Investigation of the elastic properties of mictomagnetic MnBi alloys

N. P. Grazhdankina and M. A. Novikov
Institute of Metal Physics, Ural Scientific Center of the Academy of Sciences of the USSR

(Submitted 6 July 1979)
Pis'ma Zh. Eksp. Teor. Fiz. **30**, No. 6, 333–335 (20 September 1979)

Sharp variations of the Young's and shear moduli were observed in the mictomagnetic MnBi alloys in the region of the transition temperature ($T_0 = 95$ K) between mictomagnetism-superparamagnetism.

PACS numbers: 75.30.Kz, 62.20.Dc

In recent years, the magnetic transitions in spin-glasses and in mictomagnetic alloys have been investigated thoroughly. However, it is not clear yet whether the variation of the magnetic state in the indicated systems at low temperatures $T < T_0$ (where T_0 is the freezing temperature of the spin-glass) can be called a magnetic phase transition.

According to the theories based on the molecular-field approximation,[1,2] the transition of spin-glass to the paramagnetic state is a magnetic phase transition and hence anomalous temperature dependences of the magnetic susceptibility (χ) and of the specific heat (C_p) should be observed at the transition point T_0. A large number of experimental data indicates that a sharp peak of the low-field magnetic susceptibility indeed exists at T_0; however, the specific heat is almost completely free of any pecu-

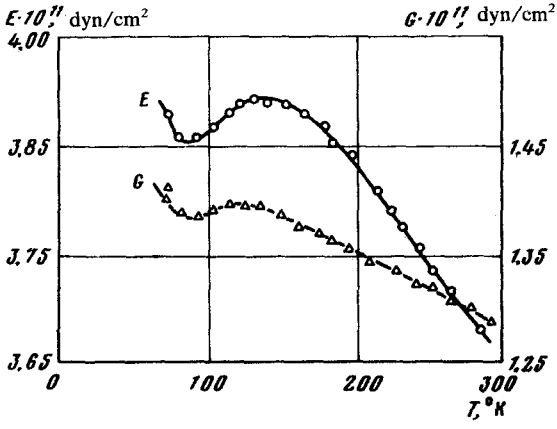

FIG. 1. Temperature dependence of the magnetic susceptibility of mictomagnetic MnBi alloy.

 0021-3640/80/180308-03$00.60

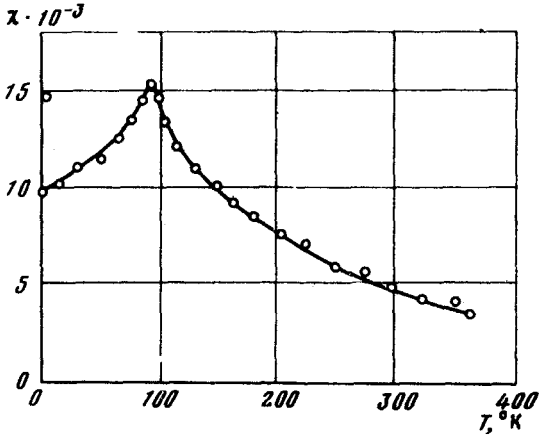

FIG. 2. Temperature dependences of Young's E and shear G moduli of mictomagnetic MnBi alloy.

liarities at T_0, and in a number of cases a very broad peak at a much higher level than T_0 can be observed on the $C_p(T)$ curve.

For mictomagnetic alloys, which, according to Beck's conception,[3] are characterized by the presence of ferro- and antiferromagnetic clusters chaotically frozen in the spin-glass, the peak on the $\chi(T)$ curve at the point T_0 is associated with the transition of the mictomagnetic state to the superparamagnetic state. The theory,[4] which takes into account the clustering of the alloy and formation of the mictomagnetic state, predicts a broad peak on the $C_p(T)$ curve at $T > T_0$ and a very small jump of C_p at T_0, which is difficult to determine experimentally.

Attempts were made to detect anomalies of the elastic properties of spin-glasses and of mictomagnetic alloys at T_0, bearing in mind that the change of the phonon spectrum and of the electron-phonon interaction due to the magnetic phase transition should change the elastic properties in the neighborhood of T_0. Of the three alloy systems investigated (Au-Fe, Cu-Mn, and Au-Cr), however, only one of them revealed an anomalous propagation rate of ultrasound near T_0.[5]

In this paper we report the results of measuring the elastic properties of mictomagnetic MnBi alloys and observation of sharp changes of the Young's and shear moduli in the region $T_0 = 95$ K of transition of the mictomagnetic state to the superparamagnetic state as a result of heating the alloy. The method of obtaining the mictomagnetic MnBi alloys and their properties will be described separately.

We measured Young's modulus (E) and the shear modulus (G) by using the resonance method, a composite vibrator and piezoelectric excitation at frequences of the order of 100 kHz in the temperature range of 77–300 K.

Figure 1 shows the temperature dependences of Young's and shear moduli from which we can see that the anomalous variation of the elastic moduli occurs only in the region of low temperatures: the minimum on the $E(T)$ and $G(T)$ curves at $T = 95$ K, near which a peak of the temperature dependence of the magnetic susceptibility, shown in Fig. 2, was observed.

The observed variation of the E and G moduli, which is totally analogous to the

anomalous variation of the elastic properties of the ordinary antiferromagnets at the Néel point, indicates that an anisotropic antiferromagnetic exchange interaction occurs in the investigated MnBi alloys. The anomalies of the elastic moduli of MnBi in the neighborhood of T_0 may be caused by the magnetostrictive effects associated with a strong volume dependence of the exchange interactions, as indicated by the large shifts of T_0 due to high pressures.

The obtained data permit us to assume that the spatially disoriented distribution of the magnetic moments of the MnBi spin-glass matrix is attributed to short-range interactions rather than to the indirect long-range interaction via the conduction electrons (RKKI type). Thus, the spin-disordered state, defined as "mictomagnetism," may occur as a result of different exchange mechanisms whose indicator is the behavior of the elastic moduli near the transition T_0.

[1]S. F. Edwards and P. W. Anderson, J. Phys. **F5**, 965 (1975).
[2]D. Sherrington and S. Kirpatric, J. Phys. **F5** L49 (1975).
[3]P. A. Beck, Met. Trans. **2**, 2015 (1971).
[4]C. M. Soukoulis and K. Levin, Phys. Rev. Lett. **39**, 581 (1977).
[5]G. F. Hawkins and R. L. Thomas, J. Appl. Phys. **49**, 1627 (1978).