Concerning the antiferromagnetism in iron-nickel invar alloys

B. N. Mokhov and V. I. Goman'kov

I. P. Bardin Institute of Ferrous Metallurgy
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A study of neutron diffraction by single-crystal classical iron-nickel invar containing 35 at.% Ni at temperatures 4.2 and 300°K has demonstrated for the first time the absence of long-range antiferromagnetic order in this alloy.

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The hypothesis of the existence of antiferromagnetism has gained some acceptance in investigations of the magnetic structure of iron-nickel invars. This possibility is discussed in a theoretical paper,[1] and also in experimental papers,[2–4] on the basis of the Mössbauer effect, of small-angle neutron scattering, and of the magnetic properties of these alloys. However, the authors of the cited papers admit to the possibility of antiferromagnetic orientation of only individual atoms in the ferromagnetic matrix, leaving the question of the existence of long-range antiferromagnetic order unanswered. Interest attaches therefore to a paper[5] whose authors conclude, on the basis of a study of neutron diffraction from a polycrystalline invar sample with 37 at.% Ni, that in this alloy there exists long-range antiferromagnetic order with a Neel temperature $T_N = 15\,°K$. It was therefore of interest to study the magnetic structure of invar with a smaller nickel content, where the effect of antiferromagnetic ordering should be more clearly pronounced. The best object for a neutron-diffraction study is in this case a single crystal, the intensity of the Bragg reflections from which is at least two orders of magnitude larger than the corre-

T,K	$\frac{I\lambda/2\,(200)}{I\,(200)}$ %	$\frac{I\lambda/2\,(200)}{I\,(220)}$ %
4.2	0.19 ± 0.01	0.17 ± 0.01
300	0.21 ∓ 0.01	0.17 ± 0.01

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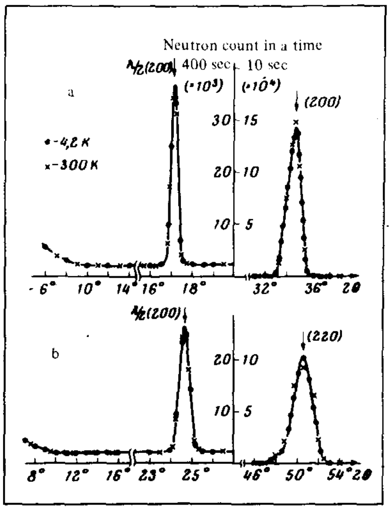

Neutron diffraction patterns from single-crystal Fe + 35 at.% Ni. Photography in the ⟨100⟩ direction (a) and the ⟨110⟩ direction (b).

sponding values obtained from a polycrystal having the same composition.

Taking this into account, we study in this paper the diffraction of neutrons by single-crystal classical invar with 35 at.% Ni at temperatures 4.2 and 300°K. The single crystal was a sphere of 9 mm diameter. The photographs were obtained in a helium cryostat using a neutron diffractometer with wavelength $\lambda = 1.07$ Å. The results of the measurements are shown in the figure. We see that within the limits of the statistical measurement error, which amounted to 1%, the diffraction patterns for both temperatures coincide. The neutron diffraction patterns contain the reflections $(\lambda/2)(200)$ and $(\lambda/2)(220)$, due to the presence of neutrons with $\lambda/2$ in the spectrum. Attention is called to the absence of reflections at angles $2\theta < 25°$ in the ⟨110⟩ direction, a fact that does not agree with the result of[5]. As seen from the table, the ratio of the integral intensities of the small-angle reflections (where, in addition to the reflections from $\lambda/2$, a contribution can be made to the intensity by the antiferromagnetic phase) to the corresponding principal reflections is constant and is exactly equal to the contribution of the $\lambda/2$ component to the intensity of the primary beam.[6]

An estimate of the possible antiferromagnetic moment per atom of alloy, obtained with allowance for the measurement errors, yields the small values 0.01 μ_B and 0.1 μ_B for the doubled antiferromagnetic cell[5] and for the cell coinciding with the chemical one, respectively. To the contrary, by specifying the appreciable moment 0.7 μ_B, as determined in[5] and also for γ-Fe in[7], we can estimate the sensitivity in the determination of the volume fractions of the indicated antiferromagnetic phases, which turn out to be 0.01 and 2%, respectively.

Thus, it follows from the results that within the indicated sensitivity there is no long-range antiferromagnetic order in classical invar.

In conclusion, we are grateful to V.V. Sadchikov for kindly supplying the single-crystal sample, to A.A. Loshmanov for help with the experiment and for useful discussions, and to I.M. Puzeĭ for constant interest in the work.

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