The magnetic glass Bi_2O_3–Fe_2O_3

K. A. Sablina, G. A. Petrakovskiĭ, E. N. Agartanova, and V. P. Piskorskiĭ

L. V. Kirenskiĭ Physics Institute, Siberian Division, USSR Academy of Sciences
(Submitted August 10, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **24**, No. 6, 357–359 (20 September 1976)

PACS numbers: 75.50.Kj, 75.30.Qe

Since the publication of Gubanov's first theoretical paper,[1] which predicted the feasibility of long-range magnetic order in disordered solids and liquids, experimental research of amorphous magnetically-ordered substances has rapidly developed in the last decade.[2] The obtained amorphous substances demonstrate as a rule a strong weakening of the magnetic properties, as expressed by a decrease in the magnetization and in the Néel temperature in comparison with the crystal. Contributing to the attenuation due to the amorphous character itself are the diamagnetic components, which are abundantly present in the material. For example, antiferromagnetic glasses are characterized by Néel temperatures on the order of several degrees Kelvin.[3,4] A strong decrease of the Néel temperature is observed in comparison with the crystalline antiferromagnet of the initial composition.

It can be assumed, however, that the situation changes when the so-called quasi-two-dimensional antiferromagnetics are made amorphous.[5] There is a known series of crystals with layered structures, having low Néel temperatures, despite the strong exchange interactions in the layers and the large content of magnetic ions. This is a consequence of the weakness of the exchange interactions between the layers. The conversion of these compounds into the amorphous state "disturbs" the lowering and consequently also the magnetic structure. To verify this assumption, we have investigated the antiferromagnet $Bi_2Fe_4O_9$. This compound contains many magnetic ions and is characterized by a relatively low melting temperature and by a simple composition. It undergoes polymorphic transitions at 450, 775, 825, and 890 °C.[6] Its structure is layered.[7] The geometric parameters of the bonds of the Fe—O—Fe type inside the volume layers are favorable for strong exchange interactions, whereas the exchange between layers is greatly weakened. The Néel temperature is 265 °K.

Since it is difficult to obtain glasses with large contents of transition-metal ions, in view of their great tendency to crystallization, the melts must be quenched at high rates. We use for this purpose a catapult oven. The melt was

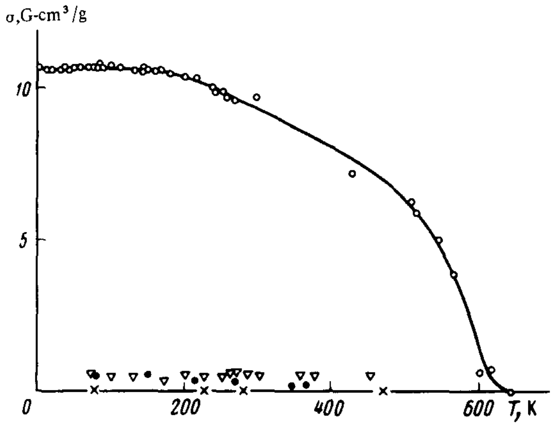

FIG. 1. Temperature dependence of the magnetization: ○—initial glass; ×—polycrystalline sample; △—heat-treated glass; ●—single crystals.

ejected by the oven into a rotating trap cooled with liquid nitrogen. The quenching rate was 10^5—10^6 deg/sec.

We obtained a glass with initial-component ratio Fe_2O_3:Bi_2O_3 = 2:1. An x-ray analysis has confirmed that the structure is amorphous. Figure 1 shows the temperature dependence of the magnetization of the glass in temperature range from 4.2 to 650 °K. The measurements were performed with a pendulum magnetometer in a field 10 kOe. Figure 1 shows also the results of measurements made on a polycrystalline $Bi_2Fe_4O_9$ sample. The sample was prepared by a ceramic technology.[8] The triangles in the figure show measurements made on glass heat treated at 700 °C for 36 h. This temperature was chosen with allowance for data of a differential-thermal analysis (DTA). The black circles denote measurements performed on single crystals grown from the melt by slow cooling.

It can be assumed from the shapes of the plots that long-range magnetic order different from the magnetic order in the crystalline analogs is present in the sample. It is difficult to identify this order definitely at the present stage of the investigation. However, an analysis of the magnetization of the glass shows that the order is not ferromagnetic. In the case of ferromagnetic order, the theoretical magnetization of the crystal is equal to 280 G-cm^3/g as against 11 G-cm^3/g for the glass. Consequently, it can be assumed that this glass is characterized by a magnetic order of the type of an uncompensated antiferromagnet.

On the basis of an analysis of the magnetic measurements and the DTA data for the initial and heat-treated samples it follows that the obtained magnetic properties of the glass cannot be attributed to the presence of Fe_2O_3 or Fe_3O_4 phases.

We are grateful to E. P. Petukhov for the x-ray analysis.

[1]A. I. Gubanov, Fiz. Tverd. Tela **2**, 502 (1960) [Sov. Phys. Solid State **2**, 468 (1960)].

[2]K. A. Sablina and G. A. Petrakovskiĭ, Amorfnye magnitouporyadochennye veshchestva (Amorphous Magnetically Ordered Substances), Preprint Phys. Inst. Siber. Div., Krasnoyarsk, 1975.

[3]T. Egami, O. A. Sacli, A. W. Simpson, and A. L. Terry, Amorphous Magnetism, Plenum, New York-London, **27** (1973).

[4]H. O. Hooper, G. B. Beard, R. M. Catchings, R. R. Bukrey, M. Forrest, P. F. Kenealy, R. W. Kline, T. J. Moran, Jr., J. G. O'Keefe, R. L. Thomas, and R. A. Verhelst, Amorphous Magnetism, Plenum, New York-London, **47** (1973).

[5]S. V. Vonsovskiĭ, Magnetizm (Magnetism), Nauka, 1971.

[6]L. A. Reznitskiĭ, Izv. Akad. Nauk SSSR, Neorganicheskie materialy **9**, 273 (1973).

[7]V. A. Bokov, S. I. Yushchuk, G. V. Popov, N. N. Parfenov, and A. G. Tutov, Fiz. Tverd. Tela **13**, 1590 (1971) [Sov. Phys. Solid State **13**, 1333 (1971)].

[8]A. G. Tutov, I. E. Myl'nikova, N. N. Parfenov, V. A. Bokov, and S. A. Kizhaev, Fiz. Tverd. Tela **6**, 1240 (1964) [Sov. Phys. Solid State **6**, 963 (1964)].