Assuming that the maximum of f' corresponds to the filling of all the vacancies, we find that the Pb vacancy concentration in the initial PbTe amounts to 2.23×10^{19} cm^{-3} (the number of Te vacancies is 2.04×10^{19} cm^{-3}). The total concentration of all the vacancies corresponds to apparently to 0.1 wt. % for In doping (curve 1) and 0.12 wt. % for La doping (curve 2), which corresponds to the ratio of their atomic weights.

It is evident from Fig. 1 that the probability of the Mossbauer effect at the maximum increases by $e^{0.8} \approx 2.1$ times compared with the undoped PbTe. From this we easily get the estimate $\bar{L}_0^2 >> \bar{L}_{dop}^2 \approx 2.3 \times 10^{-19}$ cm^2, and for the initial PbTe the rms displacement of the tellurium atom, averaged over the sample, is $\bar{L}^2 \geq 2.1 \times 10^{-19}$ cm^2.

In conclusion we thank A. M. Afanas'ev, V. I. Gol'danskii, and I. M. Lifshitz for useful discussions.

[1] V. A. Lebedev, R. A. Lebedev, A. M. Babeshkin, A. N. Nesmeyanov, Vestnik, Moscow State Univ., Chem. Series, 4, 18 (1968).
[2] W. Zachariasen, Z. Phys. Chem. 124, 273 (1929).
[3] Masatomo Fujemoto, Jasuo Sato, Japanese J. Appl. Phys. 5, 12 (1966).
[4] E. Miller, K. Komaren, and J. Kadoff, J. Appl. Phys. 32, 11 (1961).
[5] V. I. Fistul', Fiz. Tverd. Tela 6, 3738 (1964) [Sov.Phys. Solid State 6, 2999 (1965)].
[6] I. P. Suzdalev, M. Ya. Gen, V. I. Gol'danskii, and E. F. Makarov, Zh. Eksp. Teor. Fiz. 51, 118 (1966) [Sov. Phys.-JETP 24, 79 (1967)].
[7] V. I. Peresada, ibid. 38, 1140 (1960) [11, 825 (1960)].

EXPERIMENTAL OBSERVATION OF OSCILLATORY EFFECTS UPON TUNNELING OF ELECTRONS IN $Al-Al_2O_3-Bi_{1-x}Sb_x$ FILM JUNCTIONS AT VARIOUS PRESSURES

A. A. Galkin and O. M. Ignat'ev
Donets Physico-technical Institute, Ukrainian Academy of Sciences
Submitted 10 July 1966
ZhETF Pis. Red. 8, No. 6, 290 - 294 (20 September 1968)

The tunnel junctions were obtained by vacuum sputtering of the $Bi_{1-x}Sb_x$ alloys on a previously oxidized aluminum film deposited on glass. During the sputtering of the alloy, the substrate was maintained at room temperature. The alloy was deposited by the "flash" method [1] from an incandescent tantalum vessel. The thickness of the $Bi_{1-x}Sb_x$ layer was several thousand Å. The hydrostatic pressure was applied to the sample by a procedure described in [2]. The $Al-Al_2O_3-Bi_{1-x}Sb_x$ tunnel junction was connected to the measurement circuit in such a way that when the bias voltage, picked off a slide-wire resistor, was positive the potential of the alloy film was positive relative to the aluminum electrodes. The plots of the conductivity dI/dU of the junction were recorded with an x-y plotter as functions of the voltage U applied to the sample.

Figure 1a shows a typical plot of di/dU(U) for the junctions with concentration x of the antimony in the $Bi_{1-x}Sb_x$ alloy up to $x \leq 0.5$. The plot is a W-shaped curve. At room temperature there is either no maximum at all on the dI/dU (U) curve, or is weakly pronounced. When the temperature is lowered to 4.3°K, three distinct extrema are observed on the W-curve, and the distances L_1 and L_2 between the extrema change quite noticeably with the alloy composition (see Fig. 1b), and are practically independent of the temperature. When the temperature is lowered from 300 to 77°K the value of L_1 increases about 10%. The parameters L_1

and L_2 of the W curve are very noticeably affected by the hydrostatic pressure applied to the sample. The pressure causes a general narrowing of the W-curve in the direction of the axis of the bias voltage U; particularly noticeable is the effect of pressure on the value of L_1:

$$\Delta L_1/L_1 = -0.168$$

at x = 0.1, T = 77°K, and P = 5.5 katm, and

$$\Delta L_1/L_1 = -0.160$$

at x = 0.1, T = 4.2°K, and P = 1.5 katm.

We observed on the plot of di/dU(U) of the $Al-Al_2O_3-Bi_{0.9}Sb_{0.1}$ tunnel junction, at 4.2°K, a fine structure of the conductivity, in the form of a distinct system of oscillations, reflecting the band structure of the semiconducting alloy $Bi_{0.9}Sb_{0.1}$, superimposed on the W-curve. Using a procedure proposed by Esaki [3], we determined for this alloy the edges of the electron energy bands (in millielectron-volts), namely -56, -18, 2, 25, 82, and 106. The width of the forbidden band is approximately 20 meV.

It is interesting to note that the W-shaped form of the di/dU(U) curve was observed by us at antimony concentrations $0 \leq x \leq 0.5$, and the fine structure superimposed on the W-curve was observed only for x = 0.1. It can be concluded from this fact that the technology used by us to obtain the tunnel junction is far from perfect and calls for improvements.

In the alloys $Bi_{0.5}Sb_{0.5}$ and $Bi_{0.33}Sb_{0.67}$ we obtained at pressures higher than 10 katm tunnel-conductivity characteristics di/dU(U) with a clearly pronounced fine structure at bias voltages in the range ±8 mV. This structure consists of a large number of sharp peaks of dynamic resistance or of peaks of conductivity, symmetrically disposed with respect to the zero bias voltage. Two such characteristics are shown in Fig. 2. The total number of peaks reaches 15 and more in the indicated range of bias voltages. In the region of zero bias voltage

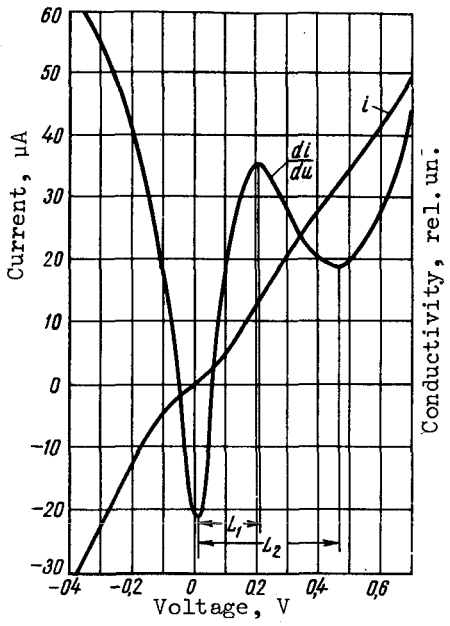

Fig. 1a. Plots of i and di/dU vs. the bias voltage for the tunnel junction $Al-Al_2O_3-Bi_{0.7}Sb_{0.3}$ at T = 77°K. The amplitude of the modulating signal is 0.7 V and the modulation frequency is 2 kHz.

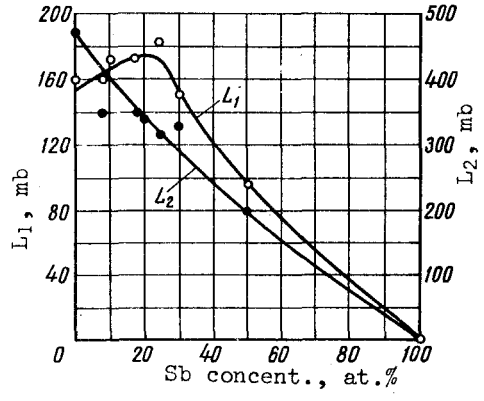

Fig. 1b. Dependence of the parameters L_1 and L_2 of the W-curve on the concentration of the antimony in the alloy $Bi_{1-x}Sb_x$.

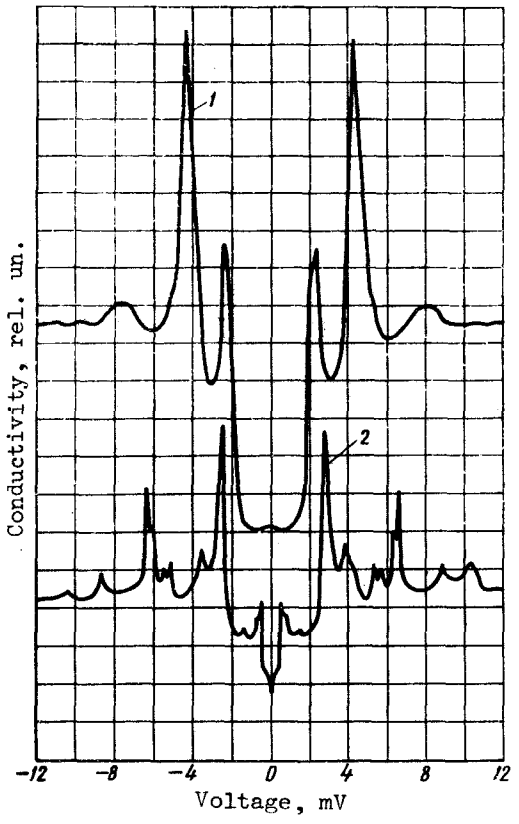

Fig. 2. Plot of tunnel-junction conductivity vs. voltage in the vicinity of zero bias voltage. Modulating signal amplitude 300 μV, modulation frequency 8 kHz. 1 - Al-Al_2O_3-$Bi_{0.5}Sb_{0.5}$ junction; T = 4.2°K, pressure 12 katm. 2 - Al-Al_2O_3-$Bi_{0.33}Sb_{0.67}$ junction; T = 4.2°K, pressure 5.5 katm.

we observed as a rule a deep resistance dip on the di/dU(U) curves; a conductivity dip was observed in this voltage region in relatively rare cases.

Distinct maxima appear at helium temperature, and sometimes also at liquid-nitrogen temperature. When the temperature is changed, the position of the maxima is shifted (without violation of the symmetry relative to the zero bias voltage), and the ratio of the heights of the peaks of the individual maxima also changes. Such a picture, albeit less clearly pronounced, was observed earlier by Williams and Shewchun [4,5] and also by others [6, 7] in the tunnel characteristics of metal-dielectric-semiconductor (single-crystal) junctions.

The tunnel characteristics di/dU(U) shown in Fig. 2 are outwardly similar to the characteristics of metal-dielectric-metal junctions in which one or both metals contain superconducting phases. On the basis of this similarity it was proposed in [5], where a similar picture was observed for metal-dielectric-semiconductor junctions, that a superconducting phase may exist in the semiconductor. We consider this assumption to be in error since it implies that the critical temperature T_c of the superconducting phase in the case of [5] exceeds 60°K [8], whereas in our case it amounts to approximately 53°K. This would be in turn evidence of the presence of a non-phonon mechanism of superconductivity [9], for which there is no experimental proof at present.

We take the opportunity to thank L. F. Vereshchagin for interest in the work and valuable advice.

[1] W. R. Beam and T. Takahashi, Rev. Sci. Instr. 11, 623 (1964).
[2] E. S. Itskevich, A. N. Voronovskii, and A. F. Gavrilov et al., PTE No. 6, 161 (1966).
[3] L. Esaki and P. J. Stiles, Phys. Rev. Lett. 14, 902 (1964).
[4] J. Shewchun and R. M. Williams, ibid. 15, 160 (1965).
[5] R. M. Williams and J. Shewchun, ibid. 14, 824 (1964)
[6] A. F. G. Wyatt, ibid. 13, 401 (1964).
[7] R. N. Hall, Proc. Intern. Conf. on Semiconductor Physics, Prague, 1960.
[8] D. L. Douglass and L. Falicov, The Superconducting Energy Gap, Progr. Low Temp. Phys. v. 4, 97 (1964).
[9] V. L. Ginzburg, Usp. Fiz. Nauk 95, 91 (1968) [Sov. Phys. Usp. 11 (1968)].

BRAGG SCATTERING OF MOSSBAUER GAMMA RADIATION BY AN IDEAL CRYSTAL

V. V. Sklyarevskii, G. V. Smirnov, A. N. Artem'ev, B. Sestak and S. Kadeckova
Submitted 10 July 1968
ZhETF Pis. Red. 8, No. 6, 295 - 300 (20 September 1968)

Yu. M. Kagan and A. M. Afanas'ev have recently developed a thoery of coherent phenomena occurring upon resonant interaction of gamma quanta with nuclei in a regular crystal. It was shown that the excitation of nuclei in such crystals has a chollective character, thus bringing about a number of interesting phenomena [1 - 3].

For an experimental investigation of these phenomena it is necessary to have crystals with a high degree of perfection on the basis of nuclei of the Mossbauer type. The isotope Fe^{57} is highly suitable for this purpose. Indeed, as is well known, it is possible at present to obtain almost ideal single crystals of iron doped with silicon. On the other hand, the low energy of the gamma quantum in the case of Fe^{57}, in conjunction with the large probability of the Mossbauer effect, greatly facilitate the conditions for the observation of coherent effects.

As the first stage of the study, we investigated the Bragg scattering of 14-keV Mossbauer radiation of Fe^{57} nuclei by an ideal crystal Fe + 3% Si of natural iron. We succeeded in demonstrating experimentally that the scattering of Mossbauer gamma radiation by an ideal crystal differs greatly from scattering by a mosaic crystal, in agreement with the prexictions of the theory [2][1)].

Three samples were prepared for the investigation. The first was cut from a single crystal obtained by crucible-less zone melting followed by prolonged annealing at t = 1420°C [9, 10]. The second and third were cut from one grain obtained by second recrystallization. To produce the mosaic structure, the surface of the third sample was subjected to mechanical damage. In all samples, the surface was the (110) plane. From the point of view of the absorption factor, all three samples were thick ($\mu t > 10$). The degree of perfection of the obtained samples was determined with a two-crystal x-ray spectrometer based on the DRON-1 diffractometer. Mo $K\alpha_1$ and quartz monochromator crystal ($10\bar{1}1$) were used. We measured the integral intensities for (110) reflection and the widths of the swing curves. The measurement

[1)] Scattering by a mosaic crystal was thoroughly investigated, mainly from the point of view of revealing the interference between the resonant nuclear and Rayleigh electron scattering, by Black et al. [4 - 7], and later by Voitovetskii et al. [8], where a clear-cut interference pattern was revealed during the course of an investigation of scattering by tin crystals.