increasing number of electrons drawn out from the α-particle track to energies exceeding the xenon excitation energy.

Curves 2a and 3a characterize the additional increase in the luminescence following application of a pulsed electric field of the same polarity as the constant field. (Pulsed field amplitude ≈2 kV, pulse duration ≈1.5 μsec, delay relative to instant of α-particle passage 150 nsec, distance between electrodes 0.53 mm.)

The presence of an additional increased luminescence in the pulsed field makes it possible, by varying the pulse delay, to determine the electron drift velocity in the liquid xenon. The obtained value $(1.3 \pm 0.5) \times 10^5$ cm/sec (at $E/p = 0.38$) agrees with the electron drift velocity in gaseous xenon [3].

We were thus able to establish the following: (i) The behavior of free electrons in liquid xenon is similar to their behavior in gas. (ii) The electrons produced by the α-particle have a sufficiently long life and can be accelerated by either constant or pulsed electric field to energies sufficient to excite the liquid-xenon atoms.

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## MAGNETIC PROPERTIES OF METALS: SOLID SOLUTIONS OF ANTIMONY IN BISMUTH

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In addition to quantizing the spectrum and causing Landau diamagnetism, a magnetic field perturbs the states of bands separated by a small gap and mixes their wave functions. This is as if the bands were to come closer together, so that the occupied states of the lower band increase their energy and make a diamagnetic contribution to the susceptibility, and the states of the upper band, to the contrary, make a paramagnetic contribution [1,2]. Consequently, this mechanism should have the unusual property that maximum diamagnetism should appear in the two-band model in the absence of free carriers, i.e., in the semiconducting situation. Such a simplified treatment of the interband contributions of the susceptibility is based more on intuitive considerations than on rigorous theoretical calculation, so that this treatment, together with the result of its application, calls for an experimental verification. Convenient media for this purpose are bismuth-antimony alloys, in which the required metal-semiconductor transition is realized by a monotonic band displacement resulting from the addition of antimony [3].

The magnetic susceptibility of single-crystal alloys containing up to 14 at.% antimony was investigated in the temperature region 4.2 - 300°K.

The results are shown in Figs. 1 and 2 (the black point in Fig. 1 is taken from [4], and the vertical error bars represent the uncertainty due to the field dependence of $\chi$).

We present below the distinguishing features of the obtained data and the conclusions based on them.

1. The diamagnetism in the direction of the binary axis ($\chi_\perp$) increases strongly at 4.2°K with decreasing number of free carriers as the antimony is added, and indeed reaches a maximum value in the semiconducting region. Thus, we have obtained direct proof that the diamagnetism of bismuth has an interband origin and, most important, that the employed qualitative approach is correct.

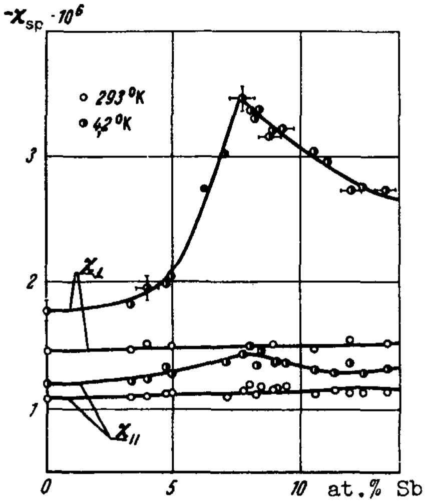

Fig. 1

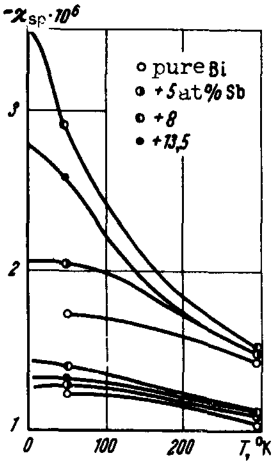

Fig. 2

2. The maximum value $\chi_\perp = -3.5 \times 10^{-6}$ cm$^3$/g coincides with the experimental estimate for hypothetically pure bismuth that has been transformed into a semiconductor [2]. Since $\chi_\perp$ corresponds to the smallest electron masses, the main contribution to the effect is made by the light-carrier bands, and consequently their structure remains unchanged when the antimony is introduced.

3. A temperature rise, by generating free carriers, decreases the diamagnetism, as expected. Inasmuch as the characteristic behavior of $\chi_\perp$ levels out at T ~ 200°K, the states that participate effectively in the interband interactions lie in an energy interval ~20 meV, which serves as an upper limit of the energy gap between the light-carrier bands.

4. The maximum of the diamagnetism is observed at an antimony concentration 7.5 at. %, although according to electric-conductivity data a thermal gap is produced at ~5 at.% [3]. The shift of the maximum is of fundamental character, since it remains practically unchanged when the perfection of the alloys is made worse on purpose. The most effective in the magnetism under consideration are the states at the band extrema, and the true band boundaries with allowance for the smearing due to the disordered nature of the lattice potential should become manifest in the susceptibility of the alloys (unlike in a number of other properties). Consequently, the observed shift makes it possible to estimate the width of the smearing of the band boundaries in the alloy, which amounts to ~3 meV at 7 at.% antimony.

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# NONLINEAR PROPERTIES OF A SUPERCONDUCTING LEAD FILM AT MICROWAVE FREQUENCIES

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Recent communications report the use of superconducting films for microwave conversion [1,2]. We observed frequency conversion in a superconducting lead film in the 3-cm band.

Lead films 200 - 400 Å thick were deposited in vacuum on one of the broad faces of a rectangular dielectric resonator (rutile single crystal measuring 4 x 4 x 1.5 mm), placed in a waveguide in such a manner that the magnetic field component was in the plane of the film. The fundamental mode of this resonator had a much lower frequency than those used in the experiment, so that one of the higher modes was employed. The coupling between the resonator and the waveguide was regulated by varying its depth of insertion in a section of waveguide operating beyond cutoff. The intrinsic Q of such a resonator in the 3-cm band was about $10^4$ at liquid-helium temperature. All the experiments were made in a zero magnetic field at 4.2°K.

When two signals of close frequency were fed to the resonator, a combination frequency spectrum $[(m + 1)f_1 - mf_2]$, $m = 0, \pm 1, \pm 2, \ldots$ was obtained. Raising the power of

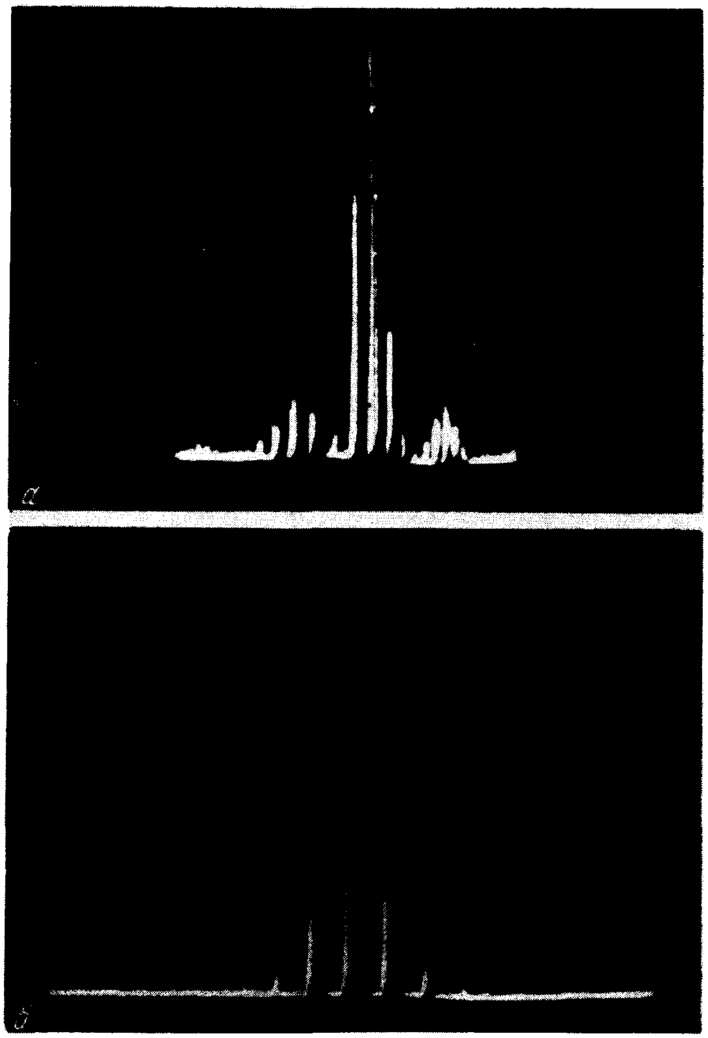

Fig. 1. a - combination spectrum of two microwave signals in the generation mode; b - the same in the presence of only the "illumination" signal (weak microwave signal turned off, frequency scale reduced).