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# Technological Features of Manufacturing APV Films

Turaev B. E[1], Rakhimov N. R[1], Ulugov B. D[2], NamozovJ. Sh[2]

[1]Ufa State Petroleum Technical University, Uzbekistan
[2]Termez branch of Tashkent State Technical University named after Islam Karimov, Termez, Uzbekistan

**ABSTRACT**
In this work, we describe a technique for obtaining APV films from binary semiconductor compounds CdSe, CdTe, CdTe: Cd by thermal evaporation in a vacuum.

***KEYWORDS:*** *Films of anomalous high photovoltage (APV), semiconducting compound CdSe, CdTe, CdTe: Cd, binary semiconducting compound*

## 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.

APV-films (abnormal photovoltage) [2-3] are a functional converter that transforms the luminous flux of intensity $F_0$ into anomalously high photovoltage VAPV. According to the adopted model [4], this transformation consists of three stages.

First, the creation of a photocurrent $I_F$, due to photo generation and spatial separation of nonequilibrium carriers at each micro p-n junction. Secondly, the emergence of elementary stresses at micro p-n-junctions as a result of the accumulation of space charges created by the photocurrent. Third, the formation of an anomalously high photovoltage by summing the elementary photovoltage at p-n junctions.

## Materials and Methods

In this article, we propose methods for creating optically controlled microcircuits based on a thin-layer AFN film.

The physical mechanism responsible for the appearance of the APV effect in semiconductor films with a periodic p-n-pstructure is known to be associated with incomplete compensation of photovoltage in p-n and n-p junctions due to a special technology of oblique deposition of films on a substrate. This small uncompensated photovoltage in the p-n-p cell ($V_H$<KT / q) arises either due to asymmetric illumination or due to the asymmetry of the dark saturation currents of p-n and np junctions. Both of the above factors can participate in the formation of the AFN effect.

The practical aspects of the effect are determined by the efficiency of APN films, which are closely related to the photosensitivity of transitions, the value of which depends on the absorption coefficient, the wavelength of the incident light, film thickness, the diffusion length of carriers, rates of surface recombination at illuminated and unlit faces, surface recombination of carriers, and the depth of light penetration. Coefficients that depend on the photosensitivity of the $a_1$ and $a_2$ transitions are included in the expressions for the transition photocurrents, i.e.$j_{F1}=a_1I$or$j_{F2}=a_2I$; $j_{F1}$–p-n-junction photocurrent,

$j_{F2}$ - photocurrent of n-p-junction,

I - illumination.

In this case, the most important tasks are the development of scientific methods for obtaining APN films (from various materials) with specified properties and methods of effective control over their properties under various conditions.

A wide class of semiconductor substances, in the films of which the APV effect was detected, confirms the possibility of obtaining APV films from any semiconductor [3-4].

To obtain APV films from CdTe and $Sb_2Se_3$ compounds, we used the method of thermal evaporation in a vacuum. The vacuum unit is assembled based on a mechanical fore-line pump of the RVN-4 type and a steam-oil diffusion pump of the N-01 type, which provides a pressure of about 10-4 mm Hg. Art. Crucibles made of aluminum oxide or beryllium were used as evaporators [5-6].

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 up to 600 ° C. The temperature on the substrate and the evaporator was controlled by chrome-alumni thermocouples attached directly to them. Glass and quartz with metal contacts were used as substrates.

The technological mode of obtaining APV films and the choice of a material depend on a large number of factors and parameters, such as the temperature of the evaporator and the substrate, the deposition angle, the film thickness, the composition and pressure of residual gases in the vacuum chamber, and the conditions for the heat treatment of the films after deposition. In this case, each semiconductor material corresponds to its optimal mode, and often small deviations from it, even in one of the parameters, lead to the disappearance of the APV effect in the films being produced [7-8]. Therefore, the development of a technology for obtaining APV films from a particular material requires a large experimental research work, a large (number) number of test sprays with a sequential variation of several technological parameters, their combinations, and finding parameters specific for obtaining the APV effect on films from a given(selected) semiconductor material.

When studying the APV effect in films of elementary semiconductors (Si, Ge, and Se) and binary semiconductor compounds, it was found that films made of binary compounds have relatively positive degradation characteristics. For example, in CdTe and $Sb_2Se_3$ APV films, the aging rate occurs at a low rate.

Therefore, the choice of a suitable material and the development of a technology for the production of APV films from these materials makes it possible to obtain high-quality APV films with stable parameters for optoelectronic devices based on the APV effect.

Physical methods for studying the composition of materials play the most important role in the study of the production technology of APV films.

**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 | $5\times10^5$ |
| K45 | 200 | 5 | $10^5$ |
| K47 | 200 | 3 | $10^6$ |
| K67 | 250 | 1 | $5\times10^6$ |
| K65 | 250 | 5 | $10^6$ |
| K72 | 300 | 0,5 | $10^7$ |
| K75 | 300 | 6 | $10^6$ |
| K81 | 350 | 5 | $10^6$ |
| K93 | 400 | 3 | $10^7$ |

Table 1 lists some features and parameters of the evaporation process, as well as recommended evaporators for materials that can be used in APV films of CdTe and $Sb_2Se_3$, comprehensive tests of APV films of CdTe and $Sb_2Se_3$ were not carried out, however, taking into account that for a period equal to After several weeks, their abnormal high-voltage open-circuit photovoltage and short-circuit current have decreased slightly, it can be assumed that these APV films are relatively stable.

**Results**

After analyzing the graphs of the temperature dependences, we can assume that the APV effect in films of the cadmium telluride type is associated with the summation of the voltages of p – n junctions formed at the interface between the hexagonal (0001) and cubic (111) phases. It should be noted that the APV effect in CdTe: Ag films and other complex semiconductor compounds are also associated with the p-n transition mechanism [9-10].

The resistivity of the films, calculated from the measured value of $\rho$ and the geometry of the films, is several orders of magnitude higher than the resistivity of the starting material. This indicates the presence of high-resistance interlayers in APV films. For the Dember mechanism of the APV effect, the role of such interlayers is fundamentally important, since they prevent the exchange of current carriers between neighboring photo-active microelements. In films with the p-n transition mechanism of the APV effect, the role of such interlayers is not fundamental. Thus, the film is a battery consisting of *N* active sections separated by interlayers.

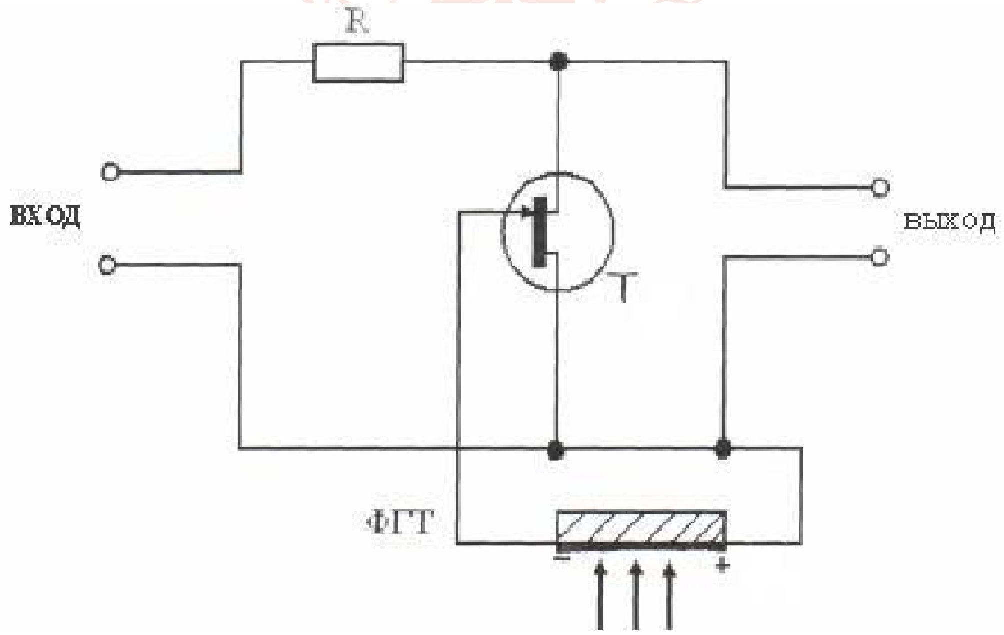


**Figure 1 Optically controlled microcircuits: T-MOS transistor, FGT-photodetector of generator type with a thin-layer APV-film.**

Microelectronics is currently facing the problem of creating microcircuits operating in the nanowatt power range (about 10-9 W). Thus, it is quite clear that the creation of such microcircuits requires a radical revision of many traditional methods and provisions.

**Discussion and Conclusions**

A striking example of this is the introduction of APV films together with MOS transistors in the technology of manufacturing microcircuits in semiconductor instrument making. In such microcircuits, power consumption is reduced, efficiency is increased, and minimal heating of the MOS transistor is ensured, which leads to low gate leakage currents and high input resistance. Microcircuits of this type have a very high gain. They can have low noise and good frequency response. High voltage gain can be obtained if the gate voltage of the MOSFET is selected close to the cutoff voltage. With the help of APV films, microcircuits on MOS transistors become optically controlled. Opto-controlled microcircuits are non-volatile (Fig. 1). In conditions of solar radiation, an external voltage source is not needed to power such microcircuits. Such microcircuits are of particular value for microelectronics since they provide the ability to create complex integrated circuits and blocks from homogeneous components manufactured using a single technology.

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