PHOTO-CURRENT-VOLTAGE CHARACTERISTICS OF WEDGE-SHAPED CdS THIN FILM

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A b s t r a c t

Photovoltaic property of CdS wedge-shaped films has been examined in term of I-V characteristics,with illumination /L/ taken as parameter. All the characteristics are linear with mutual intersection at $/I_m,V_m/$. On the bases of invariance of I_m and V_m with respect to L, an analytical expression for the characteristics has been obtained.The characteristics are uniquely determined by V_m,whose value is function on the film geometry and state of the film surface, and it can be increased by formation of heterojunction on the upper film surface.

As it was shown earlier, the wedge-shaped semiconducting thin film posses photovoltaic property, although it is homogenious in composition and uniformely illuminated[1,2].

It has been shown theoreticaly that semiconducting thin film with wedge geometry is able to generate photovoltage on the bases of Dember effect[3],and surface recombination effect[4,5]. The value of the photovoltage resulted by this mechanisms in wedge geometry never exeeds Dember voltage in bulk.

The experiments performed on many wedge-shaped CdS thin films showed higher than Dember-photovoltage. This experimental evidence proved that the generating mechanism in this case is neither Dember effect, nor surface recombination effect. In order to explain higher than Dember-voltage in wedge geometry of thin film,a new mechanism should be taken into consideration.

The aim of this work was to throw more light on the mechanism that is responsible for the photovoltaic property of wedge-shaped thin film, made of material with good photoconducting property.Therefore we have investigated photoelectric characteristics of many CdS wedge-shaped thin films, with different geometries, temperature of preparation and additional treatment of the film surface.

Preparation of CdS wedge-shaped films

Thin CdS films were prepared by pyrolysis of sprayed solution of $CdCl_2$ and thiourea onto hot glass substrate.

In order to get films with linearly varying thickness, i.e. wedge-shaped films, a special mask was inserted between the sprayer and the oscillating substrate. The mask that consisted of a series of triangular slots perfomed spatial density modulation of the jet. It was found experimentally that good film quality was obtained in a case when the sprayer worked in short intervals, in the moment when the carriage was passing through the mid position. By this method we get simultaneously three wedge-shaped films with equal quality, which could have been controlled visualy by interference strips, for the thinner film, and for thicker it was derived from the mass of deposit of two, or three sections of the film. The mean thickness of the films was found from the total mass of the deposit.

The measurement of photo-current-voltage characteristics

The films were prepared for the measurements by painting their ends with silver paste. Painted ends of the film served as terminal electrodes. The current-voltage characteristics were taken point by point, by the measurements of voltage between the terminals, and current through the film. The voltage measurement was done by precise potentiometer. Positive polarization was taken for the case when thinner end was plus, i.e. polarization which enabled compenzation of the photovoltage. In the dependence of the film property, the current was measured either by galvanometer, or by autocompenzating V-meter, shunted by decade resistor /high resistance films/. The illuminaton of the film surface was performed by Hg-fluorescence lamp, whose intensity was varied by supply voltage. The illumination of the film surface was measured in lux by means of Si-photodiode, fixed on the same holder, which served for festening of a film.

Typical photo-current-voltage characteristics of a film with three interference strips, and 0,34 μm mean thickness is presented on Fig.1. For the positive polarization the characteristics present family of straight lines that intersect in one point in the first quadrant. The intersection of the lines with I-axis, which gives short-circuit current /I_{sc}/, is proportionalto the illumination, and the intersection with V-axis, which gives open-circuit voltage /V_{oc}/, increases with illumination to saturation value /V_m/. The intersection point of straight lines, with coordinates /I_m, V_m/ is an invariant point

The same slope found from Fig.1 is

$$K = \frac{I_m + I_{sc}}{V_m} \qquad /4/$$

Since /3/ is identical to /4/,the constant parts and linear parts with respect to the illumination have to be equal,i.e.

$$Y_O = \frac{I_m}{V_m} \quad \text{and} \quad YL = \frac{I_{sc}}{V_m} . \qquad /5/$$

From /2/ and /5/ we get

$$I = (Y_O + YL)\,V - YV_mL, \qquad /6/$$

which is analytical expression of photo-current-voltage characteristics of wedge-shaped film.From /6/ it folows that the short circuit current is

$$I_{sc} = YV_mL,$$

which is linear with the illumination. The proportionality constant depends on the photoconducting characteristics of the material /Y/,and geometry of the film,and the state of the surface /V_m/.Open circuit voltage obtained from /5/ for $I = 0$,i.e.

$$V_{oc} = \frac{YV_mL}{Y_O + YL}$$

increases with the illumination, tending to saturation velue V_m.

This analyzis shows that the photovoltaic property of wedge-shaped film is uniquely determined by V_m.Examination of films should be carried in finding V_m,since it is invariant with respect to the illumination.

Conclusion

Experimental examination carried on many wedge-shaped CdS films,with different geometry /mean thickness and angle of the wedge/,prepared on different ways showed that V_m depends on the angle of the wedge and the state of the surface. For planparallel films $V_m = 0$,and as the angle increases V_m increases.For the films prepared at low temperature V_m is from 1-5 mV.For films prepared at high temperature V_m is from 10 - 100 mV.This fact sugested that surface state might play important role in enlargment of V_m.So we found that additional treatment of surface,increases the value of V_m.

with respect to the illumination and it presents characteristics for particular wedge-shaped film. Film with good photovoltaic characteristics has high value of I_m and V_m. It was found experimentaly that I_m and V_m depend on the angle of the wedge and the state of the surface. For the films prepared at relatively low temperature the value of V_m ranges from 1-5 mV. For films prepared at higher temperature V_m is from 10-100 mV. The value of V_m is drasticaly oncreased when the surface is treated chemicaly /for instance with $CuSO_4$/

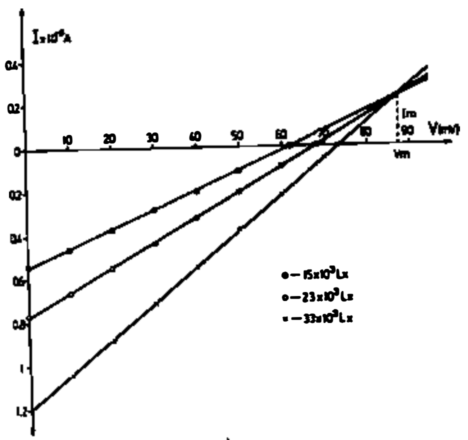

Fig.1

Analytical derivation of the characteristics

A simple analytical expression for the characteristics has been found on the bases of invariance of intersection point /I_m,V_m/. If we transform the coordinate system into a new one I'_m,V'_m, so that the new origin is put in the intersection point, we get a family of lines passing through the origin. The slope of the lines is proportional to the illumination. The physical meaning of this is that with respect to the intersection point of the film behaves like ordinary photoconductor, whose characteristic can be expressed by

$$I' = Y_0 - YL\ V' \qquad /1/$$

Since the coordinates of the new with respect to the old system are I_m,V_m, the family of lines with respect to the old system becomes

$$I - I_m = Y_0 - YL\ \ V - V_m \qquad /2/$$

The slope of the characteristics found from /1/ or /2/ is

$$K = Y_0 - YL$$

From all experimental findings one can conclude that the photovoltaic property of the wedge-shaped CdS films is due to the wedge-geometry of the film and the existance of surface barier field. On the bases of photo-current-voltage characteristics found analyticaly /5/ the behavior of the film can be described by equivalent circuit /Fig.2/. The cirquit consists of a generator V_m, and two resistors $R_0=1/Y_0$, and $R=1/YL$. Photovoltaic property of the film is uniquely determined by V_m. If V_m is zero the film is ordinary photoconductor without photovoltaic property, which is the case for planparallel geometry. As the film become wedge-shaped the value of V_m become different from zero.

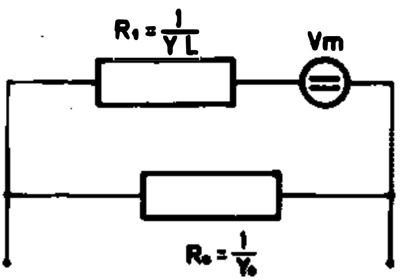

Fig.2

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