FAKI-IG 71-1327

SOVIET PHYSICS – SOLID STATE VOL. 13, NO. 5 NOVEMBER, 1971

LOW-TEMPERATURE MAGNETIC TRANSITION IN Mn_3Ge_2

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Translated from Fizika Tverdogo Tela, Vol. 13, No. 5, pp. 1414-1419, May, 1971
Original article submitted January 21, 1971

The effect of high pressure (up to 10,000 atm) and strong magnetic fields (up to 300 kOe) on the low-temperature magnetic transition $\Theta_1 = 158°K$ in Mn_3Ge_2 is investigated. The elastic properties of this compound were determined and dilatometric data were measured within the temperature interval 77 to 380°K. The Θ_1 magnetic transition is accompanied by compression of the crystal lattice; the signs of the $d\Theta_1/dP$ and $d\Theta_1/dH$ effects are negative. The possibility of applying the exchange-inversion theory of C. Kittel to explain the Θ_1 magnetic phase transition in Mn_3Ge_2 is considered.

The presence of two magnetic transitions in Mn_3Ge_2 has been first reported by Fakidov, Grazhdankina, and Novogrusskii [1], who noted that this compound is ferromagnetic between two temperature limits Θ_1 and Θ_2. The low-temperature transition $\Theta_1 = 153°K$ was later found to be a first-order magnetic phase transition which is associated with an abrupt onset of magnetization [2] and liberation of latent heat [3]. Further heating leads to the disappearance of magnetization of the point $\Theta_2 = 283°K$ that is also quite abrupt [the $\sigma(T)$ curve is cut off at a σ that is approximately equal to one half the maximum value] [2].

M. Shimizu [4] made an attempt to explain magnetic transitions in Mn_3Ge_2 with the aid of the band model of ferromagnetism. He assumed that the transitions Θ_1 and Θ_2 are associated with a disruption of the spin order and belong to magnetic transitions of the ferromagnetism-paramagnetism kind. Analyzing the dependence of kinetic and exchange energy on spontaneous magnetization of the collective-electron system, Shimizu proved that for an energy band with an arbitrary dispersion law there can exist conditions (depending on the Fermi level position) in which the system is paramagnetic at low and high temperatures and ferromagnetic within a certain intermediate interval of temperatures Θ_1-Θ_2. Both the onset and the disappearance of ferromagnetism at the limits of this interval should be first-order phase transitions.

Subsequent investigation of the magnetic properties of Mn_3Ge_2 raised some doubts as to the applicability of this magnetic transition mechanism to the given compound. Measurements made with a grain-oriented Mn_3Ge_2 sample [5] proved that the magnetic properties of this compound resemble very closely the behavior of antiferromagnets with weak ferromagnetism so that the transition can be treated as a Morin-point transition due to spontaneous reorientation of spins with respect to the crystallographic axes. As is well known, this class of magnetic transitions has been explained by Dzyaloshinskii [6] with the aid of the Landau theory for phase transitions. It could thus be assumed that the first-order magnetic phase transition at Θ_1 is associated with a change of magnetic symmetry of Mn_3Ge_2 and that the weak ferromagnetism of this compound is due to a displacement of the magnetic moments of the antiferromagnet sublattices through a small angle from strict antiparallelism.

In [7] the magnetic transition Θ_1 in Mn_3Ge_2 is treated as a transition due to an exchange inversion of the antiferromagnetism-ferromagnetism kind and is analyzed on the basis of the Kittel thermodynamic theory [8]. However, the available data on the low-temperature transition in Mn_3Ge_2 are far from being complete; in particular, little is known about the elastic properties of this compound and its thermal expansion and about the dependence of Θ_1 on high pressure. As is well known (see, e.g.,