SHORT-CIRCUIT CURRENT SPECTRA OF PHOTOVOLTAIC CdTe AND CdTe:In FILMS

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It is found that generation of anomalously high photovoltage in thin CdTe:In films deposited at a certain angle is due to illumination by photons both from the intrinsic and impurity absorption regions. The temperature dependence of the short-circuit photocurrent spectrum is analyzed.

In [1], attention was first drawn to the fact that generation of anomalously high photovoltage (APV) in the foregoing CdTe:Ag films (APV of about $10^2$–$10^3$ V/cm) is caused by the illumination by photons not only from the intrinsic but also from the impurity absorption regions [2]. The impurity APV-effect is due to the quantum electron transition from the deep impurity level to the band in the barrier regions caused by photoexcitation and space separation of free carriers of one sign and residual impurity charge under the action of the internal electric field of the asymmetric micropotential barriers of grain boundaries [3]. This work is aimed at studying possible partial contributions to APV. To this end, analysis is made of the short-circuit current spectra in CdTe films.

The doped CdTe layers were grown by thermal evaporation in $10^{-4}$–$10^{-5}$ mmHg vacuum by preparation of CdTe and In from individual crucibles. The initial mass of the evaporated impurity was 3–7 wt. % of the semiconductor compound mass. The temperature of the glass substrate was varied in the range 200–500 K. As-grown polycrystalline CdTe:In samples (evaporated at a condensation rate of $v_c = 1.5$–2.0 nm/s and an evaporation angle of 30–60°) with the thickness $d = 0.8$–1.5 µm and area $5 \times 20$ mm$^2$ appeared to have low resistance and weak APV properties ($V_{APV} = 50$–100 V). However, thermal treatment (TT) of the samples in vacuum increased the resistance by a factor of 2–3. At room temperature, however, the samples generated the maximum photovoltage up to $(2–4) \times 10^3$ V, which is an order of magnitude higher than that of the undoped CdTe samples ($V_{APV} = 200$–600 V), and the short-circuit photocurrent was also increased by more than two orders of magnitude and was high as $I_{shc} \approx 10^{-8}$ A.

Figure 1 shows typical room-temperature $I_{shc}(\nu)$ spectra for the undoped CdTe (1) and the as-grown (2) and annealed (3) CdTe:In samples. It is seen from the $I_{shc}(\nu)$ curves that the spectral sensitivity significantly differs for different samples. The maxima of the spectra coincide with each other and correspond to the intrinsic absorption edge within ±0.05 eV. The long-wavelength tails of the spectra are due to impurity light absorption in the barrier regions of the crystallites, that is, due to impurity APV, the contribution from which significantly increases in the doped CdTe:In samples (Fig. 1, curves 2 and 3). The short-wavelength decays of the spectra seem to be due to light absorption in the quasi-neutral grain regions causing volume photoconductivity of the shunt layer and, thereby, a decrease in the spectral photovoltage $V_{APV}(\nu) = I_{shc}(\nu)R_{film}(\nu)$. The integral short-circuit current in the doped films exceeds that in the undoped CdTe samples by more than two orders of magnitude. For as-grown CdTe:In films ($V_{APV}$ is 60–100 V/cm), high short-circuit current is largely due to photoconductivity, whereas for the annealed films ($V_{APV}$ is $3 \times 10^3$ V/cm) it is mostly due to the photovoltaic effect.

To analyze the mechanism of formation of APV, it is highly effective to compare the $I_{shc}$ spectra of the three samples measured at 77 K (Fig. 2). In our experiments, $I_{shc}$ is practically unaffected by temperature in the range $T = 77$–300 K, which is in good agreement with the data reported in [2] for CdTe films. However, in the case of doped CdTe:In samples, both the integral value of $I_{shc}$ and its spectral maximum decrease by more than an order of magnitude as the temperature decreases from 300 down to 77 K. A significant long-wavelength shift of the $I_{shc}(\nu)$ spectrum of the as-grown CdTe:In film is observed and a doublet structure of the spectrum appears (curve 2 in Fig. 2a). The latter is due to the contributions from the impurity and intrinsic light absorption to the integral APV. In so doing, the contribution from the
impurity absorption dominates over that from the intrinsic one (see curve 2 in Fig. 2 for $h\nu < 1.6$ eV). It should be noted, however, that the contributions from the intrinsic absorption to APV in the annealed CdTe and as-grown CdTe:In films exceed the contribution from the impurity absorption (curves 1 and 3), and the doublet structure of the spectrum with opposite tails remains unchanged as compared with curve 2 in Fig. 2. The short-wavelength shifts of the maxima of curves 1 and 3 in Fig. 2 are due to an increase in the CdTe band gap with decreasing temperature.

Thus, the generation of anomalously high photovoltage (APV) in the CdTe:In films evaporated at a certain angle is due to illumination by photons both from the intrinsic and impurity absorption regions, with the contribution from impurity absorption dominance.