Conclusions

The locus of the points of maximum efficiency (Fig. 3) is shown in Fig. 4 (solid lines). For comparison, curves of maximum efficiency for tungsten electrodes, as computed by HOUSTON [5], are also given (broken line) in Fig. 4. It is evident from Fig. 4 that if a diode could be made to work with an optimum anode potential of 0.8 – 0.9 volts (Fig. 3), the efficiency of present day diodes ($V_a > 1.6$ volts) could perhaps be more than tripled.

Acknowledgements

The author is indebted to Dr. N. S. RASOR of the Thermo Electron Eng. Corp. for his constructive criticism, and to Mr. Y. BONEH of the Nuclear Research Center — Negev for his help with the computations.

Non-linearities and Discontinuities of the Photoemission from Multi-Alkali Cathodes at Nitrogen Temperatures*

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An account is given of measurements relating to the temperature dependence of the photoemission of multialkali cathodes at temperatures in the region of 80 °K. These measurements show intensity-dependent and spectrally dependent non-linearities with hysteresis in which pronounced discontinuities of the quantum yield of the photoemission occur up to a factor of 2. With a temperature constancy in the region of ±0.01 °K these discontinuities are fully reproducible. Because of the extremely high temperature sensitivity of the effect interesting prospects are afforded when it is used for detecting thermal radiation on the basis of photoelectrons that can be utilized particularly well technically.

In discussing the increase of the photoemission from alkali halides and other polar crystals just below the fundamental-band absorption, whereby the photoelectrons are excited secondarily by excitons apparently produced by the light [1], F. SEITZ suggested that "such a process would depend on incident radiation intensity or would lead to hysteresis and irreversible changes".

APKER and TAFT [1], on the other hand, established complete invariability of their results and thus strict linearity of the photoemission when the light intensity is varied by more than a factor of 10. In the many works that have appeared since then no doubts have been cast on their findings [2].

In the following an account is given of measurements of the photoemission from multi-alkali cathodes. These measurements show the dependence on the light intensity predicted by SEITZ (non-linearity, hysteretic properties and discontinuities) and are reproducible only by reactivation in keeping with the hysteresis. At the same time extremely high sensitivity of the properties of the cathode on temperature is obtained. The latter was taken as the starting point of these investigations when a complete anomaly in the temperature dependence of the photoemission was found for the first time in 1960 [3] at multi-alkali cathode temperatures in the region of 110 °K. It was established that the quantum yield increased in a reproducible manner by a factor of 3 for photon energies of 2 eV when the temperature drops by 1 °K. This factor was determined from measurements in which, it may be pointed out by way of completion, not the photoemission with constant monochromatic light at various cathode temperatures was measured, but the spectral distribution at progressively changing temperatures.

The application of this temperature effect in a radiation detector has been proposed. Here the photoelectric current of the cathode, which is suitably illuminated in the range in question, is modified very finely when the radiation to be measured heats the cathode [4]. When continued appropriately

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1 L. APKER and E. TAFT, Phys. Rev. **81**, 698 [1951].

2 E. TAFT, H. PHILIPP, and L. APKER, Phys. Rev. **113**, 156 [1959].

3 G. FRISCHMUTH-HOFFMANN, P. GÖRLICH, and H. HORA, Z. Naturforschg. **15 a**, 1014 [1960].

4 H. HORA, DBPat. 1 137 876.

the effect is extremely useful for recording thermal-radiation pictures which are produced on the photo-cathode [5], when the photoelectrons are imaged electron-optically or the cathode scanned by the familiar flying-spot system [6].

I. Measuring Device

The measurements were carried out on multi-alkali cathodes provided by Prof. HEIMANN, Wiesbaden, constructed in cylindrical cells without thick metal contacts. The light of a tungsten lamp passed through a monochromator (Carl Zeiss, Oberkochen) and was focused with glass side illumination to give an almost perpendicular angle of incidence to the cathode. Thus, in the following tests a longish strip measuring 4 mm by 1 mm exposes the cathode. This is meant to exclude the possibility of local dependence of the effect along the cathode. At room temperature it was established that up to photon current densities I of 10^{17} photons per cm^2 sec the photoelectric current J was always proportional to I and that the anode voltage was sufficiently high in the saturation region. The cell was contained in a cooling tank comprising one Dewar flask placed inside another. The inner system with a capacity of approximately 1 litre was hermetically sealed and contained the cell, while the outer system provided for stabilizing precooling of the inner system. The temperature of the cell glass was measured directly above the cathode. This temperature T is always given in the following and it should be assumed to first approximation at least that in the extremely slow measuring procedure T can be identified with the cathode temperature. In each case it is necessary to discuss separately the difficulties involved in the temperature data, which at present call for an accuracy of a hundreth of a degree.

The following gives mainly the measurements at one point of the available cathode H 5. At other points and in other cathodes it was also possible to verify largely the phenomena with less thorough measurements. The distribution of the temperature dependence of the photoemission above the temperatures at which the effects considered here arise is dealt with in a separate paper [7]. At the same time it is possible to comment on the specific character of the cathodes involved by investigating the differences in temperature behaviour of multi-alkali cathodes measured by others [8].

II. Temperature Dependence

First an account is given of measurements in which the temerature of the cathode was varied while a constant light intensity of a certain wavelength incided. The results of one of a series of tests on the investigated part of the cathode H 5 are given in Table 1. The cathode was illuminated with light of wavelength 725 nm (photon energy 1.652 eV) and an average intensity over the illuminated area of $I = 5.1 \times 10^{-6}$ W/cm^2 $= 1.92 \times 10^{13}$ photons/cm^2 sec. During measurement the temperature rose from 77.6 to 82 °K within 15 minutes. The variation with time of the photoelectric current was extremely slow up to temperature $T = 81.9$ °K. After the second last pair of values in the table was read off it was just possible to follow with the eye the close succession of current values $J = 1.80$, 1.70 and 1.60×10^{-8} A, during which time the temperature variation could not be fixed, and from then on the current jumped to 0.85×10^{-8} A. The temperature coefficient of the photoemission of 22.4 per degree obtained from the last two values of the table represents a mean value. For the discontinuity itself, however, the coefficient would be significantly larger, provided that a quantum effect of the grid is not involved, in which case the phonon gas would produce a resonant reaction even with poor local temperature distribution.

T (°K)	J (10^{-8} A)	T (°K)	J (10^{-8} A)
77.6	1.1	81.6	2.02
77.8	1.4	81.8	1.97
77.86	1.75	81.9	1.97
81.0	2.03	82.0	0.85
81.4	2.03		

Table 1. Photoelectric current J in dependence on the increasing temperature T with constant light incidence of 1.92×10^{13} photons/cm^2 sec and a photon energy of 1.652 eV.

After the jump in temperature it was not possible with the double cooling system to cool the cathode sufficiently slowly to an accuracy of a fraction of a tenth of a degree. From numerous other measurements, however, it can be deduced with a fair degree of certainty that the jump back to the high photoelectric currents at decreasing temperature does not occur in the same temperature range as the drop, but at a lower temperature. This hysteresis, for instance, was observed ten times in succes-

[5] H. HORA, French Pat. 1398355; USA Pat. Ser. No. 377590 (Applicant: Institut für Plasmaphysik, Garching).

[6] M. GARBUNY, T. P. VOGL, and J. R. HANSEN, J. Opt. Soc. Amer. **51**, 261 [1961].

[7] H. HORA, R. KANTLEHNER, N. RIEHL, and P. THOMA, Z. Naturforschg. **21 a** [1966], in press.

[8] R. B. MURRAY and J. J. MANNING, I.R.E. Trans. Nucl. Sci. (NS) **7**, 80 [1960]. — A. L. OSHEROVICH, B. M. GLUKHOVSKI, and N. S. SHAKOV, Instruments Exp. Techn. **1962**, 150.

sion with a rather simple cryostat allowing more rapid variation of the temperature at the cell H 1 with light of wavelength 350 nm. Although the photoelectric current reached its upper value J_u at 77.4 °K, this value was maintained in the presence of heating up to 78.2 °K and then dropped suddenly by 33% to a lower value J_l. After cooling to 77.4 °K had taken place the lower value was maintained for another minute, during which time the glass at the cathode had already reached the temperature of 77.4 °K. During this measurement, moreover, almost the entire cathode front was illuminated, and so with cathodes of the type investigated the effect should not depend too strongly on the individual parts of the cathode. Similar behaviour was observed in other cathodes at temperatures just below 77.4 °K, use being made of the lowering of the boiling point of nitrogen due to the reduction in pressure. Results sufficiently precise to allow quantitative statements were obtained, however, only with the arrangement desrcibed in I. It should also be stated that precise measurements could only be made after obtaining more exact knowledge of the measurements with variation of the wavelength and intensity which are described in the following. At the same time recognized relationships relating to the hysteresis properties and jump processes were utilized in selecting intensity and wavelength. The said measurements with the cell H 1 already showed, however, that when the process was repeated the upper and lower photoelectric current always had the same values within the measuring accuracy, so that from these and other measurements it can be concluded that there is perfect reproducibility of the effect. That is, there is no reason for assuming irreversible structural changes in the cathode.

III. Spectral Dependence

An example of spectral measurement on the investigated part of the cathode H 5 is provided by the result given in Fig. 1. The photoelectric current of the cathode, as measured with the system described in I, is given here for the temperature of 77.58 °K kept constant to ±0.025 °K, the slit of the monochromator being set at 0.15 mm. Measurement

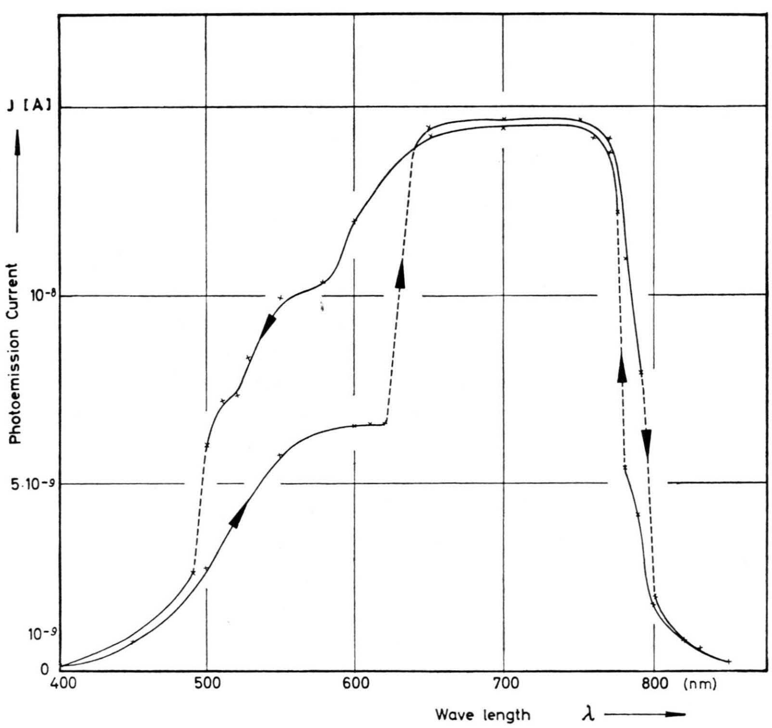

Fig. 1. Spectral distribution of the photoelectric current with temperature radiation and a monochromator slit of 0.15 mm. Cathode temperature $T=77.58 \pm 0.025$ °K (hysteresis).

proceeded from a wavelength of 400 nm to greater wavelengths and back again accordingly (indicated by the directions of the arrows). On each of the curve traces represented by a broken line between two test points there was a discontinuity. The exact position of the discontinuities was not determined in this series. Measurements with a more precise division of the wavelengths selected showed that the normal course of the curve is continued beyond the last test point and the jump occurs within a wavelength interval of less than 2.5 nm. In further similar measurements the position of the discontinuities was very highly dependent on the slit width of the monochromator, i. e. on the incident light intensity, and on the temperature of the cathode. At the investigated part of the cathode the discontinuity of the spectral sensitivity was observed at light intensities of up to 10^{17} photons/cm^2 sec and at temperatures of up to 85 °K. The equality of the photoelectric currents, as seen from Fig. 1, in both directions arrowed for those wavelengths outside the hysteresis was achieved only by the temperature constancy of ± 0.025 °K.

From measurements of the kind in Fig. 1 not many other physical conclusions, apart from the fact of the hysteresis and the wavelength of the discontinuities, can be drawn at the temperature and light intensity in question since a part is played in the measurements by the highly special spectral dependence of the incident light, which is determined only by the colour temperature of the light source and the dispersion properties of the monochromator. Since LENARD's measurement of the linear dependence of the photoemission current on the light intensity [9] any complication of the experiments owing to this property was excluded hitherto in investigations of the photoemission, even in such a complicated mechanism as the measurements of APKER and TAFT [1]. Because of the established dependence of the photoemission on the light intensity, however, it was possible to refer the measurements to a physically reasonable scale, as was done in the usual way in Fig. 1.

First of all the photoemision currents measured were converted to quantum yields. For calibration of the absolute values of the incident light intensity, use was made of the fact that at room temperature the spectral distribution of the quantum yield can be represented by a function

$$Q(\nu) = \begin{cases} 0 & \text{for} \quad \nu \leqq \nu_0 , \\ \frac{1}{2}\,(\nu-\nu_0)^2/\nu^2 & \text{for} \quad \nu > \nu_0 \end{cases} \tag{1}$$

if a simple RICHARDSON equation of the photoemission with a threshold frequency ν_0 is assumed on the basis of a phenomenological theory [10]. This assumption shows relatively close agreement [11] with absolutely measured quantum yields of HEIMANN cathodes [3] and with the measurements of SPICER [12], if an excitation energy of $h\,\nu_0 = 1.4$ eV for the level of the valence band photoemission [13] is used. The longwave tail between 1.3 and 1.4 eV of the measurements are not described with these assumptions. Instead, an additional energy band more poorly populated than is the case with valence electrons would have to be aded to the expression of the equ. (1) [13]. One necessary condition for applying the calibration method is that the cathodes have sensitivities close to the maximum value of 200 μA/lumen. This was true in each of the cases investigated. The inaccuracy of this assumption is not essentially greater than the inaccuracy of an absolute measurement of the light intensities with thermal radiation detectors.

Fig. 2 contains measurements of the spectral distribution of the quantum yields from the investigated part of the cathode H 5. Given in addition to the spectral distribution at room temperature to which the calibration of the absolute intensities was reduced, is a test series using various slit widths in order to demonstrate the intensity dependence. The succession of slit widths is indicated by the figures in brackets in Fig. 2. In measurements (1) to (4) the temperature of the cathode was 77.5 °K. These temperature data are given to an accuracy of ± 0.015 °K in relation to the boiling temperature of the technically pure nitrogen used, the absolute value of which may have been subject to possible fluctuations in the degree of purity and changes of air pressure. Measurement (5) was done at 77.53 °K and measurement (6) at 77.85 °K. From Fig. 2 it can be seen that the rise of the photon energy of the discontinuity as the intensity increases is mono-

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[10] P. GÖRLICH, H. HORA, and W. MACKE, Experim. Techn. Phys. **5**, 217 [1957]; Jenaer Jahrb. **1957**, 131.

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[13] P. GÖRLICH and H. HORA, Optik **15**, 116 [1958].

tonic as long as the temperature of the cathode was constant to within 0.03 °K, as was the case in measurements (1) to (5). The final measurement at a temperature raised by a few hundreths of a degree already indicates a departure from monotony. A check at the first temperature with a slit width of 0.2 mm showed the discontinuity to be between those of slit widths 0.1 mm and 0.4 mm. On repetition of the measurement after nine days, during which time the cathode was restored to room temperature, the position of the discontinuity was reproduced for slit width 0.4 mm according to Fig. 2 at the same temperature within ±0.03 eV. It is also important to note that the measurements in Fig. 2 always proceeded from a wavelength of 400 nm up to higher wavelengths, and so only the branch of the hysteresis running to the right is given according to Fig. 1. Also noteworthy is the fact that at 3.1 eV and with suitable light intensity the quantum yields may increase from the usual values of 0.15 to the value of 0.38, which for the case of the photoemission is unusual. With regard to our calibration method this value has an accuracy of ±30%. In discussions on improving the efficiency of microwave phototubes, for instance, the high quantum yields due to the temperature effect which were established from previous measurements [3] were of interest for receiving the mixing of two laser modes [14].

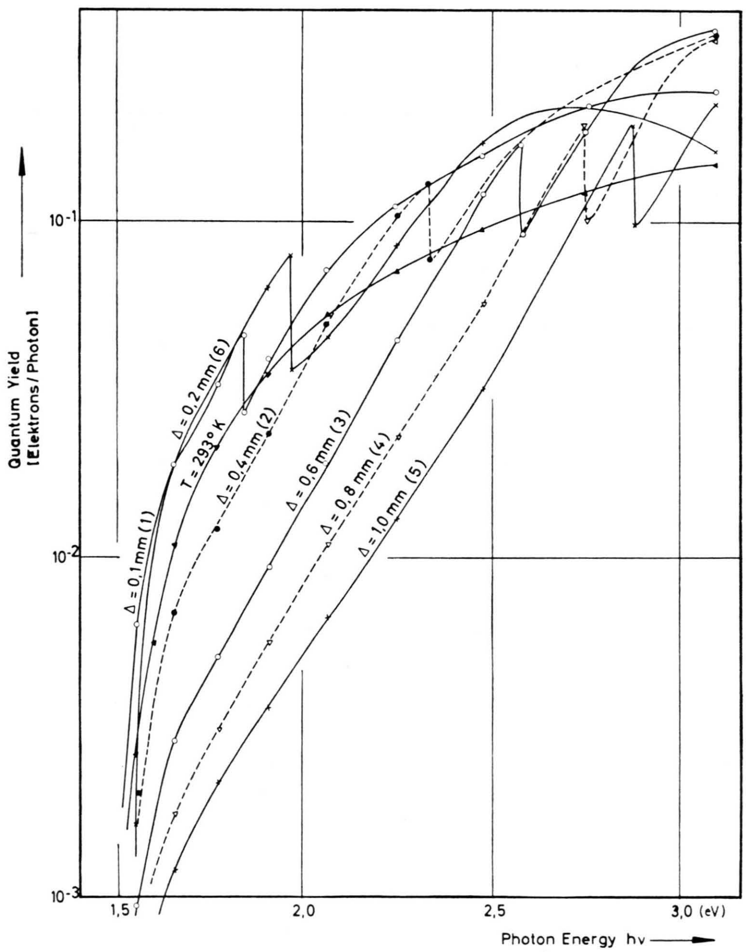

Fig. 2. Spectral distribution of the quantum yields with various slit widths of the monochromator at temperatures $T=77.50$ °K (1) to (4), $T=77.53$ °K (5) and $T=77.58$ °K (6).

[14] A. E. Siegman, B. J. McMurtry, and S. E. Harris, Third Int. Sympos. Quantum Electr. Paris 1963.

IV. Intensity Dependence

In keeping with the said evaluation of the measurements, which, because of the complicated intensity dependence, is physically easier to follow, the quantum yields were now evaluated as a function of the light intensity from the results in Fig. 2. The result is shown in Fig. 3. The light intensity is given in photons/cm^2 sec. In each case the quantum yields of a certain wavelength (photon energy) measured at the various slit widths are connected by a curve. Actually, however, first all the points located farthest left in the individual curves of the individual test series were traversed, then those second farthest to the left etc. It is interesting to note that in this grouping in results the quantum yields may either rise or fall as the light intensity increases.

Special attention is directed at the points of discontinuity. The point of discontinuity for the third most intense slit width (3) in Fig. 2 is located right at 450 nm, and so the discontinuity is directly visible in the trace of the curve in Fig. 3. In the case of the other slit widths the discontinuities were always between the discrete wavelength evaluated in Fig. 3. The points on the curve between which the discontinuities occurred, are connected by dash-and-dot lines and the intensity at which the discontinuity occurred is found by interpolation and marked on these lines with a circled cross. It is worth noting that at the initial temperature of 77.50 to 77.53 °K the intensity at which the discontinuities occur is concentrated in the region between 0.8 and 2.5×10^{13} photons/cm^2 sec. Another interesting fact is that independently of the sequence of wavelengths the point of discontinuity in this range raises monotonically with successive measurements. On the basis of the test conditions it can be stated with certainty that the cathode temperature, even though incommensurable, does rise slowly. In the sixth test series, the temperature of which was already 0.05 °K higher than the preceding temperatures, the point of discontinuity shifted to an intensity of almost 7.5×10^{13} photons/cm^2 sec. Inexact though they may be, the following provisional conclusions can be drawn from the foregoing result:

a) The points of discontinuity at a certain temperature independently of the photon energy of the light occur at a certain photon current density I_0 (discontinuity current density);

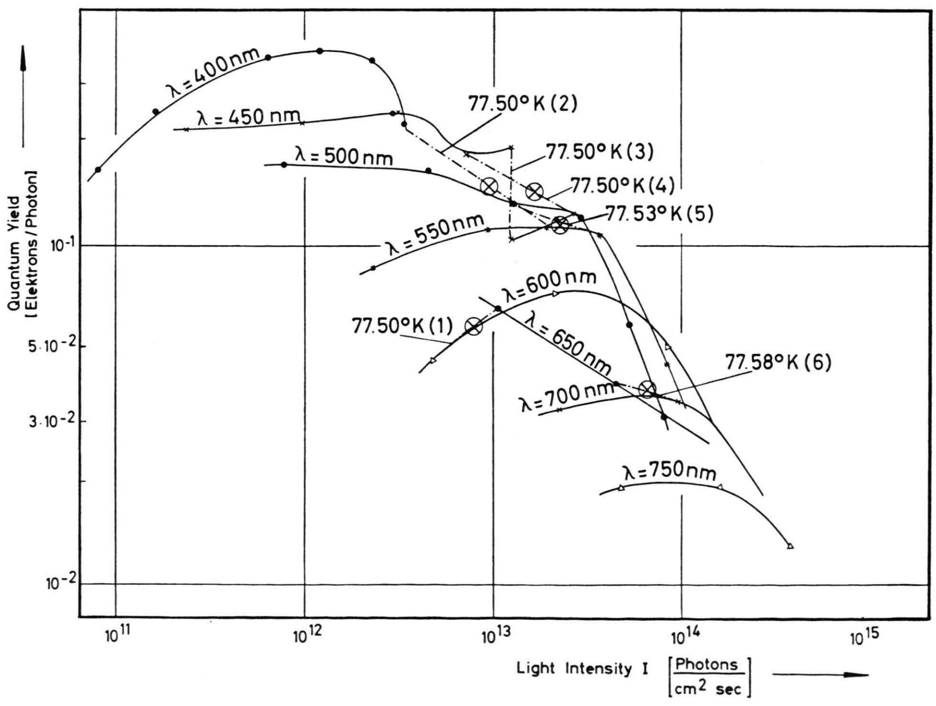

Fig. 3. Conversion of the quantum yields measured in Fig. 3 in dependence on the photon current density I of the incident radiation. The position of the jumps is indicated by circled crosses.

b) This discontinuity current density increases as the temperature rises $I_0(T)$.

From the measurements (1) and (6) of the discontinuities in Fig. 3 it results that, when the temperature of 77.50 °K for the cathodes investigated rises by 0.08 °K, the discontinuity current density increases by a factor of 10. This high temperature sensitivity is of quite considerable significance as regards measuring technique.

A direct measurement of the intensity dependence of the photoelectric current, which is synonymous with the integral of the quantum yield curves in Fig. 3,

$$J(I) \sim \int Q(I)\, dI \,. \qquad (2)$$

is given in Fig. 4. During the measurement the temperature of the cathode was not constant in the same degree as in the preceding measurement. By indicating the sequence of the measurements in round brackets the individual test series give the photoelectric currents measured for various intensities I of incident light of a definite wavelength. In each case low intensities were started from. As can be seen, the trace of the graphs of low intensities I is slightly sublinear compared with the linear curve $J \sim I$. This is basically in contradiction with the curves in Fig. 3, in which quantum yields increasing with I should give according to (2) a superlinear trace. As already pointed out, the measurements in Fig. 3 were not made in the same order as the curves. Instead, quantum yields for the same wavelength and increasing I of various test series were connected with one another. This results in a complicated relativation of the results obtained from each of the tests. In spite of this complication, however, it is evident that in Fig. 4 the position of the points of discontinuity is similar to that in Fig. 3. If on the basis of the above knowledge a) an intensity dependence of the points of discontinuity is assumed which is temperature – but not frequency – dependent, it is posible, for instance, to correlate the point of discontinuity (2) at 77.72 °K and the point of discontinuity (4) at 77.76 °K with

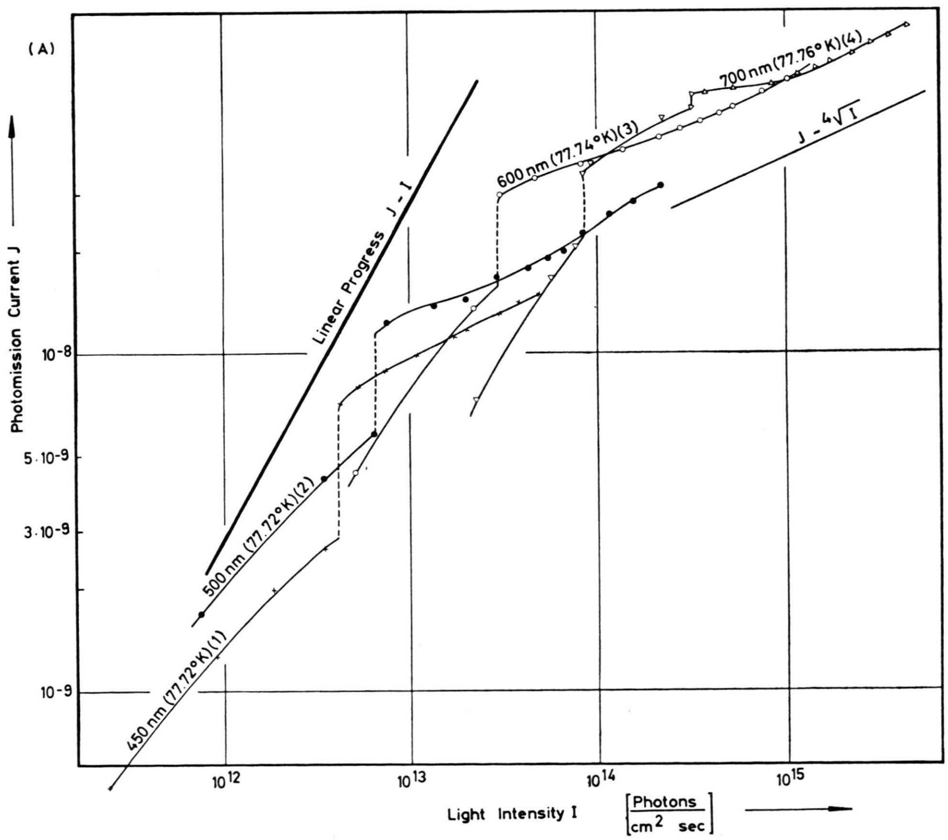

Fig. 4. Photoelectric current J measured with increasing intensity in dependence on the incident photon current density I.

the light intensities of 6.3×10^{12} and 8.5×10^{13} photons/cm^2 sec respectively. Here as well a temperature change of about 0.05 °K would correspond to a variation in intensity of about 10. When the total level of the temperatures in Fig. 4 exceeds that in Fig. 3 by 0.2 °K, although the position of the discontinuities in dependence on I are virtually the same, this may be due to the fact that the measurements were made on different days and the temperature level of the nitrogen used as a basis was shifted by the small amount stated.

In Fig. 4 the trace of $J(I)$ is appreciably flatter above the discontinuities than below and appears remarkably linear in the diagram. This would correspond to a trace

$$J \sim \sqrt[4]{I} \qquad (3)$$

This curve, however, is only roughly true because another, albeit small discontinuity was detected, for instance, in the test series for 700 nm at 3×10^{14} photons/cm^2 sec. Even at high light intensities above 10^{14} photons/cm^2 sec the photoelectric current shows a definite, though sublinear rise as the light intensity increases. This is the surest sign that despite the low temperature it is not due to insufficient transverse conductivity of the cathode that the cathode shows deviations from the linear curve. Nor could this fact account for the position of the discontinuities and their existence itself. At the low temperatures a change in the anode voltage caused no change in the photoelectric current. As a simple estimate of the conductivity of the multi-alkali cathodes tested in 1960 at low temperatures shows [15], it can be seen from the foregoing that the cathodes tested were perhaps somewhat thicker than those tested originally and that the concentration of acceptors is certainly greater in the present case. Saturation due to insufficient transverse conductivity was doubtless the reason why a sharply reduced, spectrally almost independent sensitivity was measured at 80 °K in other makes of multi-alkali cathodes [8].

It should also be noted that in the measurements according to Fig. 4, if the light intensity is lowered again after rising, the downward jump is shifted hysteretically as in the measurements according to Fig. 1 to lower intensities compared with the upward jump [16].

V. Conclusions

Together with a wealth of other experimental material the results indicated should leave no doubt as to the existence of the described effect of the photoemission of multi-alkali cathodes. It will also have become apparent, however, how difficult it was to rediscover the effect at all considering the intensity dependence, which is highly unusual for the photoemision, the complicated spectral dependence and the extreme temperature sensitivity, especially as the first experience of the effect in 1960 can be regarded on the basis of the present results as fortuitous. There would be no call for surprise if the effect was not obtained at all by others using cathodes of other makes. Even though the results obtained and the rough relationships indicated by them are nothing more than a beginning, they are at least useful for avoiding unsuccessful attempts at reproducing the effect experimentally.

At the present stage of the investigation it is of course by no means easy to obtain a theoretical statement on the results. The discontinuities rise or fall of the photoemission has certainly some connection with a mechanism of the whole lattice and the photon current contained and with the phonon gas with its complicated structure, this mechanism being triggered in a resonant manner by an elementary process. The question as to the existence of excitons and their effect in the lattice cannot be ignored as a matter of course since it is also possible to produce discontinuities at wavelengths below 400 nm and with suitably high photon current density, i. e. well within the region of the fundamental-band absorption. Even though it is not out of the question that the very results obtained perhaps allow specific properties of the excitons to be identified, it is obvious from the outset that the problems involved are not simple, bearing in mind the diversity of dissociation and collision processes in connection with the photoemission and photoconductivity of polar crystals on the basis of the existing exciton theory [17].

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[16] H. Hora, R. Kantlehner, and N. Riehl, Z. Phys., in press; Bull. Amer. Phys. Soc. **11** [1966], in press.

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The complicated connection between the parameter of intensity, spectral dependence, temperature and cathode quality can only be measured in stages, and for the time being no statement on the nature of the anomalies is available, apart from the fact that they have now been identified definitely as discontinuities. Further development of the results now obtained will probably benefit from the prospect of relationships in solid state physics being clarified on the lines of the assumption made by SEITZ which was mentioned at the outset. Also useful should be a significant advance, in the form of a purely electronic high-sensitivity radiation detector, into spectral regions that have been virtually inaccesible till now.

Acknowledgements

We should like to express our appreciation to Prof. W. HEIMANN, Wiesbaden, for providing the photoelectric cells, to Prof. A. SCHLÜTER, Munich, for valuable advice and to Dr. P. THOMA for making the measuring equipment available.

Kombination von galvanomagnetischen- und Feldeffekt-Messungen an Germanium-Bikristallen

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Mitteilung aus der Physikalisch-Technischen Bundesanstalt

(Z. Naturforschg. **20 a**, 1599—1611 [1965]; eingegangen am 24. August 1965)

The transport properties in a magnetic field of the p-type space charge region adjacent to 20° tilt grain boundaries in n-type germanium bicrystals were investigated as a function of a reverse bias voltage between bulk and grain boundary (field effect). The average HALL mobility at 77 °K of the holes decreased with increasing bias, demonstrating the existence of a size effect caused by diffuse boundary scattering in connection with the small width of the space charge layer. The results obtained for symmetrical bias are in agreement with a simplified theory based on a constant space charge field and allow to estimate an average hole density. The transverse magnetoresistance also decreased with increasing field effect-voltage, as expected.

Als Korngrenze bezeichnet man eine Fläche in einem Festkörper, an der zwei einkristalline Bereiche einander berühren. Es ist lange bekannt, daß Korngrenzen die elektrische Leitfähigkeit von Metallen und Halbleitern [1] beeinflussen können. Seitdem gezeigt wurde [2, 3], daß es möglich ist, durch Ziehen von Germanium-Bikristallen mit vorgegebenem Verdrehungswinkel ebene Korngrenzen großer Ausdehnung herzustellen, ist eine Reihe von Arbeiten erschienen, die sich mit dem Stromtransport in diesem Material parallel und senkrecht zu Korngrenzen befassen [3–8]. Die Auswirkungen von Korngrenzen (in Bikristallen mit nicht zu kleinem Verdrehungswinkel) in n-leitendem Germanium sind besonders markant, da sie sich mit einer dünnen, p-leitenden Raumladungszone umgeben, und somit Anlaß zu einer Potentialstufe sind. Die Ursache für die Defektleitung an der Korngrenze ist gegenwärtig nicht mit Sicherheit bekannt. Vieles deutet darauf hin, daß der Akzeptorcharakter von Versetzungen herrührt, die nicht abgesättigte chemische Bindungen aufweisen. Überlegungen, die auf der Versetzungstheorie [9] beruhen, führen zu dem Schluß, daß (bei Voraussetzung eines einfachen kubischen Gitters) ein Bikristall, dessen Hälften gegeneinander verdreht und nicht verschraubt sind, dann mechanisch am stabilsten ist, wenn in der Berührungsebene eine regelmäßige Anordnung von Stufenversetzungen vorhanden ist. Dieses Konzept wird bei Verdrehungswinkeln, die größer als ca. 15° sind, problematisch; außerdem sind die Verhältnisse beim Diamantgitter komplizierter. HORNSTRA [10] hat jedoch gezeigt, daß beim Germa-

* Braunschweig.

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