When all the superconducting cold-deposited Cu-Ge films were heated to room temperature, they did not become superconducting after cooling to 1.2°K; the same applied to Ag-Ge down to 1.0°K.

Thus, it can be stated that superconductivity was observed in the systems Au-Ge, Ag-Ge, and Cu-Ge at temperatures from 1.5 to 2.7°K. The onset of the superconductivity can apparently be attributed to the formation of new unstable phases in these systems, owing to the exceedingly large rate of condensation upon evaporation of the alloy by the laser pulse. As already noted earlier [3], the occurrence of superconductivity of nonequilibrium phases, observed in a number of systems, may be due to the fact that these phases have a stronger electron-phonon interaction than equilibrium alloys of the same concentration. It is possible that this is precisely why these phases are unstable.

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GIANT ZERO-BIAS ANOMALIES AND SPACE-CHARGE-LIMITED CURRENTS IN TUNNEL JUNCTIONS

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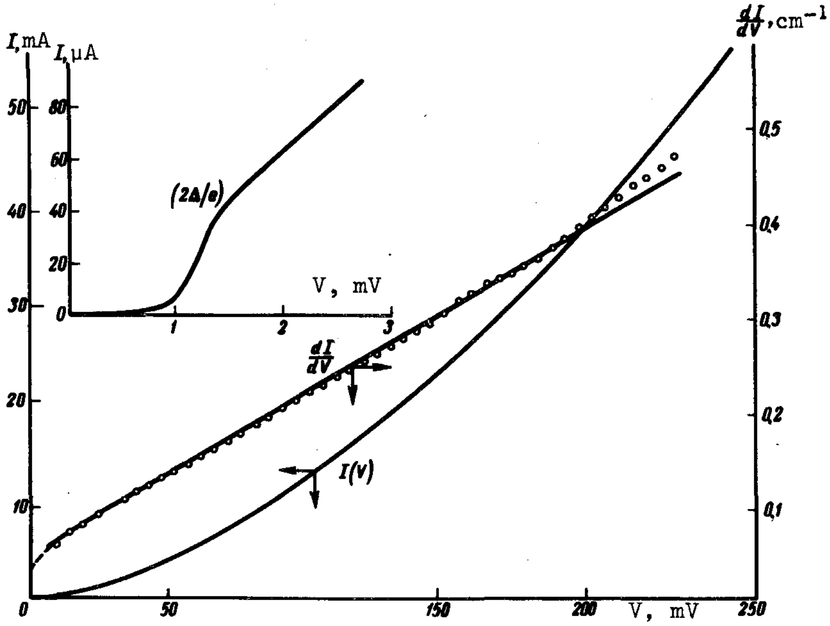
There exists a special type of zero-bias anomaly of tunnel characteristics, called "giant zero-bias anomalies" and first observed by Rowell and Shen in Cr-I-Ag and Cr-I-Pb tunnel junctions [1, 2]. A giant zero-bias anomaly is a burst of differential resistance of the contact, dV/dI, at V = 0, symmetrical with respect to the ordinate axis and independent of the magnetic field, and corresponding to an approximate tenfold or larger increase of the conductivity dI/dV in the voltage interval from zero to several dozen or even hundreds of millivolts. Attempts to explain the origin of the giant zero-bias anomalies as being due to strong interaction of the tunneling electrons with the antiferromagnetic (or ferromagnetic) barrier [4, 5] are unsatisfactory, mainly because they cannot cover from a unified point of view the entire variety of the phenomena observed in the experiments [1 - 3]. In the present paper we propose an explanation of the giant zero-bias anomalies on the basis of space-charge-limited conduction currents (SCLC) through the dielectric. Such currents can flow in tunnel junctions together with the ordinary tunnel current. We present also preliminary experimental results of an investigation of giant zero-bias anomalies in Sn-I-Sn contacts, where the dielectric layer was produced as a rule by oxidizing the Sn base film in air at room temperature. By varying the film-condensation and oxidation regimes it was possible to obtain both contacts exhibiting standard tunnel characteristics in a wide interval of voltages (0 - 500 mV) and the anomalous characteristics described below.

Figure 1 shows typical current-voltage characteristics of an Sn-I-Sn tunnel contact, exhibiting an anomalous increase of the conductivity in the voltage interval 0 - 250 mV. In the insert is shown the current-voltage characteristic in the region $V \sim 2\Delta/e = 1.21$ mV, demonstrating convincingly that at those voltages the current is determined by the tunnel mechanism. It is important to emphasize that at large voltages, dI/dV is proportional to V in a wide interval, i.e.,

Fig. 1. Current-voltage characteristic of Sn-I-Sn tunnel junction, T = 1.6°K. The characteristic dI/dV(V) was obtained by inverting the dV/dI(V) automatically-plotted curves. The amplitude of the modulating voltage was <100 μV.



$$dI/dV = 2AV + B, \quad I = I_1 + I_2; \quad I_1 = AV^2, \; I_2 = BV, \tag{1}$$

where A and B are constants.

The theory of SCLC, constructed for currents flowing through dielectric metal-diode-metal (MDM) diodes [6, 7], presupposes that the intrinsic conductivity of the dielectric can be neglected compared with the conductivity due to the carriers injected from the electrodes. The detailed injection mechanism, as well as the conductivity mechanism, is immaterial for a qualitative understanding of the main features of the current-voltage characteristic. In the general case the current-voltage characteristic at small V iv linear, followed by a quadratic section $I \propto V^2$, which at sufficiently large V goes over again into Ohm's law $I \propto V$. In spite of the fact that, as noted by Adirovich [7], the current-voltage characteristic does not always contain a quadratic section, its presence can always be regarded as convincing evidence favoring the existence of SCLC in MDM systems. An approximate derivation of Child's law for SCLC leads to the expression [8]

$$I_1 = \frac{1}{4\pi}\frac{\epsilon\mu}{d^3}V^2, \tag{2}$$

where ε is the dielectric constant, d is the thickness of the dielectric, and μ is the mobility of the carriers. Figure 2 shows the current-voltage characteristic in a logarithmic scale immediately after the preparation of the contact (1) and after annealing at room temperature for 12 hours (2). As seen from the curves in the insert, prior to the annealing almost the entire current has a non-tunnel nature, whereas after annealing a noticeable part of the total current is the tunnel current, which has a singularity at $V \simeq 2\Delta/e$. The slope of the curve in the logarithmic scale gives the exponent if the current-voltage characteristic is approximated by the equation $I = \text{const}\cdot V^n$. As can be seen, the slope increases for both curves, from a value close to unity to a value equal to 2, and then decreases again. The latter singularity greatly emphasizes the difference between the observed current-voltage characteristics from the tunnel characteristics, which are characterized by a monotonic increase of the slope. Annealing of the Sn-I-Sn samples leads to an effective decrease of the thickness of the barrier layer [9]. It is characteristic that the divergence

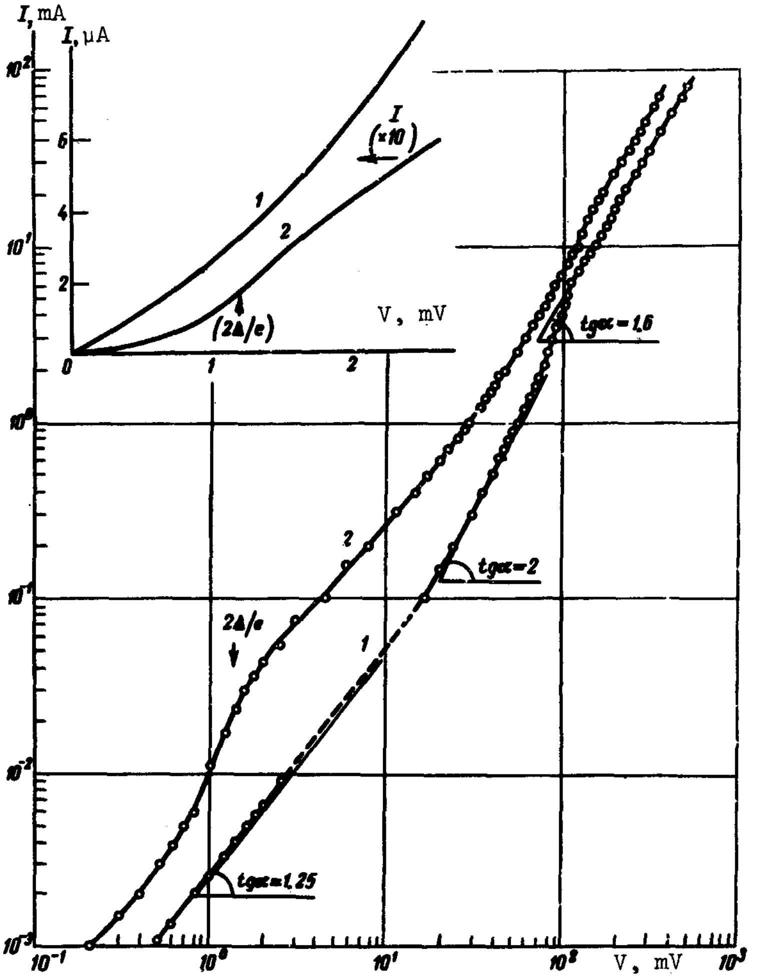


Fig. 2. Current-voltage characteristics of Sn-I-Sn junction: 1 - prior to annealing; 2 - after annealing for 12 hours at room temperature. $T = 1.6°K$.

of the current-voltage characteristics close to unity and to two, is small in the ohmic region at large V, where $I \approx 1/d$ increases in the quadratic region, where according to (2) $I \propto d^{-3}$, and is maximal in the region of small V, where the specific contribution to the tunnel current, which depends on d exponentially, $I \propto e^{-ad}$, is appreciable. This affords also a natural explanation for the results of Rowell for Cr-I-Pb junctions [2] (Pb in the superconducting state), from which it follows that the "tunnel behavior" of the samples becomes worse with increasing voltage V. Indeed, at small V it is easy to visualize a situation wherein $I_1 << I_2$ and almost the entire current is due to the current mechanism. With increasing V, the relative contribution of the quadratic term increases rapidly, and this leads to the observed deterioration of the "tunnel behavior." We note that at sufficiently larve V (on the order of the height of the barrier) the tunnel current increases exponentially with the voltage, and again becomes predominant.

The theory of SCLC [7] leads to a linear dependence of the differential resistance at zero on the reciprocal temperature T^{-1} (provided the mobility μ is independent of the temperature)

$$R_0 = \frac{4ed^3}{3\pi\epsilon\mu}\frac{1}{kT}, \tag{3}$$

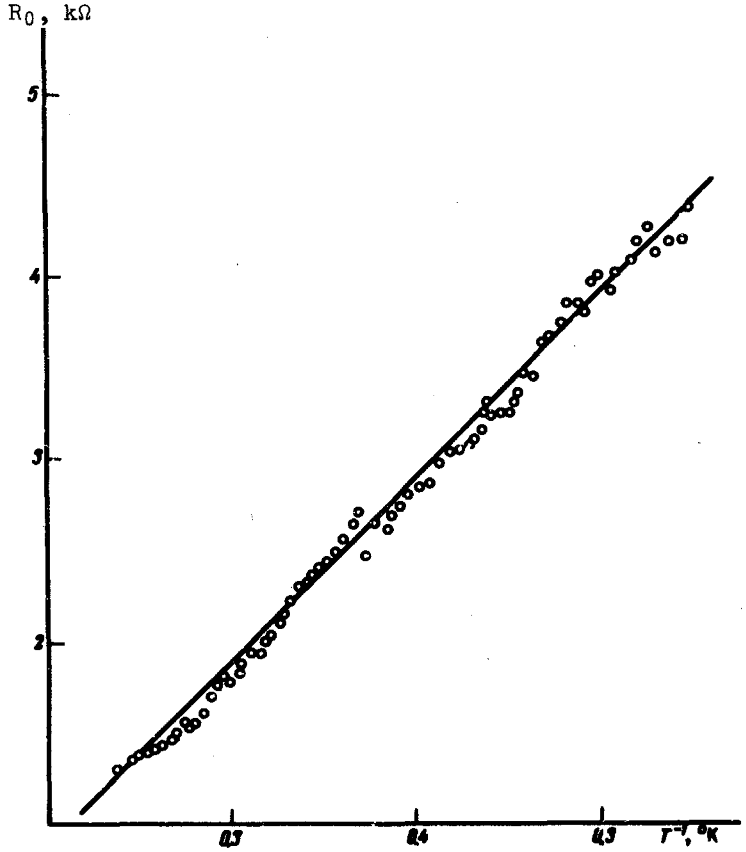


Fig. 3. Temperature dependence of the dynamic resistance at V = 0 for the Sn-I-Sn junction with a non-tunnel conductivity mechanism.

which is indeed observed in experiment. Figure 3 shows a plot of $R_0(T)$ for a contact having $I_1 \gg I_2$ even in the region of small V, and therefore there is no increase of the current at $V = 2\Delta/e$. In a number of cases, however, a weaker dependence of $R_0(T)$ is observed, and this obviously is connected with the different structure of the barrier layer, which determines the injection and conductivity mechanisms. Of particular interest is the influence of the space charge on the superconducting film characteristics and the singularities connected with the excitation of the vibrations of the impurity organic molecules in inelastic tunneling. In the former case, apparently, one should expect a smearing of the current jump at $V = 2\Delta/e$ (see the inserts of Figs. 1 and 2), and in the latter case a screening of the electric field of the impurity molecule, leading to a weakening and possibly a vanishing of the absorption bands in the tunnel spectra [10].

Thus, investigations of the current-voltage characteristic of tunnel junctions, which exhibit giant zero-bias anomalies of the resistance, points to the existence of one more mechanism of current flow through a tunnel contact - a conductivity current limited by space charge, which, like the additional current flowing through the microscopic short circuits penetrating through the barrier layer, can serve as a serious hindrance to the observation and interpretation of data on the tunnel effect.

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OPTICAL ORIENTATION OF Kr ATOMS IN THE METASTABLE $^3P_2$ STATE

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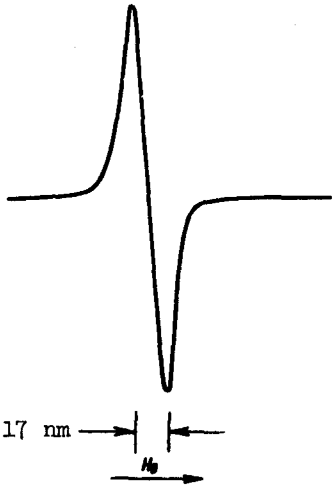
The phenomenon of optical pumping of inert-gas atoms in the metastable $^3P_2$ state has been observed so far only in three gases, Ne, Ar, and Xe [1 - 3]. We report here the first experiments on optical orientation of Kr atoms in the $^3P_2$ states.

We use in the experiments the usual procedure of observing optical-pumping signals as revealed by the change of absorption of light by the atoms at magnetic resonance, using the differential-passage technique (frequency modulation of the resonant RF field was used). To increase the pump-light intensity, we used a disk lamp (3 cm diameter, 0.4 cm thick) similar to that used for optical orientation of helium atoms in [4].



Derivative of absorption signal in optical orientation of Kr atoms in the $^3P_2$ state (registered wavelength λ = 8929 Å, Kr pressure 1.4 mtorr, resonant frequency ν_0 = 3 MHz).

The discharge was excited in the lamp with the aid of a GS-6 oscillator (frequency 450 MHz, power 3 W). The pump lamp and the absorbing call (4 cm diameter, 8 cm length) were connected to a vacuum system that made it possible to vary the Kr pressure in the lamp and in the cell independently.

Metallic cesium was used as a getter to eliminate the influence of the impurities [5].

Signals of optical pumping of the Kr atoms were obtained at 8929 and 8113 Å, corresponding to the transitions $5s\,^3P_2 \rightarrow 5p\,^3S_1$ and $5s\,^3P_2 \rightarrow 5p\,^3D_3$. An interference filter was placed ahead of the photoreceiver to separate each of the indicated wavelengths. The magnetic-resonance signals were observed at a g-factor value close to 1.5. The largest attained signal/noise ratio was 2×10^3 in a band of 0.5 Hz. The figure shows the magnetic-resonance signal of the Kr atoms in the $^3P_2$ state at a pressure 1.4×10^{-3}