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CALORIMETRIC EVIDENCE FOR THE ABSENCE OF A MAGNETIC PHASE TRANSITION IN GALLIUM NEAR 1.7°K*

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Newbower and Neighbor[1] have recently reported the discovery of an anomaly in the electrical resistance of large single crystals of very pure gallium. They found that the resistance in zero magnetic field has a narrow plateau near 1.7°K, which is displaced to lower temperatures as the field is increased. In this Letter we discuss very precise calorimetric measurements which show that there is no corresponding anomaly in the specific heat of gallium. The result is of interest because it virtually rules out the possibility of a bulk phase transition in the range 1.1-2.3°K. This includes in particular an antiferromagnetic transition.[1] It should be noted that if we were dealing with spin-density-wave antiferromagnetism[2] we would expect the associated fractional change in electronic entropy to be of the same order as the increment in resistivity,[2,3] i.e., no more than a few percent. A principal motivation for the present work was that the existence of such a small anomaly in the specific heat could not be established or ruled out unambiguously on the basis of available data.[4,5] This was in part due to scatter in the data and in part due to the effect of a magnetic field not having been explored above 1.1°K. In view of the depression of the resistive anomaly to lower temperatures with increasing field, it is clearly advantageous to compare heat capacity data taken in zero field with data taken in various external fields. If the anomaly were in fact caused by a phase transition, such a comparison would indicate directly the associated change of entropy.[6]

Our specimen consisted of 7.9 moles of "super-pure" gallium obtained from the same source[7] as that used by Newbower and Neighbor, and grown in the form of a cylindrical single crystal 13 cm long and 3 cm in diameter. The heat capacity was measured using the continuous warming method and apparatus described elsewhere.[8] In two pairs of relatively low-resolution runs (temperature steps ~0.03°K) zero-field data were compared with data taken in 8 Oe and in Earth's field, respectively. In addition, we made several high resolution runs (temperature steps less than 0.005°K) to insure that no fine structure had been overlooked.

None of the measurements gave any indication of a phase transition. For example, Fig. 1 shows measured values of the specific heat difference $\Delta C \equiv C(H=0)-C(H=8\ \text{Oe})$ expressed as a fraction of $C(H=0)$. The presence of a small, systematic component in ΔC is revealed by Fig. 2, in which the data have been converted by integration to an entropy difference ΔS, assuming $\Delta S = 0$ above 2.3°K. This component of ΔC, which amounts to less than 0.2%, is of no special significance. It corresponds to a variation of less than 0.5 erg/min in stray heat input to the specimen, which is smaller than

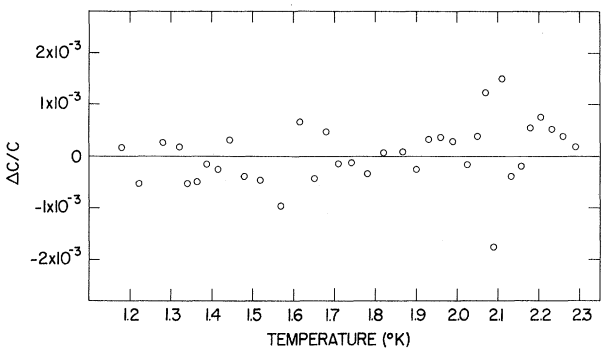

FIG. 1. Measured values of ΔC, expressed as a fraction of the heat capacity measured in zero field.

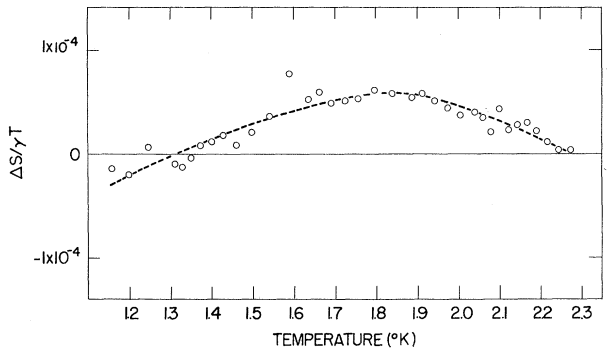

FIG. 2. Values of ΔS derived from the data shown in Fig. 1, expresses as a fraction of the normal electronic entropy.

our estimate of the uncertainty in stray heat over the course of a run. The significant features of Fig. 2 are the very small upper limit to ΔS in comparison with the normal electronic entropy ($\Delta S/\gamma T \lesssim 6\times10^{-5}$), and the corresponding absence of any substantial discontinuity or sudden change of slope near 1.7°K.

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[6]We can measure small differences in specific heat arising from the application of the magnetic field to far higher accuracy than a specification of the error in the specific heat itself would indicate. A problem analogous to the current one is the determination of the electronic heat capacity in strong-coupling superconductors [see, for example, J. E. Neighbor, J. F. Cochran, and C. A. Shiffman, Phys. Rev. 155, 384 (1967)].

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PHOTOACTIVITY IN BISMUTH GERMANIUM OXIDE

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Bismuth germanium oxide,[1] $Bi_{12}GeO_{20}$, is an electro-optic[2] semiconductor which belongs to the cubic point group 23.[2] It is also piezoelectric,[1,3] photoconductive,[1,4] optically active,[2] and has unusually good ultrasonic properties.[5] The dark resistivity, ρ, is of the order of 10^{10} Ω cm and it was found[2] that the optical activity can be changed by an externally applied electric field. During an investigation of these effects, we have observed very large electric-field-biased, photoinduced, static changes in optical polarization using low-intensity monochromatic polarized light as an optical probe. We have also observed transiert and oscillatory effects of a similar nature. Since the major axis of the resultant elliptically polarized light is rotated by the photoinduced charge carriers, the effect can be called photoactivity.

These modifications in polarization may be induced under various conditions of excitation and are explained in terms of the charge carrier initiation of high electric field domains. In the absence of light, bismuth germanium oxide is an insulator. Since it is also photoconductive, the illumination of a small spot or region will result in the generation of free electrons, holes, or hole-electron pairs. Under the influence of the applied static field either or both kinds of charge carriers will be displaced, setting up a high electric field domain. Examination of static and slowly moving electric field domains also has been possible in other high-resistivity crystals. For example, the Franz-Keldysh effect has been used[6] in CdS to determine the regions of field inhomogeneity, and a scanning light spot has been used[7] in GaAs to map the regions of changes in photoconductivity response produced by field inhomogeneities.

The experimental arrangement employs a polarizing microscope in which the source light passes through a narrow-band optical filter before being transmitted through the crystal. Several types of compensators are employed as required. In bismuth germanium oxide, for a dc voltage applied parallel to either the