Secondary Electron Emission in Thin Layers of Be II

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A study was made of the change in the coefficient of secondary electron emission σ and the distribution of secondary electrons according to energies in the deposition of thin layers of Be on a silver backing. It was established that, in the deposition of thin layers ($\Theta \sim 1$) of Be on Ni and Ag, the maxima of the curves of the distribution of secondary electrons from Ni and Ag are displaced in the direction of the smaller energies of the secondary electrons.

1. SECONDARY emission properties of thin layers of Be, deposited on a nickel target, were described in a previous paper[1], henceforward cited as I. In order to verify the results obtained and to determine the effect exerted by the backing on the secondary-emission properties of the layers of Be, we have studied in this work the change in σ and the distribution of the secondary electrons with respect to energies in the adsorption of Be on a silver target. For Ag $\sigma_{max} = 1.56$ at $E_p = 800$ ev, for Be – 0.6 at $E_p = 200$ ev, so that $\sigma_{Ag} - \sigma_{Be} > \sigma_{Ni} - \sigma_{Be}$ and therefore, the required condition $\sigma_p \gg \sigma_s$[1,2] in this case is fulfilled better than in investigation I for the vapor of Ni – Be.

2. The experimental procedure has been described previously[1,3]. Using the apparatus shown in Fig. 1 it was possible to obtain molecular beams of Be and Ag. The calibration of the silver gun was carried out by a method similar to the calibration of the beryllium gun. At a constant intensity of incandescence of the molecular gun, the speed of the deposition of a monatomic layer ($\Theta = 1$) on the backing is equal to 44 seconds.

The experiment was carried out in the following manner. In order to verify the accuracy of the performance of the apparatus we have first obtained the curves $\sigma = f(E_p)$ and $d\sigma/dE_s = f(E_s)$ for the backing (Ni). After this a thick layer of silver was deposited on the Ni and the curves $\sigma = f(E_p)$ and $d\sigma/dE_s = f(E_s)$ for Ag were obtained. Moreover, the constancy of emission with respect to time was being checked near the operating beryllium gun. Then layers of beryllium of different thickness (Θ = 0.9; 2; 3; 5; 8; 16; 22; 28; 45; 55; 70; 85; 104; 130 etc.) were deposited on the target and the curves $\sigma = f(E_p)$ and $d\sigma/dE_s = f(E_s)$ were obtained.

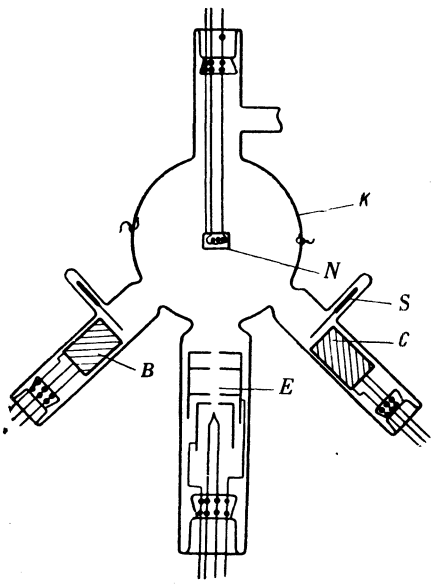

FIG. 1. The apparatus in which was studied the secondary electron emission of thin layers of beryllium deposited on a silver backing; *E* - electron gun; *B* - beryllium molecular gun; *C* - silver molecular gun; *S* - screen; *N* - nickel target; *K*- collector of secondary electrons – a glass sphere the inner surface of which is coated with a layer of nickel.

As in investigation I, the results of the measurements were repeatedly reproduced and they did not depend on the fact whether the layer of Be of a given thickness was obtained at once by using a single portion, or in steps by using smaller portions.

3. The results of measurements of the dependence of σ on E_p for various Θ are shown in Fig. 2. From Fig. 2 it is evident that in this case, as in the case of the adsorption of Be on Ni, with an

[1] I. M. Bronshtein and T. A. Smorodina, J. Exper. Theoret. Phys. USSR 27, 215 (1954).

[2] A. E. Kadyshev, J. Exper. Theoret. Phys. USSR 15, 651 (1945).

[3] I, M, Bronshtein, Zh. Tekh. Fiz.13, 176 (1943).

increase in Θ, σ decreases monotonically and approaches the value of σ_{Be} for all values of E_p. Curve 14 already corresponds to the emission of pure Be ($\sigma_{max} = 0.58$ at $E_p = 200$ ev).

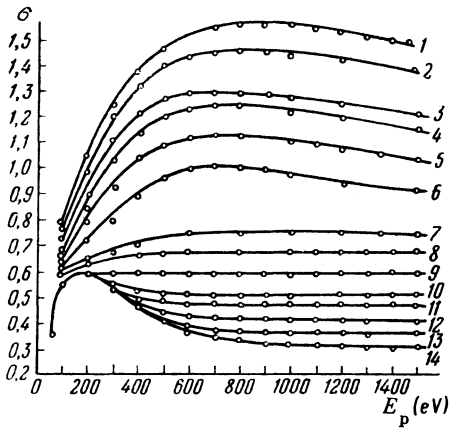

FIG. 2. The curves of the dependence of σ on E_p for various values of Θ. *1* - $\Theta = 0$; emitter – pure silver; *2* - $\Theta = 0.9$; *3* - $\Theta = 2$; *4* - $\Theta = 3$; *5* - $\Theta = 5$; *6* - $\Theta = 8$; *7* - $\Theta = 16$; *8* - $\Theta = 22$; *9* - $\Theta = 28$; *10* - $\Theta = 45$; *11* - $\Theta = 55$; *12* - $\Theta = 70$; *13* - $\Theta = 85$; *14* - $\Theta \geq 104$ atomic layers.

From Fig. 2 is derived the dependence of σ on Θ for various values of E_p, which is shown in Fig. 3. The curves of Fig. 3 indicate that σ for a given value of E_p, beginning with some value of Θ, ceases to vary. To this value of Θ corresponds, apparently, the limiting maximum depth from which at a given E_p secondary electrons can be emitted – the depth of yield d of secondary electrons.

The dependence of d on E_p, shown in Fig. 4, indicates that in the region of E_p from 100 to 600 ev there exists a linear relationship between the depth of yield d of the secondaries and the energy E_p of the primary electrons, and in the region $E_p > 600$ ev d is found to be a constant values (~ 23 mμ) independent of the energy of the primary electrons.

In Figs. 5 and 6 the curves are shown of the dependence of σ on the stopping potential on the collector in the adsorption of Be on Ni and Ag.

The energy distribution curves of the secondary electrons were obtained by differentiating the stopping curves drawn on a large scale. The distribution curves for the adsorption of Be on Ni are shown in Fig. 7. Curve 1 corresponds to pure nickel; its maximum is located at $E_s = 3.2$ ev. The value $\Theta = 0.6$ corresponds to curve 2; its maximum had been displaced to the left, in the direction of lower energies, and it is located at $E_s = 2$ ev. The

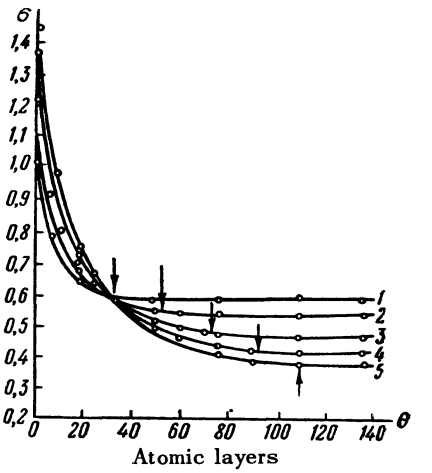

FIG. 3. The curves of the dependence of σ on Θ during the adsorption of Be on Ag. Curve *1* corresponds to $E_p = 200$; *2* - $E_p = 300$; *3* - $E_p = 400$; *4* - $E_p = 500$; *5* - $E_p = 600$ ev; the rate of the establishment of emission, corresponding to a massive layer of Be, is a function of the energy of the primary electrons. The arrows in Fig. 3 indicate the values of Θ beginning with which the coefficient of the secondary electron emission of the emitter ceases to vary.

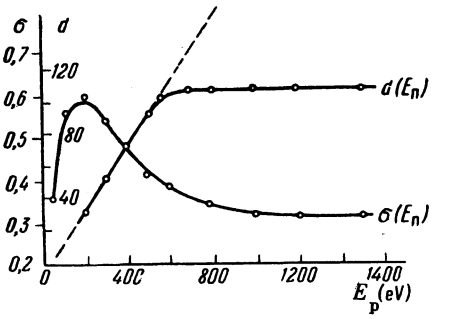

FIG. 4. The curves of the dependence of the depth of origin of the secondary electrons d and of the coefficient of secondary emission σ on the energies of the primary electrons.

maximum of curve 3($\Theta = 1.3$) is located even further to the left, at $E_s = 1.3$ ev. The value $\Theta = 4$ corresponds to curve 4; its maximum, the same as the maxima of the other curves for which $\Theta \geq 2$, is located further to the right ($E_s = 2$ ev). This curve coincides with the curve of distribution of the secondary electrons for a massive layer of Be ($\Theta > 100$). The curves of distribution obtained during the adsorption of Be on Ag are shown in Fig. 8. Curve 1 pertains to Ag; its maximum is located at 2.3 ev. At $\Theta = 0.9$ (curve 2) the maximum of the curve had been displaced to the left in the direction of lower energies and is located at 1.3 ev. At $\Theta = 2$ (curve 3) the distribution curve coincides with that for a thick layer of Ag.

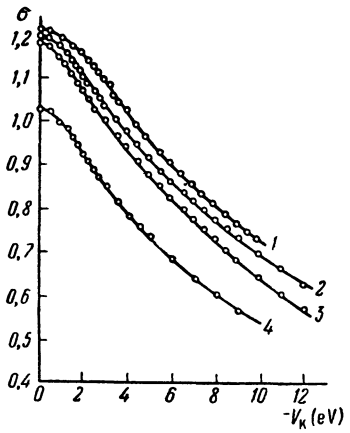

FIG. 5. The curves of the dependence of σ on the stopping potential ($-V_k$) during the adsorption of Be on Ni. *1* - $\Theta = 0$ (pure Ni); *2* - $\Theta = 0.6$; *3* - $\Theta = 1.3$; *4* - $\Theta = 4$. All curves are obtained at $E_p = 300$ ev.

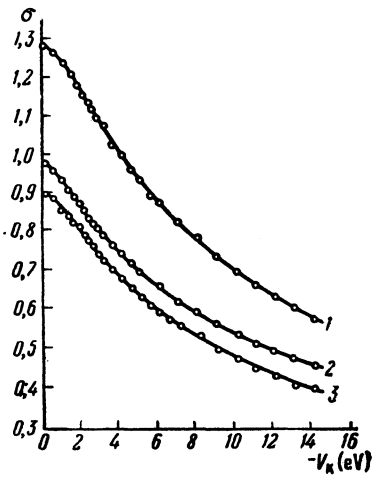

FIG. 6. The curves of the dependence of σ on the stopping potential of the collector ($-V_k$) during the adsorption of Be on Ag. *1* - $\Theta = 0$ (pure silver); $E_p = 300$ ev; *2* - $\Theta = 0.9$; $E_p = 200$ ev; *3* - $\Theta = 2$, $E_p = 200$ ev. At $V_k \geq 0$ it was observed that σ is constant.

4. The results of this investigation are similar to the results of investigation I. During the adsorption of Be atoms ($\varphi = 3.9$ ev) on the surface of Ag ($\varphi = 4.4$ ev) the yield performance of the target at $\Theta \sim 2 - 3$ should decrease to the value φ_{Be}. It is possible that at $\Theta \sim 1$ the yield performance of the emitter is $\varphi < \varphi_{Be}$. Nevertheless, as is shown by the data in Fig. 2, the coefficient of the secondary emission of the target for all energies of E_p of the primary electrons monotonically decreases from the value σ_{Ag} to the value σ_{Be} as Θ increases. This

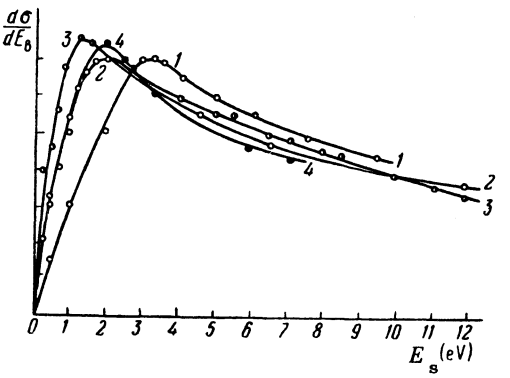

FIG. 7. The curves of the distribution of secondary electrons with respect to energies during the adsorption of Be on Ni. Curve *1* corresponds to pure nickel; *2* - $\Theta = 0.6$; *3* . $\Theta = 1.3$; *4*- $\Theta = 4$ atomic layers. All curves were obtained at $E_p = 300$ ev.

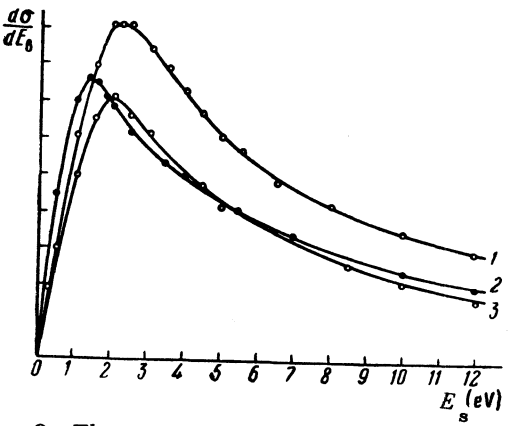

FIG. 8. The curves of the distribution of secondary electrons with respect to energies during the adsorption of Be on Ag. Curve *1* corresponds to pure silver, $E_p = 300$ ev; *2* - $\Theta = 0.9$, $E_p = 200$ ev; *3* - $\Theta = 2$ atomic layers, $E_p = 200$ ev.

indicates, apparently, that small changes in the yield performance produce no effect on the change in the values of the coefficient σ. This is understandable, since the secondary electrons possess considerable energies; therefore, small changes in the performance of the yield will produce practically no change in the value of σ.

As regards the energy distribution of the secondary electrons it is essentially dependent on the yield performance of the emitter. As was shown by Kadyshevich[4], upon changing the yield performance of the target, the maximum of the distribution curve should at first (when φ decreases) be displaced in the direction of the lower energies,

[4] A. E. Kadyshevich, J. Exper. Theoret. Phys. USSR 15, 600 (1945).

and then (when φ increases) it will again shift in the direction of the higher energies. This was observed experimentally[3] in the study of the secondary emission of thin films of Ag on Ni.

We have also obtained a similar result for the adsorption of Be on Ni and Ag. Although the method of differentiating the stopping curves, which we have used, is not very precise, still from the curves of Figs. 7 and 8 one may draw the conclusion that the energy distribution of secondary electrons is dependent on the change in the performance of the yield of the target.

The position of the maximum of the distribution curve for Be, which we have obtained by the method of the stopping field, agrees well with the position of the maximum of the distribution curve obtained in investigation[5] by the method of magnetic analysis. This fact, as well as the invariable and good reproducibility of the results, permits the assumption that the positions of the maxima of the distribution curves of the secondary electrons, which we have determined by the method of the stopping field, are correct. Nevertheless, it stands to reason that in the future it will be necessary to study the distribution of the velocities of the secondary electrons by another method, which will not depend on the differentiation of curves, and measure simultaneously the changes in the performance of the yield.

The distribution curves are found to be independent of the energies of the primary electrons over the entire interval of E_p investigated.

As in investigation I, during the adsorption of Be on Ag in the region $E_p = 200 - 600$ ev there exists a linear dependence of the depth of yield of secondary electrons d on the energy of the primary electrons[6,7]. From Fig. 4 it is evident that the maximum of the secondary emission corresponds to a thickness of the Be layer $d \sim 7 m\mu$. The maximum emission is attained at $E_p = 200$ ev. With an increase in the energy of the primary electrons their path increases, and together with this there is an increase in the depth of origin and in the yield of secondary electrons but the emission decreases. Beginning with $E_p = 600$ ev the depth of yield d of secondary electrons ceases to depend on the energy of the primary electrons. Moreover, it is obvious that the path of the primary electrons exceeds 100 atomic layers, but secondary electrons, originated at such depths, owing to elastic and inelastic losses are unable to escape. The secondary emission current in this region of energies of primary electrons is ensured by those electrons which were produced at depths $d \leq 100$ atomic layers.

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