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Contribution to the Problematics of Cuprous Oxide Rectifiers

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Introduction

The influence of pre-illumination and heating on the voltampere characteristics of cuprous oxide rectifiers and on the capacitance of the barrier layer has been studied in previous papers [1], [2]. It was shown that the concentration of acceptor type imperfections increases permanently in the barrier layer by pre-illumination, but decreases by heating. These effects can be explained by presuming the association of copper ion vacancies by heating and their dissociation by pre-illumination. Further experiments performed on cuprous oxide rectifiers lead to additional conclusions. First of all a more detailed analysis of curves of the total semiconductor impendace of rectifiers was performed with a greater number of samples. Changes of characteristics in relation to time were followed, the causes of deterioration of the characteristics of rectifiers after a certain time after their production were examined and the changes in the concentration of acceptors and re-

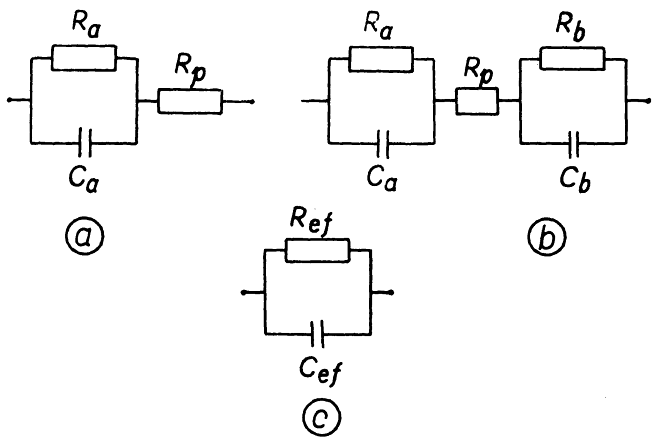

Fig. 1. *Equivalent circuits of rectifier*

sistance of the barrier layer were examined during the illumination and heating. The experimental data were compared with the respective theory.

I. The Total Impedance of Cuprous Oxide Rectifiers

The measurement of the total impendance of cuprous oxide rectifiers was performed with the same apparatus as used in paper [1]. The rectifiers in the form of 7 mm diameter discs produced from Chilian copper, were used for the measurements. The diagrams of the total impedance were circles [1] as required by the equivalent circuit of the rectifier, i.e. a resistance R_a with a parallel capacitance and a resistance R_p (Fig. 1a). Also Schottky and Deutschmann [3] obtained exact circular diagrams and so did Hanisch. However, other authors, as Rose [5] for instance mention deviations from circules for frequencies higher than 10 kHz. Pfotzer [6] mentions similar deviations from 5 kHz. That is the reason for the further investigation of this problem even on other rectifiers. It was really shown that the semicircles were not perfect for all the rectifiers, the diagrams, however, had a similar form as in paper [6]. Fig 2. shows the diagram of the total impedance Z for sample No. 1 (curve *b*) at zero bias voltage.

$$Z = A - jB$$

$$A = \frac{R_{ef}}{1 + R_{ef}^2 \omega^2 C_{ef}^2} \qquad B = \frac{\omega C_{ef} R_{ef}^2}{1 + R_{ef}^2 \omega^2 C_{ef}^2} = A\omega C_{ef} R_{ef} \tag{1}$$

R_{ef} and C_{ef} are the measured values of the equivalent circuit 1*c*.

It can be seen that the diagram is not an exact semicircle; the exception occurs already at comparatively low frequencies from 1000 Hz upwards. The obtained relationship dependence B(A) (curve *b*) shows that the equivalent circuit 1*a* is not exactly suited to the measured rectifier for zero bias.

Let us examine some more complicated equivalent circuit shown in Fig. 1*b* which considers for instance the influence of a non-ohmic upper electrode. We shall introduce the following notations:

$$\frac{R_b}{1 + \omega^2 R_b^2 C_b^2} = D \qquad \frac{R_a}{1 + \omega^2 R_a^2 C_a^2} = F$$
$$\frac{\omega R_b^2 C_b}{1 + \omega^2 R_b^2 C_b^2} = E \qquad \frac{R_a^2 \omega C_a}{1 + \omega^2 R_a^2 C_a^2} = G \tag{2}$$

For the real part of the total impedance we get

$$D + F + R_p = A \tag{3}$$

and for the imaginary part

$$E + G = B \tag{4}$$

We are especially interested in a simple determination of the capacitance of the barrier layer C_a and its resistance R_a and in the utility of the mentioned equivalent circuit.

For low frequencies, when $(\omega R_a C_a)^2 \ll 1$, $(\omega R_{ef} C_{ef})^2 \ll 1$ and $(\omega R_b C_b)^2 \ll 1$, we get

$$C_{ef} = \frac{R_a^2 C_a + R_b^2 C_b}{(R_a + R_b + R_p)^2} \tag{5}$$

and

$$R_{ef} = R_a + R_b + R_p \tag{6}$$

For a more exact determination C_a we need to know R_a, R_b, R_c and R_p. When the resistances R_b and R_p are small, we can neglect them with regard to R_a, however, we cannot assume anything about the capacitance C_b. It is possible that for the time being

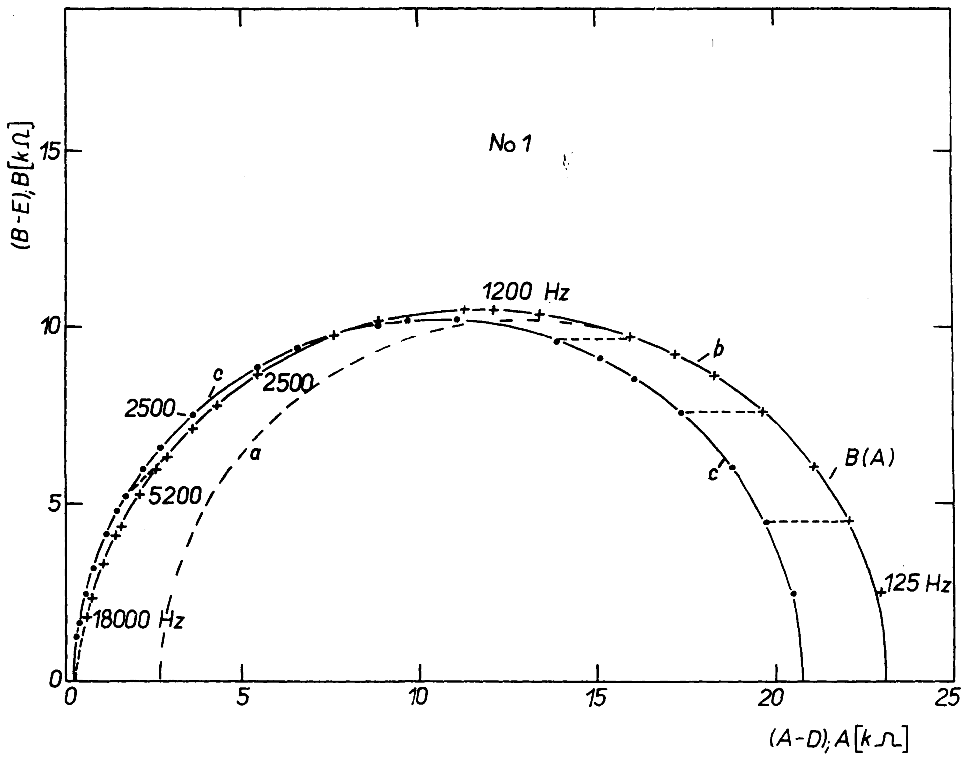

Fig. 2. *Diagram of the total impedance of rectifier.*

it will be higher than C_a. We may further assume that $(C_aR_a)^2 > (C_bR_b)^2$ is valid. Then with increasing frequency the case where $(\omega C_aR_a)^2 \approx 1$ but $(\omega C_bR_b)^2 \ll 1$ occurs. For the real part of the total impedance we get

$$\mathrm{F} + R_b + R_p = \mathrm{A} \tag{7}$$

and the capacitance C_a can be calculated by means of the phase tangent φ_a

$$\mathrm{tg}\, \varphi_a = \omega R_a C_a \tag{8}$$

and from this

$$C_a = \frac{\mathrm{B}}{R_a\omega\,[\mathrm{A} - (R_b + R_p)]} \tag{9}$$

When we plot the diagram B(A) then we get for the range of frequencies, where the mentioned assumptions are fulfilled, a part of the semicircle, the centre of which is on the axis A at a distance $(R_p + R_b + R_a/2)$ from the origin. In our case it is the semicircle (*a*)

(Fig. 2), the left side of which is marked by dashes. The mentioned conditions are fulfilled in the range of frequencies from 0 to about 1000 Hz. The left side of the semicircle intercepts the real axis at a point with a distance from the origin equal to $(R_p + R_b)$, so that it is possible to calculate the capacitance C_a by means of the semicircle.

We must ascertain once more whether the equivalent circuit 1*b* is now satisfactory of whether it will be necessary to use a more complicated representation. For this the remaining factors of the equivalent circuit R_b and C_b will have to be determined from the diagram in which we shall plot the real axis with $D + R_p = A - F$ and the imaginary one with $E = B - G$. This diagram is shown in Fig. 3 and as it can be seen that it is an exact semicircle of diameter R_b. The capacity C_b can be obtained from the relationship:

$$C_b = \frac{E}{\omega R_b D} \qquad (10)$$

For our case we shall obtain for C_b the value of $\sim$ 15200 pF, whereas for $C_a \sim$ 7000 pF.

In this way we can determine all parameters of the equivalent representation 1*b* and simultaneously the equivalent representation is confirmed as satisfactory. Even the further relation $G = B - E$ on $F + R_p = A - D$ (Fig. 2, curve c) confirms this fact. We get a very exact semicircle and the capacitance C_a calculated from this is constant for all frequencies within the limits of exact measurement.

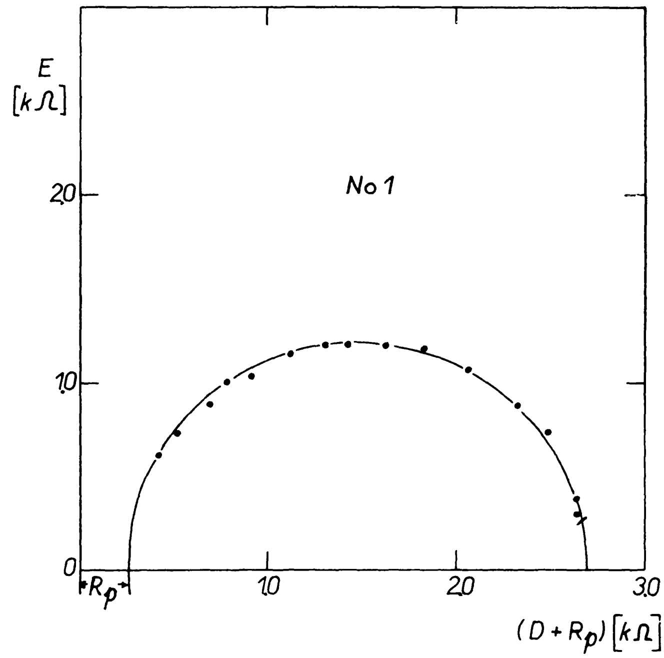

Fig. 3.

We thus arrive at the conclusion that it will not be possible to use the simple equivalent circuit 1*a* for all cuprous oxide rectifiers, however, the equivalent circuit 1*b* will be satisfactory. The capacitance C_b can be caused for instance by an unsuitable upper electrode or some further influences may come forward. This fact can explain the different results found by some authors [3], [4], [5], [6].

To find out which equivalent circuit can be applied by means of the diagram of the total impedance is rather complicated. Certain information can be obtained from the frequency dependence of the effective capacitance C_{ef}. It is shown that for the case of the equivalent circuit 1*a* this dependence is almost constant in a vide range of frequencies whereas with the equivalent representation 1*b* the capacitance depends on the frequency as shown in Fig. 4. For sample No. 9 the diagrams are very exact semi-circles.

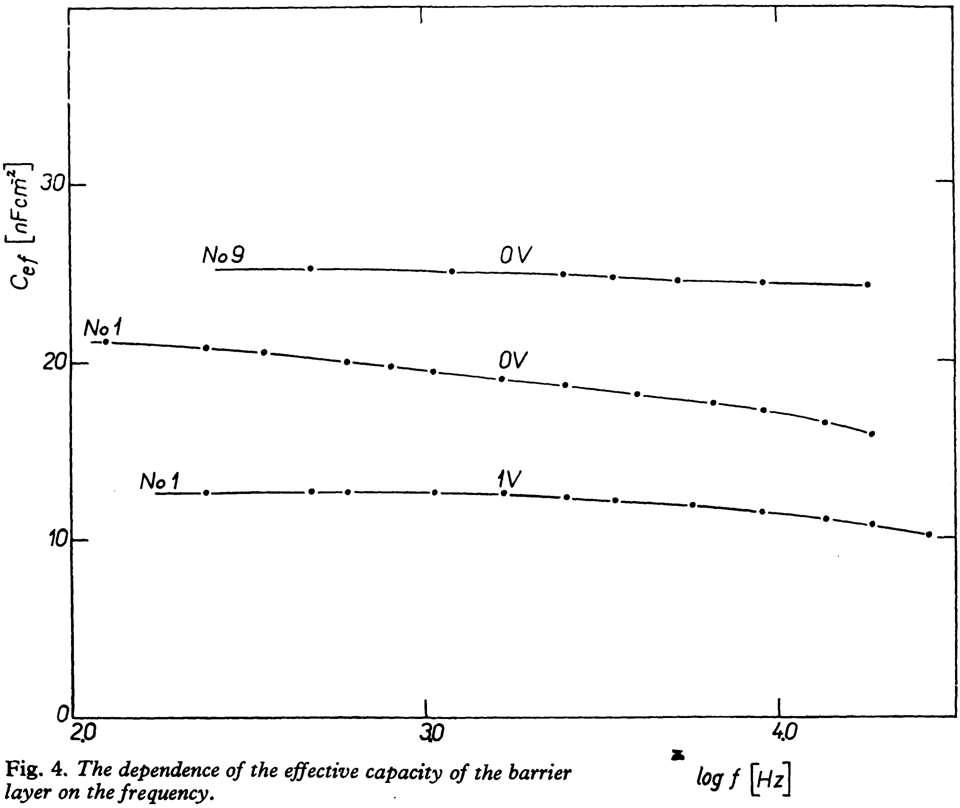

Fig. 4. *The dependence of the effective capacity of the barrier layer on the frequency.*

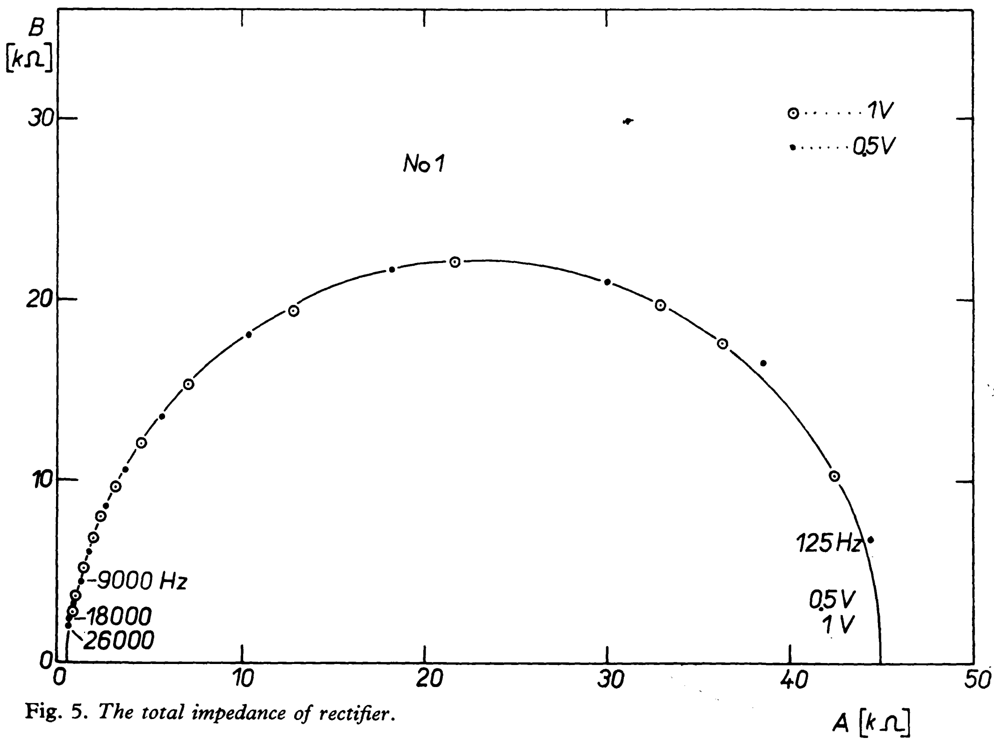

Fig. 5. *The total impedance of rectifier.*

Let us return to equation (5). According to the value R_b in comparison with R_a cannot be neglected and the capacitance C_{ef} is always lower than the capacitance C_a. The size of the error depends on the ratio of the resistances R_a and R_b when we consider the capacitance of the barrier layer equal to the capacitance C_{ef} found at low frequencies. In our case the capacitance C_{ef} is about 17% lower than C_a.

The diagrams of the total impedance for the reverse voltage from 0.5 V upwards are already almost exact semicircles (Fig. 5). We found smaller exceptions only for higher frequencies. In such a case the equivalent circuit of the rectifier 1*a* is satisfactory and the capacitance of the barrier layer can be calculated from the resp. diagram for any frequency. This would mean that by the increase of bias voltage the resistance R_b decreases and the capacitance C_b most probably increases and so they influence the measurements less and less. At the same time we can assume that in the case of the measurement for the forward voltage the capacitance C_b and the resistance R_b will make on the contrary the determination of the capacitance of the barrier layer C_a difficult and therefore it would be incorrect to use values C_{ef} instead of C_a during further considerations regarding the barrier layer of the rectifier.

For instance it is possible that the decrease in the capacitance C_{ef} together with the increasing forward voltage, measured by Pfotzer, could be caused just by these circumstances. Schottky and Deutschmann who obtained circular diagrams did not find such a decrease.

2. The Change in Resistance of the Barrier Layer Caused by Illumination and Heating of the Rectifiers

It was found that the pre-illumination of the cuprous oxide rectifier increases the capacitance of the barrier layer and decreases its resistance. Heating of the rectifier to a temperature of 150°C has a reverse influence — the resistance increases and the capacitance decreases [1, 2] (Fig. 6, 7). This effect was explained by means of dissociation of imperfection complexes during illumination and by their association when the sample was heated. By this method we are able to change the concentration of electrically active imperfections at relatively low temperatures. This enables on the other hand to verify some basic theoretical relationships.

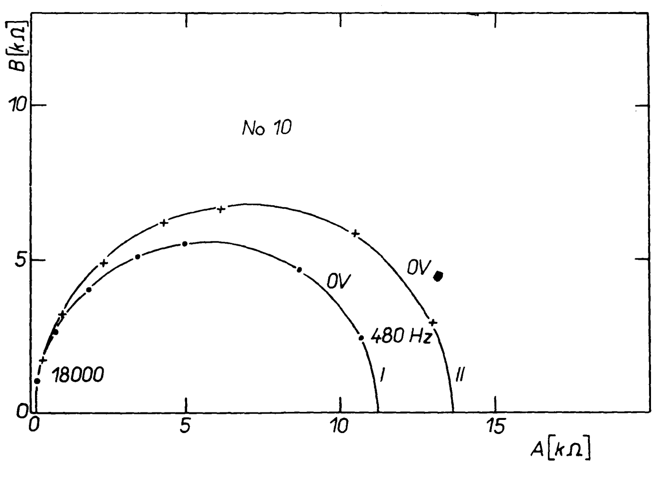

Fig. 6. *The total impedance of rectifier: I the original sample II the heated sample (145°C, 1/2 hour)*

Up to date several theories on the rectifying effect have been elaborated. One of the most important is Schottky's diffusion theory of dry rectifiers [7] where formation of a barrier layer at the metal-semiconductor boundary is assumed. In later opinions and theories it was assumed that the rectifying effect originated at the junction between two semiconductors of a reverse type of conductivity. One of the latest theories is that of the p-n junction between semiconductors with various crystallographic lattices elaborated by Dolega [8].

Let us first investigate how far our results agree with Schottky's theory. We shall compare at least how far the change in resistance of the barrier layer corresponds to the change in the concentration of imperfections in this layer. The resistance of the barrier layer was determined from the circular diagrams and the concentration of impurities from the dependence $1/C^2$ on bias voltage (Fig. 7). According to some works this theory is most satisfactory in the vicinity of zero-voltage and therefore a comparison for a currentless state was performed even for this case. For the resistivity of the barrier layer R_o the following relationship is valid [3]:

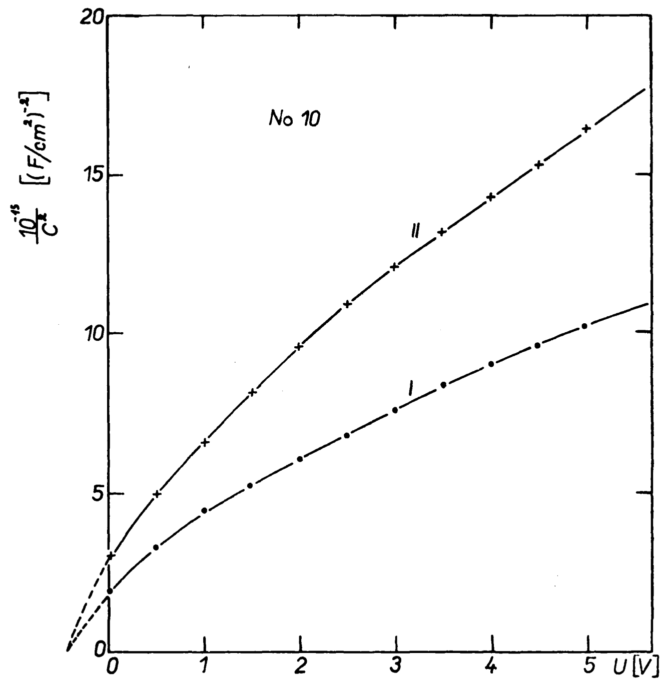

Fig. 7. *The dependence of $1/C^2$ on bias voltage*
I. the original sample
II. the heated sample (145°C, 30 min.)

$$R_o = \frac{k\,T}{\sigma_o e \left(\dfrac{8\pi\, eN\, V_D}{\varkappa}\right)^{\frac{1}{2}}} = \frac{k\,T}{eE_o\,\sigma_o} \tag{11}$$

where

σ_o – is the conductivity at the metal-semiconductor boundary ($x = 0$)
N – the concentration of imperfections
V_D – the diffusion potential
E_o – the electric intensity at the metal-semiconductor boundary
$\varkappa$ – the dielectric constant
e – the electron charge
k – the Boltzmann constant

The resistivity of the barrier layer varies indirectly with the square-root of the concentration of imperfections. For the ratio of the resistance of the heated and original rectifier we obtain according to (11)

$$\frac{R_{ov}}{R_{op}} = \frac{\sigma_{op}}{\sigma_{ov}} \left(\frac{N_p V_{Dp}}{N_v V_{Dv}} \right)^{\frac{1}{2}} \tag{12}$$

where the indices p and v correspond to the original and heated samples respectively. At the same time we assumed that the dielectric constant had not been changed. In the first approximation we may presume that there is no change in the work function between the metal and semiconductor and in the diffusion potential V_D. Then the following equation is valid:

$$\frac{R_{ov}}{R_{op}} = \left(\frac{N_p}{N_v} \right)^{\frac{1}{2}} \tag{13}$$

This relationship can be very easily verified when the concentration of imperfections and the respective resistances are known. A certain difficulty is caused by the fact that equation (11) is valid only under the assumption that the concentration of imperfections is the same for the whole depth of the barrier layer l_o. This was not fulfilled in all cases. The case of inhomogeneous distribution of imperfections was investigated for instance by Spenke [9]. For our purposes it is sufficient to calculate the electric field for $x = 0$, because the equation (13) may be changed to:

$$\frac{R_{ov}}{R_{op}} = \frac{E_{op}}{E_{ov}} \tag{14}$$

Assuming that $E(x = l_o) \approx 0$ we obtain for the electric field at the metal-semiconductor boundary ($x = 0$) the following equation:

$$E_o = \frac{4\pi e}{\varkappa} \int_0^{l_1} N(x)\, dx \tag{15}$$

In order to be able to estimate the electric field of the metal-semiconductor boundary it is necessary to know the dependence $N(x)$ which is only approximatively determined in the interval $(0, l_o)$ with the exception of cases, when the distribution of imperfections is homogeneous. In spite of this we shall to verify equations (13) and (14).

We may assume that the distribution of concentration of imperfections N in the interval $(0, l_o)$ is almost constant in the origin and that a larger increase develops at distances of about $4 \,.\, 10^{-5}$ cm for most rectifiers. The electric field E_o will in these cases be determined mostly by the concentration of imperfections in this area. In the first approximation we may substitute for N_p and N_v the values corresponding to this area ($x \approx 0$). The parabolic course of the concentration of impurities will make a somewhat better approximation. The calculated values of the respective ratios of measured quantities for both cases are indicated in Table 1.

The ratio of the resistance of the barrier layer at the zero bias voltage for the heated and original samples is shown in column 2 and their ratio for the original and pre-illuminated samples (R_{oo}) is shown in column 6. The ratios of the square roots of the respective concentration of imperfections are presented in columns 4 and 8.

Results of calculations made according to formula (14) are shown in columns 5 and 9.

Let us first investigate sample No. 10 for which the concentration of imperfections in the area $(0 - l_o)$ is almost constant (Fig. 7). The value of the ratio $R_{ov}/R_{op} = 1.23$, $(N_p/N_v)^{\frac{1}{2}} = 1.22$ and $(E_{op}/E_{ov}) = 1.21$. The correspondence of all three values is in this case unusually good. Similar agreement is obtained for samples Nos 12, 13 and 15. There are differences only of a few percents. Somewhat greater differences are found for sample No. 14. The best agreement is obtained for the ratio E_{op}/E_{ov} and E_{op}/E_{oo} with the exception of sample No. 13 where the parabolic approximation was not too suitable.

On the bases of the above mentioned results we can presume that the agreement of measured values with the equation (13) and (14) is very good. If we compare the ratio of the resistances with the calculated values in the columns 4, 5 event. 8, 9, we find out that this ratio is always higher. It will be probably caused by the fact that we had presumed that the work function between the metal and the semiconductor was not influenced by the change in electric field E_o, which is not fully fulfilled. According to Schottky [7] the work function changes in the following value

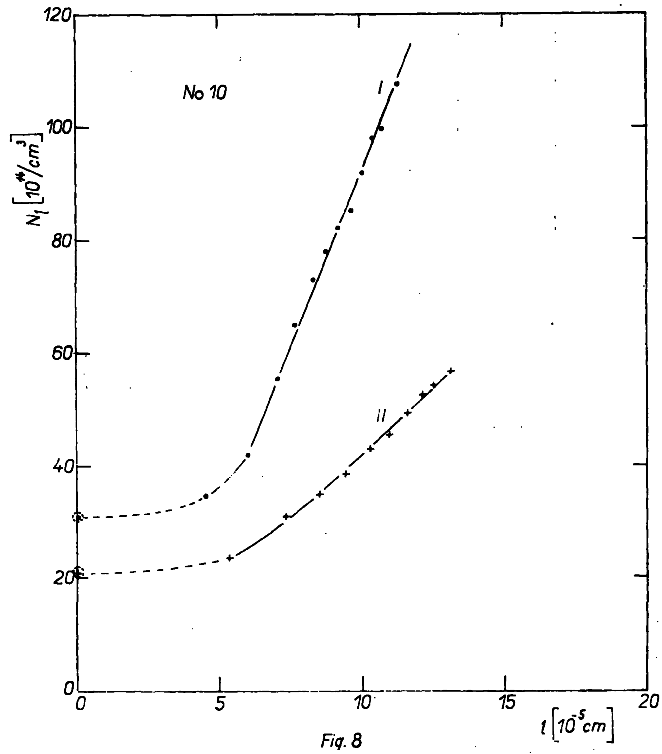

Fig. 8. The distribution of impurities in the barrier layer
I. the original sample
II. the heated sample (145°C, 30 min.)

$$\frac{e^{\frac{3}{2}} E_0^{\frac{1}{2}}}{\varkappa} = kT \cdot y \tag{16}$$

Schottky also proved that the current of the rectifier increases

$$e^y (1 + 2y)^{-\frac{1}{2}} \tag{17}$$

times for a decrease in the work function.

The influence of change in the work function will become apparent in the results for an electric field $\sim 10^4$ V/cm. The sample No. 10 has an electric field for instance 1.5×10^4 V/cm so that we may expect that results to be influenced by the change in the work function due to the electric field which was modified as a result of the changes

Table I.

1	2	3	4	5	6	7	8	9
No. of samples	$\frac{R_{ov}}{R_{op}}$	$K_{vp}\left(\frac{R_{ov}}{R_{op}}\right)$	$\left(\frac{N_p}{N_v}\right)^{\frac{1}{2}}$	$\frac{E_{op}}{E_{ov}}$	$\frac{R_{oo}}{R_{op}}$	$K_{op}\frac{R_{oo}}{R_{op}}$	$\left(\frac{N_p}{N_o}\right)^{\frac{1}{2}}$	$\frac{E_{op}}{E_{oo}}$
10	1.23	1.20	1.22	1.21				
12					1.10	1.08	1.08	1.10
13	1.31	1.26	1.25	1.20	0.89	0.91	0.90	0.92
14	1.70	1.56	1.49	1.54	0.90	0.96	0.87	0.87
15					1.25	1.21	1.17	1.24

in the concentration of impurities. Considering this influence we must substitute equation (13) by the relationship

$$K_{vp}\frac{R_{ov}}{R_{op}} = \left(\frac{N_p}{N_v}\right)^{\frac{1}{2}} \tag{18}$$

and equation (14) by the expression

$$K_{vp}\frac{R_{ov}}{R_{op}} = \frac{E_{op}}{E_{ov}} \tag{19}$$

The factor K_{vp} is the ratio of values of expression (17) for the heated and the original samples. The results corrected by this factor are given in Table I column 3 and for the original and pre-illuminated samples (factor K_{po}) in column 7. The value K_{pv} varies from 0.98 to 0.92 so that it brings in a correction of 2–8%. When comparing the corrected values in columns 3 and 7 with the respective values in columns 5 and 9 we can see that the agreement is unusually good, the differences are only of a few percents. The found results can be very well explained on the basis of Schottky's theory.

We shall now compare our results with the respective relationships corresponding to the theory made by Dolega [8]. Dolega obtained the following equation for the resistivity of the barrier layer:

$$R_o = \frac{kT}{e}\left[\frac{1}{8\pi e\,V_D}\left(\frac{1}{\varkappa_n N_D} + \frac{1}{\varkappa_p N_A}\right)\right]^{\frac{1}{2}} \cdot \\ \cdot \left\{\frac{\varkappa_n a_n^o(\exp\left[eV_D/kT(1+Q)\right]-1)}{e\,b_n N_D} + \frac{\varkappa_p a_p^o(\exp\left[eV_D/kT(1+Q^{-1})\right]-1)}{e\,b_p N_A}\right\} \tag{20}$$

where $\varkappa_n, \varkappa_p$ – are the dielectric constants of the n- and p-type semiconductors,

b_n, b_p – the mobility of electrons resp. holes

$$Q = \frac{\varkappa_n N_D}{\varkappa_p N_A}$$

a_n^o, a_p^o – numerical factors.

It is rather difficult to verify this equation more exactly and therefore let us mention two further cases, i.e. a symmetrical and assymetrical junction. For the case of a symmetrical junction where Q = 1 and

$$\frac{b_n N_D \varkappa_p}{b_p N_A \varkappa_n} = 1$$

the following equation was obtained:

$$R_o = \frac{kT}{e} \left(\frac{\varkappa_p}{\pi e\, N_A\, V_D}\right)^{\frac{1}{2}} \frac{1}{e\, b_p\, N_A} \exp \frac{e\, V_D}{2kT} \tag{21}$$

so that the resistivity R_o varies directly to $N_A^{-\frac{3}{2}}$.

For the unsymmetrical junction where $Q > 1$, $b_n N_D / b_p N_A > 1$

$$R_o = \frac{kT}{e} \left[\frac{1}{8\pi\, e\, V_D} \left(\frac{1}{\varkappa_n\, N_D} + \frac{1}{\varkappa_p\, N_A}\right)\right]^{\frac{1}{2}} \frac{\varkappa_p}{e b_p\, N_A} \exp\, [eV_D/kT\,(1 + Q^{-1})] \tag{22}$$

From these relationships it is apparent that the ratio of the barrier layer resistance of the heated and original samples, for instance for a symmetrical junction, will be equal to $\left(\frac{N_p}{N_v}\right)^{\frac{3}{2}}$ i.e. about 1.7 for sample No. 10. The respective ratio for the unsymmetrical junction will probably be higher. From this fact it is obvious that this rectifier mechanism corresponds to our results much less than that of the metal-semiconductor boundary. Only in the case of a strong unsymmetrical junction $Q \to \infty$ [8] are the results identical. Neither can our results be explained according to Shockley's theory of the p-n junction, in which the resistance of the junction increases with the concentration of imperfections.

3. Changes of Some Rectifier Properties with Time

The stability of rectifiers over periods of time is an important problem connected with their preparation. Often a deterioration of V–A characteristics especially an increase in the reverse current above its respective limit after some time after the production of the rectifiers is observed. Closer attention was therefore paid to the changes of characteristics with time after production, pre-illumination and heating. Fig. 9 shows the dependence in the reverse current and the capacitance of the barrier layer on the d.c. potential U. Curve I corresponds to a sample measured immediately after the heating, curve II corresponds to the same sample measured 1 month later. The reverse current increased during this

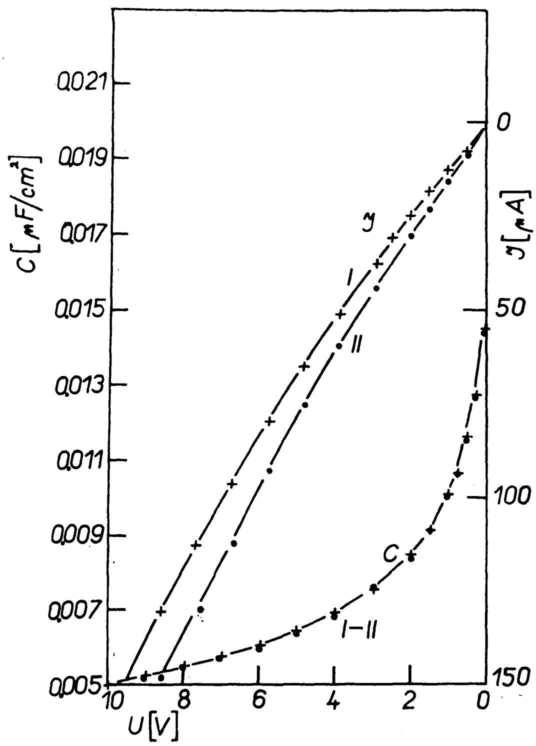

Fig. 9. The dependence of the capacity of the barrier layer and the reverse current on bias voltage
I. measured after heating
II. measured 1 month after heating

time which means that the resistance of the rectifiers decreased. On the other hand the capacitance of the barrier layer and therefore also the concentration of imperfections in this layer remained unchanged. It is apparent from these results that the reverse current increase is not caused by an increased concentration of imperfections in the barrier layer. Similar results were observed after pre-illumination of the rectifier only with the difference that a small decrease in the barrier layer capacitance of 1–1.5% was found, during one to two days after illumination. No further changes were observed. It may therefore be noted that after illumination and heating of the rectifier the concentration of imperfections is practically unchanged and the deterioration in volt-ampere characteristics, especially the increase in the reverse current, is caused by other reasons.

To explain the causes of the reverse current increase after a certain lapse of time after the production a greater number of rectifiers of 7 mm diameter were produced from OFHC copper. Different temperatures were used for the oxidation (910–1020°C). and the annealing (480—550°C). However deterioration of the quality of the rectifiers was observed for all the produced samples. This means that the production method is not a factor decisive for these changes. As is shown in Fig. 9 no change in impurity concentration in the barrier layer occurs. As molecules of some vapours contained in the atmosphere may condense under the influence of a strong electric field along the edge of the sample and thus take part in the deterioration of the characteristics, it is possible that short-circuiting of the barrier layer along the edge of the sample may occur. In order to ascertain the influence of the short-circuit on the circumference of the sample, its edge was carefully etched by means of a thin glass rod with diluted nitric acid and thoroughly washed with water. The golden evaporated upper electrodes remained unchanged. The reverse current usually decreased after this process almost to the original value measured immediately after the production. After some days, however, the current increased again; after repeated etching of the edge it again decreased. This shows that the deterioration of the barrier characteristics of rectifiers will be really caused mostly by the short-circuit alongside the edge of the sample.

Our next task is to prevent the deterioration of the above mentioned characteristics. This may be achieved for instance by spreading a protecting insulating layer over the

Table II.

1	2	3	4	1	2	3	4
20	58	26	55	28	60	27	26
16	148	31	61	8	33	17	14
42	120	35	77	42	80	37	35
20	60	25	60	21	102	35	40
40	58	43	82	22	90	26	38
36	72	36	92	14	65	13	16
20	102	38	120	12	62	16	20
32	148	28	134	15	38	17	22
80	120	58	124	14	55	18	21
20	50	16	60	14	90	19	48

edge of the rectifier. By applying a silicon laquer the results actually improved, though not always by a 100%. For illustration some values are given in Table II. In the respective columns the reverse current is indicated in micro-amperes at the voltage 2 V. The values ascertained immediately after the production and 15 months later are shown in columns 1 and 2 respectively. In columns 3 the currents measured after the edge of the rectifier had been etched are presented. The decrease of current in some cases to a value lower than that measured after the production is well apparent.

The values presented in columns 4 were measured 18–25 days after etching of the sample edges. The current increased again during this period considerably for samples with edges that had not been protected by an insulating layer. For samples that have insulating silicon layers, the current also increased some extent but mostly only very slightly (see the right part of the table, column 4). This means that it will be possible to prevent the increase of the reverse current by means of a protecting layer which prevents the access of the atmosphere and thus also of some vapours contained in the air, to the barrier layer of the rectifier. According to Fritzsche [10] the most dangerous are the vapours of hydrogen, sulphide, sulphur and amoniac.

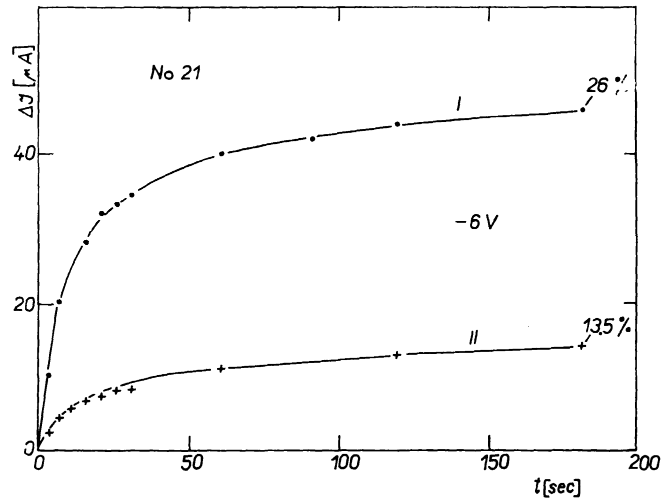

Fig. 10. The dependence of the reverse current on time
I. the original sample
II. the heated sample (100°C, 10 min.).

Let us further note the change of current with time after applying a constant voltages For some rectifiers this change is rather large the current will increase by tens of percents.

The performed experiments have shown that rectifiers heated upto temperature, of 80–130°C exhibited a much smaller change of current in time than did the same rectifiers before heating. A rather large change was observed for instance for sample No. 21 as is apparent from Fig. No. 10. (curve I), 3 minutes after the application of an electric field the current of a 6V voltage increased by 26%. After pre-heating of this sample at temperature of 100°C for 10 min. the reverse current decreased and so did its change in time. Three minutes after applying the reverse voltage (6V) the total change of current was about 13.5% of the original value and the absolute change in the current was also considerably lower (Fig. 10, curve II).

From these and previous experiments [1], [2] the importance of pre-heating of cuprous oxide rectifiers at temperatures 130°C is well apparent. During long-lasting heating up to especially combined with higher temperatures, the characteristics may, however, on the other hand deteriorate. The reverse current of rectifiers decreases and the stability increases by heating. One can thus considerably accelerate the so called aging process. The heated rectifiers will have a greater temporal stability not only in the reverse but also in the forward direction and may be used at higher temperature without changes of their characteristics occuring. This is the method used for the treatment of rectifiers in some factories for cases where a high stability and applicability at higher temperatures are required [10]. Our hypothesis regarding the association and dissociation of impurities may clarify some already before ascertained findings.

Conclusion

Some questions regarding cuprous oxide rectifiers have been discussed in this paper.

It has been proved that even for cases of non-circular diagrams of the total impedance of rectifiers the capacitance of the barrier layer may be easily determined.

The relative changes in resistance of the barrier layer, caused by illumination or heating may be explained by the association and dissociation of impurities and by means of Schottky's diffusion theory of dry rectifiers.

The deterioration of barrier V–A characteristics with time after the production of the cuprous oxide rectifiers was explained by the occurrence of a short-circuit along the edge of the sample. This may be prevented by means of a suitable insulating layer, spread over the edge of the rectifier.

The importance of heating the rectifiers at temperatures of 80–130°C was demonstrated. The heating causes a decrease of the reverse current and a higher stability over periods of time.

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