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Microphotogram of the germanium L-spectrum region with peaks labeled $L\alpha_{1,2}$, $L\alpha_x$, $L\beta_1$, and $L\beta_x$.

Figure 1: Microphotogram of the germanium L-spectrum region with peaks labeled $L\alpha_{1,2}$, $L\alpha_x$, $L\beta_1$, and $L\beta_x$.

Abstract

Full Text

PHYSICS

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ON THE SATELLITES OF THE LINES $L\alpha_{1,2}$ AND $L\beta_1$ IN THE SPECTRUM OF GERMANIUM

(Presented by Academician G. V. Kurdyumov on February 6, 1957)

In the article ([1]) data were given on the lines $L\beta_3$ and $L\beta_4$ of the L-spectrum of germanium, corresponding to the transitions $L_I \to M_{III}$ and $L_I \to M_{II}$. The discovery of the lines $L\beta_3$ and $L\beta_4$ confirmed the statement made in that article that the L-series of the spectrum of germanium had been studied insufficiently fully. Since germanium is one of the most important semiconductor materials, we considered it necessary to continue the study of the L-series of the spectrum

Fig. 2. Dependence of the energy interval ΔE between the levels M_{IV} and N_I on the atomic number Z

of germanium with the aim of establishing the presence in it of lines not previously detected, in particular the lines $L\beta_6$ (transition $L_{III} \to N_I$), $L\gamma_5$ (transition $L_{II} \to N_I$) and $L\gamma_{2,3}$ (transition $L_I \to N_{II-III}$). The experimental setup described in article ([1]) was used.

The obtained x-ray spectra of the L-series of germanium in the wavelength region 10 150–10 400 X, containing the lines $L\alpha_{1,2}$ (transition $L_{III} \to N_{IV-V}$) and $L\beta_1$ (transition $L_{II} \to M_{IV}$), proved to be sharply different from the spectra known from the literature data ([2]). In our photographs, bright lines were found on the short-wavelength side near the lines $L\alpha_{1,2}$ and $L\beta_1$. Figure 1 shows a photograph of this region of the spectrum, and Fig. 2 gives the corresponding microphotogram. In the photograph of Fig. 1 the blackening density is greater than unity, and therefore this photograph does not give a correct

notions about the ratio of intensities of the lines present in the photograph. The blackening density of the photograph from which the microphotogram was taken does not exceed 0.5. At such a blackening density, according to the literature

Fig. 3

Figure 2: Fig. 3

Fig. 4

Figure 3: Fig. 4

data and to our control photographs obtained with different exposure times, the ratio of the intensities of the individual lines is not distorted.

As can be seen from the microphotogram presented, the doublet line formed by the superposition of the lines $L\alpha_{1,2}$ and another unknown line ($L\alpha_x$) is asymmetric. This circumstance indicates that the width of the unknown line $L\alpha_x$ is greater than the width of $L\alpha_{1,2}$. If one takes into account that the intensity maxima of these lines are close in magnitude to one another, it must be acknowledged that, in the L-series spectrum of germanium, the number of transitions accompanied by emission of the line $L\alpha_x$ exceeds the number of transitions accompanied by emission of the line $L\alpha_{1,2}$ (incidentally, the line usually regarded as the brightest line in the L-series). An analogous situation also obtains for the satellite of the line $L\beta_1$.

Fig. 3

Such a considerable intensity of the lines $L\alpha_x$ and $L\beta_x$ makes it unlikely that these lines are satellites of the lines $L\alpha_{1,2}$ and $L\beta_1$, respectively. For this reason it was decided to determine whether these unclear lines $L\alpha_x$ and $L\beta_x$ might not be ordinary diagram lines whose presence in the L-series spectrum of germanium could have been expected, but which for some reason had not previously been found. The fact that the satellites of $L\alpha_{1,2}$ and $L\beta_1$ are separated from them by approximately the same distance makes it probable that these lines are associated with a transition from the levels L_{II} and L_{III} to the level N_{I}. To check this, the graph in Fig. 3 was constructed, showing the dependence of ΔE, which is the energy difference between the levels M_{IV} and N_{I}, on the atomic number Z. As can be seen, ΔE in the region of atomic numbers 35 (Br)–42 (Mo) varies approximately linearly with Z. The value of ΔE for germanium, determined by us from the photographs obtained, falls well on the extrapolated portion of this straight line. Thus it may be concluded that the positions of the lines $L\alpha_x$ and $L\beta_x$ observed by us coincide with the positions of the lines $L\beta_6$ (transition $L_{\text{III}} \to N_{\text{I}}$) and $L\gamma_5$ (transition $L_{\text{II}} \to N_{\text{I}}$). On this basis, we consider the satellites of the lines $L\alpha_{1,2}$ and $L\beta_1$ found in germanium to be the diagram lines $L\beta_6$ and $L\gamma_5$, respectively.

Fig. 4. Microphotogram of the spectrum of GeO_2

Further confirmation of this conclusion was obtained when comparing the L-series spectra of germanium and GeO_2, the microphotogram of which is given in Fig. 4. As can be seen from a comparison of Figs. 2 and 4, the relative intensity of the satellites

of the satellites of the lines $L\alpha_{1,2}$ and $L\beta_1$ in germanium dioxide falls sharply in comparison with pure germanium. This was to be expected, since germanium in the molecule GeO_2 is tetravalent and gives four electrons to oxygen. Among these four electrons are both N_I electrons. We also observed a weakening of the intensities of the lines $L\beta_6$ and $L\gamma_5$ of pure germanium as a result of carrying out long exposures with the primary method of exciting the spectrum. Apparently, in this case oxidation of the germanium surface takes place. It should be noted that photographs of the L-series of the germanium spectrum obtained by Gwinner [2] resemble in their form the photographs obtained by us for germanium dioxide. Since Gwinner excited the spectrum by the primary method, he was dealing not with pure germanium, but with oxidized germanium. This is also confirmed by the fact that Gwinner did not find any substantial difference between the spectra of pure germanium and its dioxide. Since the radiation of the L-series of germanium is produced by a surface layer (the half-absorption layer is $2.5 \cdot 10^{-5}$ cm), it is evident that, under strong heating of the anode, which occurs in the primary method of excitation, oxidation of the anode surface occurs, as a result of which the intensity of the lines $L\beta_6$ and $L\gamma_5$ decreases sharply. We measured the wavelengths of the lines $L\alpha_{1,2}$, $L\beta_1$, $L\beta_6$, and $L\gamma_5$. The calculation of the wavelengths was made from microphotograms. The linear dispersion in this region of reflection angles is about 32 X/mm. The comparison lines used were $K\alpha_1$ and $K\alpha_2$ of Mn in the 5th order, and also $K\alpha_1 K\alpha_2$ of Cu in the 7th order. The mean value of the measured wavelengths, determined from 10 photographs, is given in Table 1 (the wavelengths are given in X).

Table 1

	$L\alpha_{1,2}$	$L\beta_6$	$L\beta_1$	$L\gamma_5$
Ge	10408	10365	10146	10103
GeO_2	10415		10155	

The error of the wavelength values given in Table 1 is 2 X. The values found by us for the wavelengths of the lines $L\alpha_{1,2}$ and $L\beta_1$ for germanium oxide are close to the wavelength values given in handbooks for pure germanium.

In addition to the lines $L\beta_6$ and $L\gamma_5$, we found in the L-series of the germanium spectrum a weak line with wavelength 8709 ± 5 X, corresponding in its position to the line $L\gamma_{2,3}$ (transition $L_I \to N_{\mathrm{II-III}}$) of germanium. The presence of this line in the spectrum of germanium shows that, in germanium in the solid state, the level $N_{\mathrm{II-III}}$ is partly filled with electrons (this is confirmed by the presence of the line $K\beta_2$ in the spectrum of germanium). On this basis one may consider that the level N_I in germanium must be filled and, consequently, the transitions $L_{\mathrm{III}} \to N_I$ and $L_{\mathrm{II}} \to N_I$ must occur.

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CITED LITERATURE

1. G. P. Borovikova, M. I. Korsunskii, DAN, **114**, No. 6 (1957).

2. E. Gwinner. Zs. f. Phys., **108**, (1938).

Note: Figure translations are in progress. See original paper for figures.