Since the experimental thresholds were determined by us with high accuracy, we can determine from them ΔE, which for the $Mg^+ + Rb$ pair is equal to 0.4 eV, and we obtain $\Delta R = 24$ a. u.

For the $Mg^+ + Cs$ pair, the 4^3S_1 level of Mg lies below the resonant levels $6^2P_{1/2}$ and $6^2P_{3/2}$ of the cesium atom[1], the distance between which is 0.07 eV. In this case, the potential curve crosses in succession the curves 3 and 2 as the particles move apart; the intersection points R_1 and R_2 are quite far from each other (Fig. 2b). This gives rise to two periods in the total excitation cross section of the 4^3S_1 level of Mg, and therefore, in contrast to the $Mg^+ +$ Rb pair, the interaction between the terms corresponding to the excited $6^2P_{1/2}$ and $6^2P_{3/2}$ levels of Cs and the 4^3S_1 level of Mg must be considered independently. Then, in accord with the law of conservation of the probabilities of excited-state population, an exact counterphase relation should be observed also for the excitation function of the $\lambda = 8943$ Å line of Cs, the initial level $6^2P_{1/2}$ of which is only 0.031 eV removed from the interfering 4^3S_1 level of the magnesium atom, and it is natural to assume a stronger interaction between these levels.

Calculation by formula (3) of the crossing (pseudocrossing) distances of the potential curves for the $Mg^+ + Cs$ pair yields $\Delta R_1 = 10.4$ a.u. and $\Delta R_2 = 8.4$ a.u. (at $\Delta E = 0.5$ eV).

Thus, the two oscillation periods, which we were the first to observe, are a direct experimental confirmation of the theoretical conclusions made in [3], that several oscillation modes can appear in the total level-excitation cross sections in ion-atom collisions due to interaction of several inelastic channels.

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[1] The transition from the $6^2P_{1/2}$ level of Cs ($\lambda = 8943$ Å) which lies closer to the 4^3S_1 level of Mg, could not be measured because of the lack of sensitive receivers for this region of the spectrum.

[1] O. B. Shpenik, A. N. Zavilopulo, and I. P. Zapesochnyi, Zh. Eksp. Teor. Fiz. 62, 879 (1972) [Sov. Phys.-JETP 35, 466 (1972)].
[2] H. Rosenthal and H. Foley, Phys. Rev. Lett. 23, 1484 (1969).
[3] V. A. Ankudinov, S. V. Bobashev, and V. I. Perel', Zh. Eksp. Teor. Fiz. 60, 906 (1971) [Sov. Phys.-JETP 33, 490 (1971)].

EXPERIMENTAL OBSERVATION OF CONFIGURATION EMF's

T. M. Lifshitz, O. Yu. Polyanskii, and V. V. Romanovtsev
Institute of Radio Engineering and Electronics, USSR Academy of Sciences

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We have investigated the nonlinear properties of single-crystal Bi and n-GaAs films, governed by the sample configuration. The observed nonlinearity is attributed to the existence of an intrinsic Hall effect (in the Bi films) and to an effect similar to the Bernoulli effect in an incompressible liquid (in the GaAs films).

When current flows through a conductor of variable cross section, one can expect to observe in it an emf due to the change in the current density along it. The appearance of this emf is usually ascribed to an effect analogous to the Bernoulli effect in an incompressible liquid [1 - 4], or to the Hall effect in the current's own magnetic field (the intrinsic Hall effect) [5]. There are, however, no reliable reports of actual observation of these effects. Thus, the experiments of Ivashenko [1] were subsequently refuted by Dorfman and Kagan [2], who have shown that what Ivashenko actually observed was the thermal emf produced in the experiments. Chester [3], in experiments on bismuth films, obtained a "Bernoulli emf" larger by about four orders of magnitude than the expected value, apparently also because of the produced thermal emf. There is no methodological assurance that in the experiments of Jaggi [5], which were aimed at observing the intrinsic Hall-effect emf, it was possible to prevent the occurrence of a thermal emf (low frequencies, 30 – 60 Hz, a strong dependence of the effect on the sample temperature, impossibility of comparing the Hall coefficient calculated from the observed emf with direct measurement data). Thus, it cannot be assumed the configuration emf's have been observed experimentally.

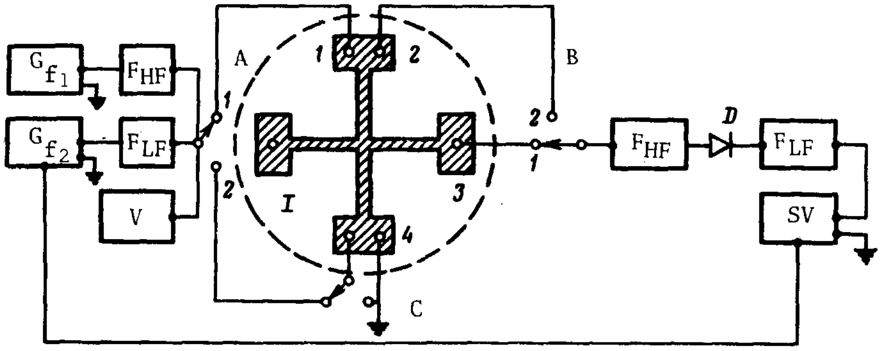

Fig. 1. Block diagram of measurements and configuration of samples. I — film on insulating substrate. Film dimensions: GaAs - thickness d = 2.5 μ, length of narrow part ℓ = 100 μ, width of narrow part W = 10 μ; Bi - thickness d = 0.3 μ, ℓ = 1 mm, W = 70 μ. G_{f_1} and G_{f_2} - generators, V - voltmeter, F_{HF} and F_{LF} - high-pass and low-pass filters, SV - selective microvoltmeter with synchronous detector, D - crystal detector.

We have investigated the configuration effects on a number of single-crystal bismuth films grown on mica substrates (trigonal axis perpendicular to the plane of the film), and epitaxial single-crystal n-GaAs films grown on insulating substrates of the same material. The carrier density in the Bi films was $n_e = n_p = 1.3 \times 10^{19}$ cm^{-3}, and the electron and hole mobilities at room temperature were $\mu_e = 2.5 \times 10^3$ and $\mu_p = 2.9 \times 10^3$ cm^2/V-sec, respectively. In the GaAs films we had $n_e = 3.5 \times 10^{16}$ cm^{-3} and $\mu_e = 2.9 \times 10^3$ cm^2/V-sec. Lowering the temperature from 300 to 77°K did not change this quantity more than 20%. The configurations and linear dimensions of the films are shown in Fig. 1.

The measurements were performed by mixing a high-frequency voltage (f_1 = 2 MHz or 180 MHz) with a low-frequency voltage (f_2 = 1 kHz) on the nonlinear sample. The mixed signal was passed through a high-pass filter, detected, and measured with a low-frequency selective amplifier with a synchronous detector. The operation of the circuit was monitored by replacing the sample with its ohmic equivalent. The signal observed under these conditions was regarded as parasitic; it did not exceed 40 nV and 0.5 μV in the measurements of the bismuth and GaAs films, respectively. By manipulating the switches A, B, and C we have established that the mixing signal is observed only when switches A and B are in position 1, and in this case the signal magnitude does not depend on the position of switch C. It is easily understood that this result excludes the possibility of the observed emf being produced at some contact, i.e., is due to heating of the sample or of the electrons in it. It is seen from Fig. 2 that the difference between the signals at f_1 equal to 2 and 180 MHz does not exceed 20%. It follows therefore that the inertia of the observed effect is in any case less than 10^{-9} sec.

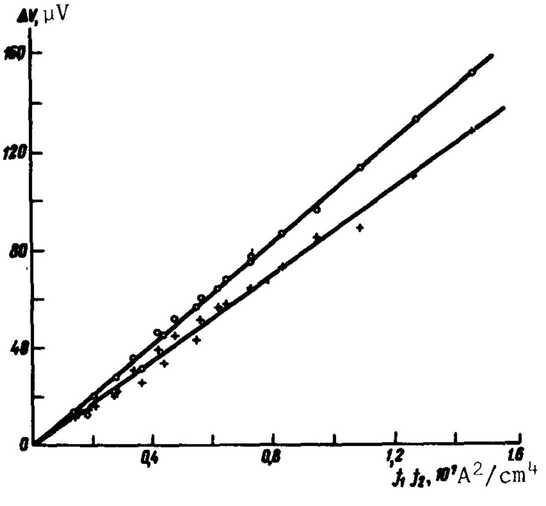

Fig. 2. Difference-frequency voltage ΔV on contacts 3-4 vs. the product of the current densities j_1 of frequency f_1 and j_2 of frequency f_2 for GaAs film: o) f_1 = 2 MHz, +) f_1 = 180 MHz. Switches A and B are in position 1.

Let us compare the observed emf's with the expected values. The "Bernoulli emf" was calculated in [4]. For arbitrary degeneracy and in the approximation in which the carriers are elastically scattered, the expression for this emf is

$$\Delta V_B = 2C \frac{F_{3k+3/2}(\eta) F^2_{3/2}(\eta)}{F^3_{k+3/2}(\eta)} j^2 \qquad (1)$$

where $C = (1 + k)m/n^2e^3$, k is the exponent in the energy dependence of the momentum relaxation $\tau = \tau_0 \varepsilon^k$, j is the current density in the narrow part of the film, n, m, and e are the concentration, effective mass, and charge of the electrons, $F_m(\eta)$ are the Fermi integrals, and η is the reduced chemical potential. For weakly inelastic carrier scattering mechanisms (acoustic and impurity), the values of k are -1/3 and 3/2, respectively, and the calculated emf for n-GaAs samples ($m = 0.06m_0$ [6]) at $j_1 = j_2 = 3.5 \times 10^3$ A/cm^2 lies in the range

ΔV_B = 100 - 200 μV. The experimentally measured emf lies likewise in this range and increases linearly with the product $j_1 j_2$ (see Fig. 2).

The intrinsic Hall emf is given by [5]

$$\Delta V_H \approx \frac{\ln 4\mu_0 S}{4\pi n e} j^2, \qquad (2)$$

where S is the area of the cross section of the narrow part of the film. Substituting in (2) the same values of the parameters for the GaAs samples we obtain ΔV_H = 1 μV. We see that in the case of GaAs the "Bernoulli effect" plays the predominant role. For bismuth films at $j_1 = j_2 = 5\times10^4$ A/cm^2, assuming $m = 0.05\ m_0$ and taking into account the presence of two types of carrier (electrons and holes), we obtain respectively ΔV_B = 3 nV and ΔV_H = 320 nV. In contrast to GaAs, the Hall emf greatly predominates here. The calculated value of this emf is close to the observed one (Fig. 3).

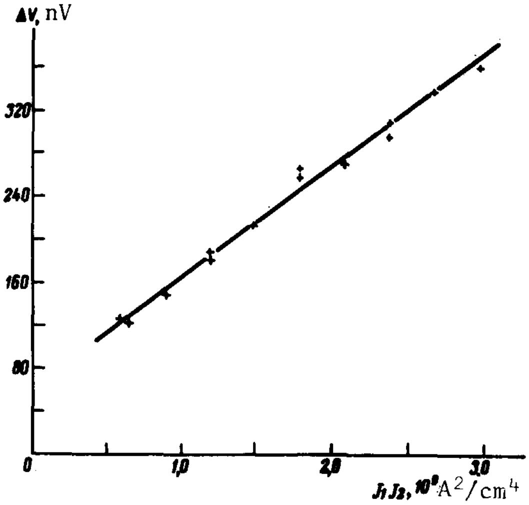

Fig. 3. The same as in Fig. 2, but for a Bi film, f_1 = 180 MHz.

We can thus state that configuration emf's of both types were observed in the described experiments, namely the "Bernoulli emf" in GaAs films and the intrinsic Hall emf in bismuth films.

[1] N. V. Ivashenko, Zh. Eksp. Teor. Fiz. 9, 892 (1949).
[2] Ya. G. Dorfman and A. S. Kagan, ibid. 10, 358 (1940).
[3] M. Chester, Phys. Rev. Lett. 5, 91 (1960).
[4] M. Chester, Phys. Rev. 133, A907 (1964).
[5] R. Jaggi, Phys. Rev. 122, 448 (1961).
[6] O. Madelung, Physics of III-V Compounds, Wiley, 1964.

EFFECT OF REVERSIBLE PRESSURE DEPENDENCE OF X-RAY K LINES OF SMARIUM IN SmS

V. A. Shaburov, A. E. Sovestnov, and O. I. Sumbaev
Nuclear Physics Institute, USSR Academy of Sciences
Submitted 3 August 1973
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A decrease in the energy of the $K\alpha_1$, $K\beta_1$, and $K\beta_{2,4}$ x-ray lines of samarium, by as much as one electron volt, was observed in SmS at pressures 6 — 9 kbar; this decrease vanished when the pressure was removed.

A reversible change in the dimensions of the crystal lattice of SmS ($\Delta v/v \simeq 14\%$) was observed at pressures 6 — 8 kbar. No change took place in the lattice symmetry (of the NaCl type before and after the transition), and the phenomenon was therefore classified as an isomorphic phase transition analogous to the known transition of metallic cerium.

It is assumed [2] that under pressure the 4f electron (electrons) of the initially divalent samarium, with configuration [Xe]$4f^6 6S^2$ goes (go) over in part to a valent level, probably 5d. The configuration is then [Xe]$4f^{6-\eta}5d^{\eta}6S^2$, and the valence approaches three ($2 + \eta \simeq 2.7$). The resultant 5d electrons produce metal-metal bonds in the SmS lattice. This model explains the observed change of volume and the appearance of metallic conductivity, and apparently also the almost complete vanishing of the magnetic moments localized at the samarium atoms [2].

It was shown in [3 - 5] that the decrease in the number of 4f electrons in chemical transformation of rare-earth elements leads to anomalously large characteristic shifts (energy decreases) of the x-ray K lines1). Therefore if the model proposed for SmS is indeed realized, then one should expect a strong and reversible pressure dependence of the energy of the principal