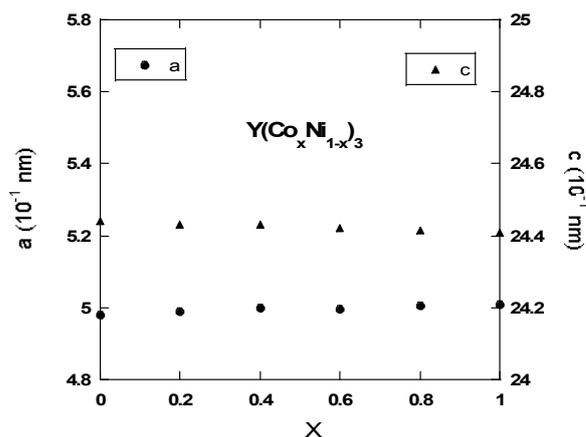


Fig. 1. Composition dependencies of lattice parameters.

The magnetic measurements were performed in the temperature range 5–300 K and fields up to 9 T. The saturation magnetizations, M_s , were determined from magnetization isotherms, according to the approach to saturation law, $M = M_s(1-a/H) + \chi_0 H$. We denoted by a the coefficient of magnetic hardness and χ_0 is a field independent susceptibility. The Curie temperatures were determined from thermal variations of magnetization in low field (0.01 T).

3. Experimental results and discussion

Some magnetization isotherms, determined in $Y(\text{Co}_{0.8}\text{Ni}_{0.2})_3$ compound, are plotted in Fig.2. At 5 K, a transition towards a state having somewhat higher magnetization is shown, at $\mu_0 H \approx 6$ T. No such behaviour was observed at higher temperatures. Similar results were

obtained for compounds with $x = 0.9$ or 0.6 -Fig.3. The transitions are relatively large and take place at near the same external field. The increase of the magnetizations are relatively small, of $0.014 \mu_B$ ($x=0.9$), $0.07 \mu_B$ ($x = 0.8$) and $0.036 \mu_B$ ($x=0.6$) – Fig.3.

Metamagnetic transitions were observed for cobalt in YCo_3 [4] or $ThCo_5$ [9]. In $Y(Co_xNi_{1-x})_3$ system, the transitions are not so sharp as in $ThCo_5$. The larger width of transitions may be correlated with the distribution of internal fields, resulting from slightly different local environments of transition metal atoms in the $R\bar{3}m$ -type lattice.

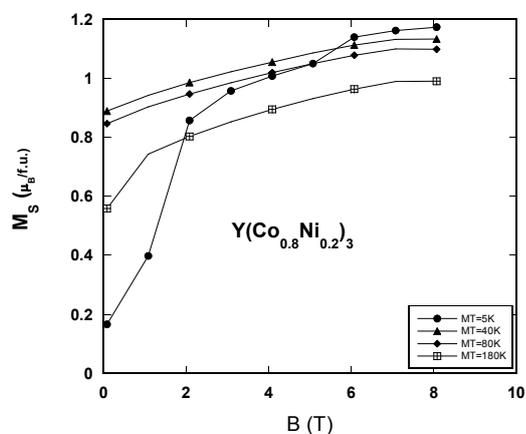


Fig. 2. Magnetization isotherms determined in $Y(Co_{0.8}Ni_{0.2})_3$ compound.

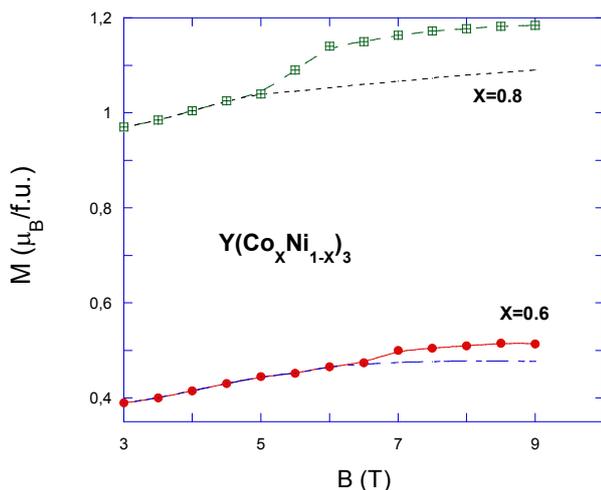


Fig. 3. Metamagnetic transitions, at 5 K, in $Y(Co_xNi_{1-x})_3$ compounds with $x = 0.8$ and 0.6 .

The observed transition in $Y(Co_xNi_{1-x})_3$ system can be correlated with nickel atoms. There is evidence that the metamagnetic transition in YCo_3 is located in field of 60 T [4]. An itinerant electron metamagnetic transition was also evidenced in field of 70 T in rare-earth cobalt Laves phases

compounds [10]. Thus, the observed increase in magnetization, shown at 6T, cannot be correlated with cobalt. The nickel atoms are more sensitive to exchange interactions, and such a transition was estimated in $(Gd_xLa_{1-x})Ni_5$ to take place in smaller exchange fields, of 35 T [7].

The neutron diffraction studies performed on $Er(Fe_xNi_{1-x})_3$ system showed that Ni atoms prefer 18h sites [11]. The above preference was confirmed also in $Y(Co_xNi_{1-x})_3$ system by Rietveld-type analyses. In these sites, nickel atoms have a small magnetic contribution as already mentioned. The induced moment is of the same order of magnitude as the moment at Ni 18h site. In $Y(Co_xNi_{1-x})_3$, from induced magnetization per formula unit and taking into account the nickel content, mean values of $0.05 \mu_B/Ni$ atom for compound with $x = 0.9$, $0.1 \mu_B/Ni$ atom for $x=0.8$ and $0.03 \mu_B/Ni$ atom for composition having $x = 0.6$ are induced. This increase is similar as the induced nickel moment when replacing Y by Gd in $(Gd_xY_{1-x})Ni_3$ system [12]. We estimated the mean exchange field, H_{exch} , in the $Y(Co_xNi_{1-x})_3$ system. For the compounds with $x \geq 0.8$ this is close to critical field expected to induce an additional nickel moment [7]. Consequently, the addition of external field allowed this transition. In case of compound with $x = 0.6$, somewhat smaller mean exchange field was determined. Thus, only a fraction of nickel atoms, favoured by their local environments, will be involved in such transition and this is reflected in a smaller change in magnetization as compared to $x \geq 0.8$ compounds. For higher nickel content than above, no such transitions were observed in $Y(Co_xNi_{1-x})_3$ system.

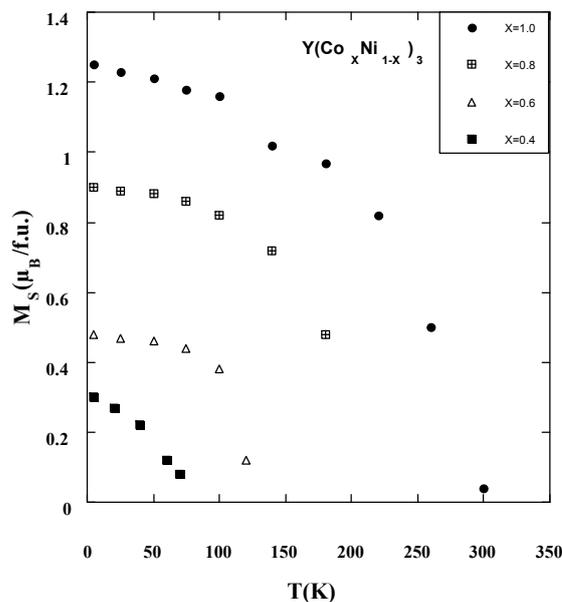


Fig. 4. Thermal variation of magnetizations.

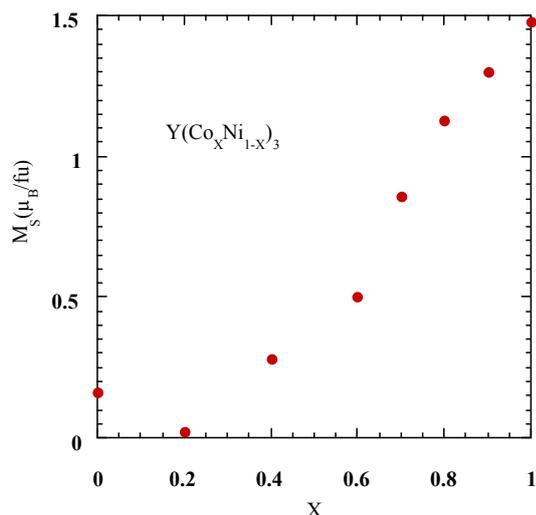


Fig. 5. Composition dependence of magnetization, at 5 K.

The temperature dependencies of magnetizations for selected samples are plotted in Fig.4. Both the saturation magnetizations and Curie temperatures decrease up to $x = 0.2$. At this composition a minimum in the magnetization is shown in Fig.5.

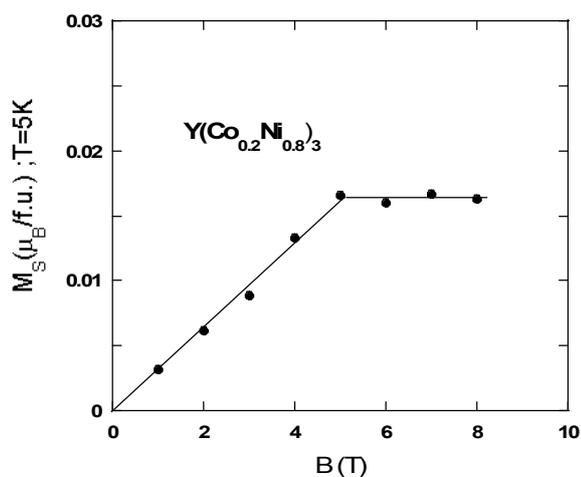


Fig. 6. Magnetization isotherm, at 5K, for $Y(\text{Co}_{0.2}\text{Ni}_{0.8})_3$ compound.

The magnetization isotherm, at 5 K, for the $Y(\text{Co}_{0.2}\text{Ni}_{0.8})_3$ compound, is plotted in Fig.6. There is a linear increase of magnetization up to $\mu_0H = 5$ T. For higher fields the magnetization remains constant and has a value of $0.018 \mu_B/\text{f.u.}$. The above data suggest that the $Y(\text{Co}_{0.2}\text{Ni}_{0.8})_3$ is a very weak ferromagnet.

The composition dependence of the magnetization, at 5K, may be qualitatively explained assuming that a local minimum in the density of states exist at $x=0.2$. When increasing both cobalt and nickel content, the Fermi level, is shifted to regions having higher density of states.

We conclude that in $Y(\text{Co}_x\text{Ni}_{1-x})_3$ system the nickel shows weak metamagnetic transitions as result of simultaneous presence of exchange and external fields.

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