Disruption of long-range order in Heisenberg antiferromagnet upon transition to reentrant spin-glass state

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The example of fcc alloy $Fe_{52}Ni_{28}Mn_{20}$ is used to show that the long-range magnetic order breaks down in Heisenberg antiferromagnets upon transition to the reentrant spin-glass phase.

Temperature-induced transitions from the ferromagnetic state to the reentrant spin-glass state are considered in most theoretical and experimental studies.[1,2] The temperature-induced antiferromagnet–spin glass reentrant transitions, however, have not been studied extensively. In the mean-field approximation the theory of such transitions has been developed for the Ising[3,4] and Heisenberg[5] antiferromagnets (AFM) with a fluctuating exchange. In the studies mentioned above it was concluded that cooling an Ising or a Heisenberg antiferromagnet with a competing exhange to temperatures below the Néel temperature gives rise to a so-called antiferromagnetic spin-glass state, in which a degenerate spin glass coexists with antiferromagnetic long-range order.

Most of the experimental studies of reentrant antiferromagnet–spin glass transitions were carried out using the Ising systems. In particular, neutron-diffraction studies have shown that in AFM systems of this sort [$Fe_xMg_{1-x}]Cl_2$ (Ref. 6) and $Fe_xMn_{1-x}TiO_3$ (Ref. 7)] a transition to the reentrant spin-glass state is not accompanied by a disruption of the long-range order. A case can be made, however, which would allow us to assume that the long-range magnetic order on Heisenberg antiferromagnets is destroyed in AFM–spin glass reentrant transitions. According to Refs. 8–10, the freezing-in of frustrated spins situated in a magnetically ordered phase gives rise to the appearance of random magnetic fields at the sites of the surrounding ordered matrix. As a result, the lower-order critical dimension of the magnet becomes twice as large. According to this approach, therefore, upon transition to a spin-glass state the long-range antiferromagnetic order is not disrupted in Ising 3D antiferromagnets. This situation has in fact been observed in Refs. 6f and 7. Heisenberg systems in the reentrant spin-glass phase, on the other hand, should have no antiferromagnetic order. It should be emphasized, however, that this problem remains unresolved.

The antiferromagnetic alloys of fcc iron are very useful systems for experimental studies of this problem. The exchange energy of these alloys, according to Ishikawa,[11] is much higher than the anisotropy energy; i.e., the test systems are Heisenberg antiferromagnets. Such systems, moreover, undergo reentrant AFM–spin glass temperature transitions, as was shown in the example of $Fe_xNi_{80-x}Cr_{20}$ alloys.[12,13] In our neutron-

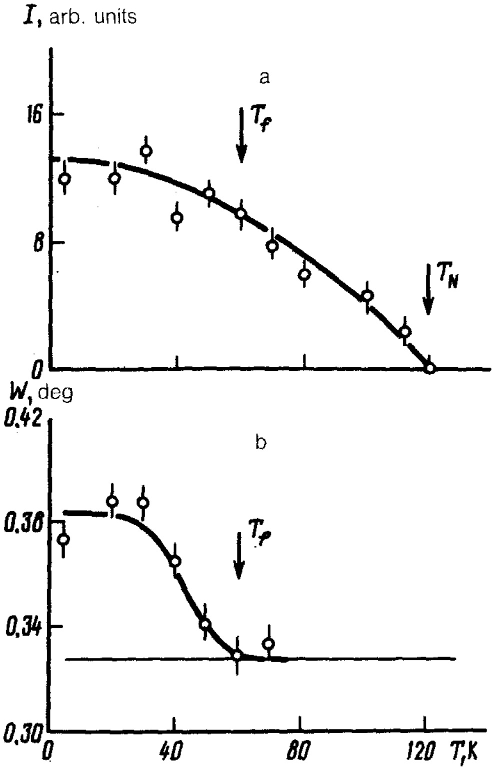

FIG. 1. The temperature dependence of the integrated dintensity I of (a) the antiferromagnetic (110) reflection and (b) its half-width W for the $Fe_{52}Ni_{28}Mn_{20}$ alloy.

diffraction studies, however, we chose the alloy $Fe_{52}Ni_{28}Mn_{20}$ which undergoes a AFM–spin glass reentrant transition at $T_f = 60$ K (Ref. 14) and which has a higher Néel temperature and a higher intensity of the (110) AFM reflection than the FeNiCr alloys.[15]

The neutron-diffraction pattern of the test sample, which had an fcc structure at all temperatures, exhibited below the temperature of ~120 K a superstructural (110) reflection, whose temperature dependence of the integrated intensity is shown in Fig. 1a. We see from the data presented here that below 120 K AFM order is established in the alloy and that the Néel temperature is in agreement with the values obtained from the magnetic measurements.[14]

At $T < T_f = 60$ K the magnetic reflection profile has a Lorentzian shape (with allowance for the instrumental resolution). We have attempted to describe the profile of this reflection by summing the two profiles: the Gaussian lineshape with the instrumental width and the Lorentzian lineshape which was convoluted with the Gaussian. Because of the inadequate statistical accuracy, however, we could not reliably discriminate them.

It can be seen from Fig. 1b, which shows the temperature dependence of the half-width (the width at half-maximum) of the AFM (110) reflection, that at $T < T_f$ the reflection is broadened and that this broadening of the reflection increases as the temperture of the alloy is lowered. The horizontal line in Fig. 1b corresponds to the instrumental half-width (the error is ±0.001°). This half-width was obtained from measurements of the nuclear (220) reflection which arises at the site of the magnetic reflection in the absence of a filter which removes the contribution of the half-wavelength neutrons to the scattering. The broadening of the magnetic reflection below T_f shows unambiguously that the long-range antiferromagnetic order breaks down in the reentrant spin-glass phase. We note in conclusion that at 4.2 K the antiferromagnetic correlation radius is estimated to be ~700 Å.

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