

Development of Optically-Controlled Microcircuits Based on Their Basis

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Abstract: In this paper, we consider the development of optically controlled microcircuits based on APV films. For this purpose, a generator-type POI with a thin-layer AFN-film was used to create optically controlled microcircuits, and their advantages and application in optoelectronics were also shown.

Keywords: Films of anomalous high photovoltage (APV), semiconductor compound, optically controlled microcircuits, optoelectronic sensor, MOS transistor.

Introduction

Knowledge of the characteristic microparameters of APV films allows us to clarify ideas about the nature of the generation of photovoltage in micro-photocells, and by them, in particular, the APV film is evaluated as a device and its scope is determined. Usually, when determining the characteristic microparameters to find the mobility, they resort to the photo hall effect, the interpretation of the results of which in film samples is associated with great difficulties. It was shown in [1-2] that, without referring to photo-Hall measurements, using the spectral dependences of APVN and APV effects, it is possible to determine characteristic microparameters, such as carrier mobility, diffusion length, number of micro-photoelements, and surface recombination rate.

Materials and Methods

To obtain APV films from CdSe, CdTe, CdTe: Cd compounds, it is necessary to use the method of thermal evaporation in a vacuum. The vacuum unit is assembled based on a mechanical fore vacuum pump of the RVN-4 type and a steam-oil diffusion pump of the H-01 type, which provides a

pressure of about 10⁻⁴ mm Hg. Art. Crucibles made of aluminum oxide or beryllium were used as evaporators [3-4].

The evaporation temperature of the semiconductor was achieved by controlling the current. The substrates were heated using an oven, the design of which makes it possible to change the substrate temperature to 600 °C [5-6]. The temperatures on the substrate and the evaporator were controlled by chrome-alumini thermocouples attached directly to them. Glass and quartz with metal contacts were used as substrates.

The substrate was cleaned by treatment in a boiling 0.5% solution of nitric acid, then defatted in acetone, repeatedly boiled in distilled water, wiped with medical alcohol, and placed in a chamber for evaporation [7-8].

After reaching a vacuum of 10⁻⁴ mm Hg. Art. firing the substrates was carried out by heating at a temperature of 300 °C for 30 minutes.

Powdered CdTe and CdSe grade "for semiconductors" was used as a starting material. Before the steady-state of evaporation was established, the crucible was covered with a shutter, which made it possible to more accurately control the

deposition time of the material. To preserve the composition of the charge and the initial flow of the evaporated material, before evaporation, the charge was annealed in the evaporation mode for 20 - 25 minutes. The small distance between the electrodes in the longitudinal mode of operation reduces the dielectric strength of the films; therefore, to obtain films with a large thickness and increase the deposition temperature, as well as to avoid entrainment and a direct hit of particles on the substrate, the crucible surface was covered with a quartz plate [9-10].

With the use of appropriate devices, we managed to obtain layers in a wide range of thicknesses (0.1 - 3.0 μm) and at high substrate temperatures (400 ° C).

In some cases, to prevent deviations from the stoichiometric composition, S or CdS was sprayed simultaneously during the evaporation process. Evaporation of the CdS + CdSe powder mixture also violated the stoichiometry. The CdSe and CdS materials in an appropriate amount were placed in a crucible and evaporated simultaneously. In films obtained by this technique, the electrophysical properties fluctuated over a fairly wide range. To preserve the stoichiometry, all samples were evaporated according to the three-temperature method using two crucibles: CdSe was placed in one and CdS in the other. Before evaporation, the CdSe and CdS powders were fired in the evaporation mode for 20 minutes [11-12].

The use of a two-crucible method for preparing films from CdTe: Cd made it possible to change the composition and obtain films in a wide range of substrate temperatures. Some of the main parameters of the films are given in the tab. 1.

Table 1

Sample number	Substrate temperature	Evaporation rate, mg / min	Sample resistance, Ohm
K31	100	3	10 ⁵
K51	150	3	10 ⁵
K53	150	0,5	5×10 ⁵
K45	200	5	10 ⁵
K47	200	3	10 ⁶
K67	250	1	5×10 ⁶
K65	250	5	10 ⁶
K72	300	0,5	10 ⁷
K75	300	6	10 ⁶
K81	350	5	10 ⁶
K93	400	3	10 ⁷

The technological mode of obtaining such films depends on a large number of parameters, such as the temperature of evaporation and substrate, film thickness, composition and

pressure of residual gases in the vacuum chamber, and conditions of thermal treatment of films after deposition.

The optimal technological parameters of APV films, for which the photovoltage reached 1000 V / cm² at room temperature, are as follows (Tab. 2).

Table 2

Semiconductor material	Vacuum (mm) Hg Art.	Substrate temperature, ° C	Spraying angle	Film thickness, microns
CdTe	10-4	200 - 250	35°	0,7 - 1,5
CdSe	10-4	200 - 300	35°	0,7 - 2,0

When films are obtained by thermal deposition of substances on a substrate, the important characteristics are the thickness of the films and the distribution of this thickness along the length of the film. In [2-5], the calculation of the distribution of thickness along the length of the film for the general case when the plane of the substrate is not necessarily parallel to the plane of the evaporator. This problem is of independent interest not only for APV films but also for ferromagnetic films, films widely used for the orientation of liquid crystals, etc., which are specially obtained by oblique-angle deposition of the initial substance [13].

Denoting by Θ the angle of inclination of the substrate relative to the normal, and carrying out the corresponding calculations, the distribution of the thickness along the length of the film was obtained for the case of an evaporator with a small surface.

$$\frac{d}{d_0} = \left[1 + \left(\frac{l}{h}\right) \sin \theta \right] \cos \theta \left[1 + \left(\frac{l}{h}\right)^2 + 2 \left(\frac{l}{h}\right) \sin \theta \right]^{-2} \tag{1}$$

Where $d_0 = M(4\pi\rho)^{-1}h^{-2}$ (2)

d_0 - film thickness at a point above the evaporator;

h - is the distance from the evaporator to this point;

l - is the distance from a point in the substrate above the evaporator to the point under consideration;

M, ρ - mass and density of the condensed matter material.

The maximum of expression (1) is observed at values of l/h equal to

$$\frac{l}{h} = -\sin^{-1}\theta \left\{ 1 - \left(\frac{\cos\theta}{\theta}\right) \left[\cos\theta + (3 + \cos^2\theta)^{1/2} \right] \right\} \tag{3}$$

Similarly, for the case of a point evaporator.

$$\frac{d}{d_0} = \cos \theta \left[1 + \left(\frac{l}{h}\right)^2 + 2 \left(\frac{l}{h}\right) \sin \theta \right]^{-2/2} \tag{4}$$

$$L/h$$

$$\theta = 00 (1), 300 (2), 450 (3)$$

Results

It follows from these expressions that the thickness distribution is very sensitive to the deflection angle (Θ) of the substrate from the normal. With increasing angle Θ , the maximum thickness value increases; the maximum thickness shifts towards larger values of the substrate length; symmetry about the maximum thickness is broken (Fig. 1).

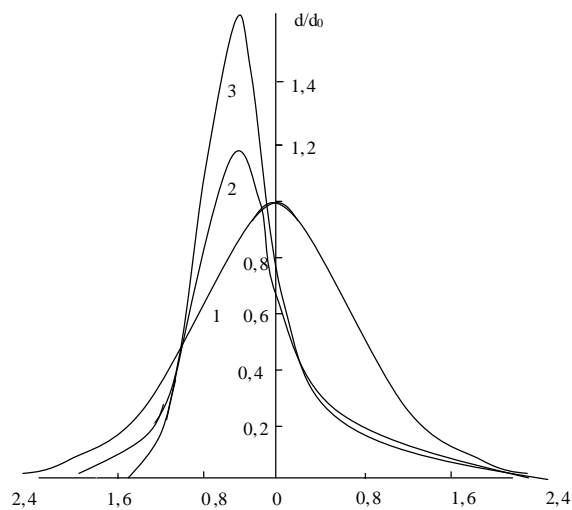


Figure 1. Thickness distribution for evaporation from a small surface evaporator.

A method is described for eliminating thickness nonuniformity along the length of the APV - film, with oblique deposition, by additional dusting. This issue is crucial for obtaining films with an optimal thickness.

To obtain films of uniform thickness, several methods are used. One of them employs several small evaporators arranged in a ring parallel to the substrate or one evaporator rotated about an axis perpendicular to the plane of the substrate.

In another technique for obtaining films of uniform thickness, the substrate is rotated around an axis perpendicular to its plane.

These techniques are not applicable for the case of APV films, since upon evaporation by the methods described above, a specific structure with inclined dendritic protrusions, which arises during oblique deposition, is disturbed and the APV disappears.

Another disadvantage of these techniques, in general, is the use of many evaporators, which is not always technically

possible, and even more so the rotation of the evaporator or substrate with conductors.

Also, in [5], a method was developed for eliminating thickness inhomogeneity along the length of the APV film during oblique deposition. To do this, we install a metal shutter between the evaporator and the substrates in the vacuum chamber, which can be moved with a magnet parallel to the source surface. Upon reaching the optimal thickness of the film end close to the evaporator, we begin to move the shutter at a speed depending on the deposition rate of the substance, thereby closing the path of the molecular beam entering this part of the substrate [10-12].

In this way, the rest of the film will gradually reach its optimum thickness. For example, in one of our experiments when the film is deposited at an angle of 60° , the distance from the substrate to the evaporator is 5 cm, the layer length is 1.7 cm, when the optimal thickness of $1 \mu\text{m}$ is chosen, the end of the film close to the evaporator grows at a rate of $0.04 \mu\text{m} / \text{min}$, the distal end of $0.02 \mu\text{m} / \text{min}$, the shutter movement speed was $1 \text{ mm} / \text{min}$.

Discussion and Conclusions

The results of the experiments on additional dusting for 6 CdTe samples are shown in Table 3 (the length of the samples is 1.7 cm).

Table 3 Influence of additional doping on APV in CdTe films.

Sample number	V_{APV}, B before	V_{APV}, B after	Additional V_{APV}, B	
	addition	dusting	B	%
9	84	101	17	16,8
11	95	137	42	30,7
12	103	152	48	31,8
14	110	143	33	23
16	120	165	45	27,3
19	115	168	53	31,6

It can be seen that when using the developed method, the increase in APV reaches 30%. By removing the dependence of V_{APV} on the film length, it is shown that in films with a thickness gradient, V_{APV} is distributed unevenly, and in films obtained by the above-described technology, it is evenly distributed.

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