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INELASTIC NEUTRON SCATTERING IN γ-Mn(12%Ge) ALLOY ABOVE AND BELOW THE NÉEL TEMPERATURE

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The magnetic excitations different from spin waves in the γ-Mn(12%Ge) antiferromagnet are the subject of the present investigation. The inelastic neutron scattering was measured at 4 temperatures above T_N. The Lorentzian-type formula for the inelastic neutron scattering cross-section with the spectral width for a hydrodynamic region was used for data analysis. The obtained values of the "stiffness constants" are of the order of 200 meV Å and they depend weakly on temperature in the range of $1.04-1.25T_N$. The inelastic neutron scattering for energy transfers below and close to the value of the gap energy of the spin wave spectrum was measured at room temperature. The observed intensities can be treated as a sum of intensities of neutrons scattered on spin waves around the magnetic Brillouin zone centre and those scattered on fluctuations at the zone boundary.

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1. Introduction

The inelastic neutron scattering (INS) in the paramagnetic phase was actively studied in ferromagnetic 3*d* metals and alloys during the previous decades. For 3*d* antiferromagnets there are only a few published data on the INS in the paramagnetic phase.

Our measurements of the INS in Mn(12%Ge) alloy in a wide temperature range up to $1.25T_N$ were reported some time ago [1], but at $T > T_N$ they were not considered in terms of dispersionless fluctuations. The aim of the first part of the present paper is the analysis of those data in terms of fluctuations taking into account the anisotropy. The subject of the second part of this paper is the investigation of the INS for energy transfers lower and close to the energy gap of the spin wave spectrum for long wavelengths. The aim was a search for the excitations at the magnetic Brillouin zone (MBZ) boundary in polydomain Mn(12%Ge) alloy. In a polydomain sample with a 1-Q AF1 magnetic structure in a fcc (fct) crystal structure, the spectrometer arrangement for the MBZ centre in one type of magnetic domains, coincides with the reciprocal lattice point close to the MBZ boundary for another domain type. Usually the low energy INS is treated as due to spin waves with wave vectors close to the MBZ centre only. In our earlier work on Mn(12%Ge) [1] we have found that at 300 K ($0.62T_N$) and higher temperatures it is difficult to keep this assumption. Our INS measurements in Mn(13.7%Ni) alloy with unequal domain population demonstrated the presence of INS at the MBZ boundary [2]. The intensity of the INS at the zone boundary is, at T_N, equal to the INS intensity at the MBZ centre and it decreases with temperature, but is still observable at 300 K in this alloy. We have found that the INS around those specific points at the MBZ boundary can be described by the Lorentzian-type cross-section used for the hydrodynamic modes in the paramagnetic phase and that the values of parameters obtained in both cases are of the same order.

2. Paramagnetic region

The INS in the paramagnetic phase in the γ-Mn(12%Ge) antiferromagnet was measured by a 3-axis neutron spectrometer 1T1 at ORPHEE Reactor in LLB CEA Saclay, France. The sample description and the experimental conditions were reported earlier [1]. In the paramagnetic phase the INS was measured for energy transfers 20.7 and 33 meV around the (110) rlp and for 53.8 meV around the (112) rlp at 4 temperatures. Examples of the measured and computed distributions are presented in Fig. 1. In Fig. 1 the solid line is the computed distribution and the dashed line is the estimated background and intensity of the incoherent scattering (ICS) level. In Fig. 1b the gray dashed line is the background plus the ICS intensity

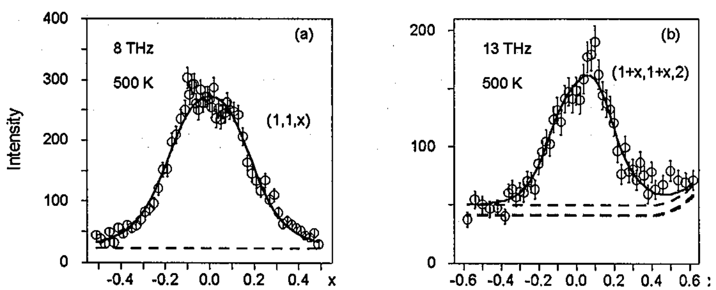

Fig. 1. The intensity distributions $I(q)$ measured at 500 K; for energy transfer 33 meV (8 THz) and $q \parallel [001]$ (a) and for 53.7 meV (13 THz) and $q \parallel [110]$ (b).

estimated from the low temperature measurements. The Lorentzian-type formula for the INS cross-section was used for the data analysis. We used the following hydrodynamic formula for spectral width generalised for anisotropic q dependence:

$$\Gamma_q = \Gamma_0 + A_{\parallel} q_{\parallel}^2 + A_{\perp} q_{\perp}^2. \tag{1}$$

The "stiffness constant" $A_{\parallel}$, determined from the distributions for 20.7 and 33 meV along [001] direction, decreases from 215 ± 11 meV Å^2 at 500 K ($1.04T_N$) to 180 ± 10 meV Å^2 at 600 K ($1.25T_N$). The values of the "stiffness constant" $A_{\perp}$ determined from the distributions for 53.7 meV along [110] direction are very close to those for $A_{\parallel}$ and they depend on temperature in a similar way.

3. Additional measurements for antiferromagnetic region

The additional measurements for the same sample were performed at room temperature ($0.61T_N$) by a 3-axis spectrometer at MARIA reactor at IEA in

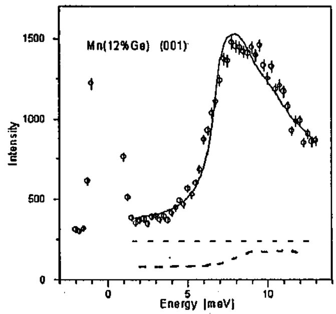

Fig. 2. The $I(E)$ distribution for the (001) reciprocal lattice point obtained at room temperature.

Świerk. The $I(E)$ distribution obtained at the (001) rlp is shown in Fig. 2. The solid line is the computed distribution for the best fit parameters of the INS cross-section by damped spin waves only. In Fig. 2 we have shown also the highest possible background plus the ICS level obtained from the $I(q)$ distributions. It is lower than that from the $I(E)$ scan by about 120 counts at low energies (2–5 meV). The gap of the spin wave spectrum is 6.8 ± 0.2 meV at room temperature. The $I(q)$ distributions were measured for an energy range of 2–12 meV in [001] and [110] directions around the (001) rlp. The $I(q)$ distributions for energy transfers 3, 4, and 5 meV are presented in Fig. 3. As seen from Figs. 2 and 3 some part of the observed intensity is difficult to analyse in terms of damped spin waves only. Guided by our results for Mn(13.7%Ni) alloy with unequal domain population [2] we postulated that some INS intensity is present around the MBZ boundary point and for a polydomain sample this intensity is mixed with the scattering due to the spin waves around the MBZ centre. The spin diffusion modes were predicted [3] and observed [4] for incommensurate spin density waves in chromium around "silent" satelites in a single domain sample. For the data analysis we used the sum of the neutron scattering cross-section for damped spin waves and that for spin diffusion modes. The cross-section for scatterring on spin waves was taken in the following form:

$$\frac{\partial^2\sigma_{\mathrm{sw}}}{\partial E\partial\Omega}\simeq\frac{E\Gamma_{\mathrm{sw}}(q)}{(E^2-E_q^2)^2+E^2\Gamma_{\mathrm{sw}}}(q)^2, \tag{2}$$

where $E_q^2=v^2q^2+E_g^2$ and $\Gamma_{\mathrm{sw}}(q)=\Gamma_{\mathrm{sw}}(0)+\Gamma_1\dot{q}$. The cross-section for neutron scattering at the MBZ boundary was used in the Lorentzian form with the spectral width given by Eq. (1). The parameters of the Lorentzian cross-section were obtained by fitting the $I(q)$ distributions for energies 2–6 meV assuming the value of the spin wave velocity obtained earlier [1] and the value of the energy gap and damping parameter obtained from the fit of the $I(E)$ distribution with a higher background plus ICS level. The obtained values of the "stiffness constants" were $A_{\|}\approx 300$ meV Å^2 and $A_{\perp}\approx 120$ meV Å^2. The obtained values of the "stiffness constants" are of the same order as the values obtained above T_{N}, but the spatial anisotropy is now large. As seen from Fig. 3 the intensity of the scattering on the fluctuations at the MBZ boundary is of the same order as the intensity of the scattering on the spin waves around the MBZ centre for energy transfer up

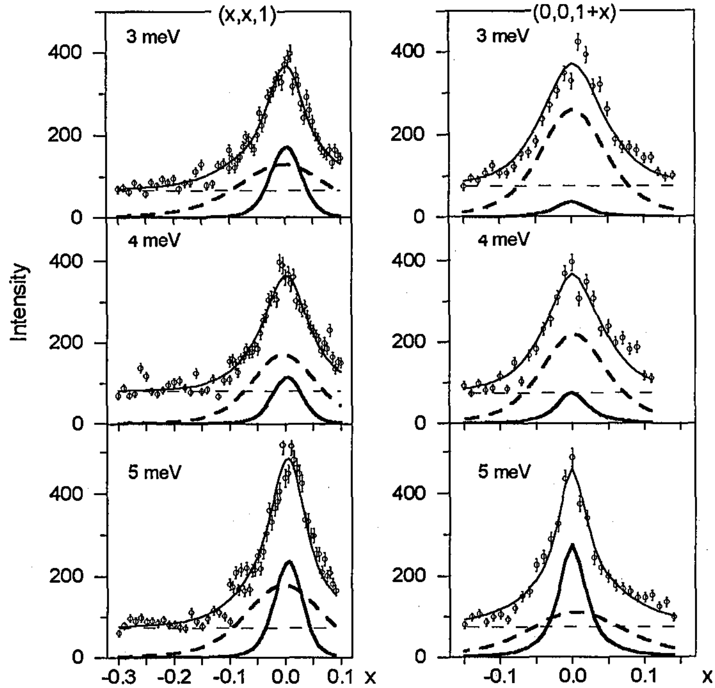

Fig. 3. The $I(q)$ distributions for energy transfers below the spin wave gap energy for $q \parallel [110]$ and $q \parallel [001]$ obtained at room temperature. The thick solid line is the contribution from spin waves, the thick dashed line is the spin diffusion type contribution, the thin dashed line is the background plus incoherent scattering. The thin solid line is the sum of all three components.

to 5 meV. For higher energies (6–12 meV) the intensity of the scattering on the spin waves around the MBZ centre dominates, but since it decreases with energy faster than the intensity of INS at the zone boundary [2] for still higher energies, the fluctuation component may be important for energies above 20 meV as we claimed in Ref. [1].

Acknowledgments

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