CHARACTERIZATION OF PHOTOVOLTAIC DEVICES BASED ON CdTe

Petru DUMITRIU, Dumitru DUCA,
Natalia MATICIUC, Tamara POTLOG

Three types of CdTe thin-film photovoltaic heterojunctions were fabricated on glass substrates with an area of 2×2 cm2 covered with an SnO_2 layer with a sheet resistance of about 10 Ω/□. We used the optimized component films to fabricate CdTe thin-film photovoltaic heterojunctions (HJs). The first type of thin-film photovoltaic heterojunctions consists of a SnO2/CdS/CdTe stack. Both undoped CdS and CdTe layers were grown sequentially without intermediate processing by the CSS method. After the CdTe layer was deposited, the structures were held in $CdCl_2$/metanol saturated solutions and then annealed in air at 400°C for ~30 min. To minimize the back contact barrier, an additional layer (~70 nm) of Te was used. The ZnSe/CdTe and CdS/CdTe cells were completed with an Ni metal contact thermally deposited in vacuum. Since the CdS layer with a bandgap energy of about 2.4 eV limits the cell optimum performance level one of the major objectives in the field of CdTe technology remains the alternative buffer layer development. Therefore the second type of thin-film photovoltaic heterojunctions is based on the SnO_2/ZnSe/CdTe stack. After the deposition of ZnSe on glass/SnO_2, the structure is held in $ZnCl_2$:H_2O saturated solution and then annealed in vacuum at 400^{o}C for ~30 min. After the CdTe was grown the same procedure as in the case of CdS/CdTe was applied. The third type of thin-film photovoltaic heterojunctions consists of a SnO_2/p-ZnTe/n-CdTe stack. The p-ZnTe/n-CdTe heterojunctions are interesting candidates for solar applications, because the theoretical limit for the solar energy conversion efficiency is relatively high - it exceeds 20%. The structure glass/SnO_2/ZnTe is immersed in the same $ZnCl_2$:H_2O saturated solution as in the case of ZnSe and then annealed in vacuum at 400°C for ~30 min. For CdTe thin films in the third type of thin-film photovoltaic heterojunctions, $CdCl_2$ activation and annealing was not applied. An indium thin layer was evaporated on the surface of the CdTe of the ZnTe/CdTe thin-film photovoltaic heterojunction, and then the structure was annealed in vacuum at 250°C. The ZnTe/CdTe cells were completed with an indium (In) metal contact thermally evaporated in vacuum. SnO_2 was used as front contact for all types of cells. The resistivity of the CdTe:In reaches a value of ~10^4 Ω·cm. All types of CdTe thin-film photovoltaic heterojunctions were fabricated in a superstrate configuration.

The photovoltaic characteristics of CdTe thin film HJs were investigated through the wide band gap components at the room temperature (300 K) and illumination at 100 mW/cm^2. In order to see if there is any effect on the photovoltaic parameters due to the small variation in the substrate temperature of the CdTe layer we investigated the current-voltage characteristics of the solar cells, changing the substrate temperature from 300°C to 340°C. We choose this domain of temperatures because the results on the properties of the CdTe films deposited at a substrate temperature higher than 350°C were investigated by other researchers. The influence of the CdTe thin film substrate temperature on the photovoltaic characteristics of CdS/CdTe solar cells is illustrated in Figure 1.

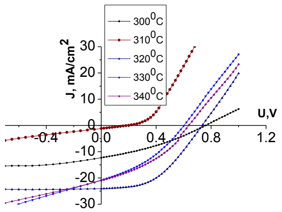

Fig.1. Current-voltage characteristics of the CdS/CdTe solar cells at different substrate temperatures

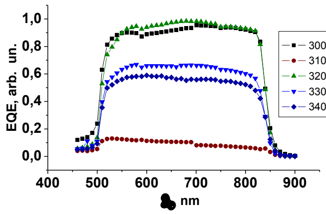

Fig. 2. External quantum efficiency of the CdS/CdTe solar cells at different substrate temperatures

The best photovoltaic parameters for CdS/CdTe solar cells were achieved at the substrate temperature of 320°C and the source temperature of 590°C. The value of the open circuit voltage (U_{oc}) and the current density (J_{sc}) achieve 0.81 V and 22.75 mA/cm^2, respectively. The CdS/CdTe solar cells with efficiency (η) of 9.56 % were obtained. The external quantum efficiency

(EQE) curves for front illumination of CdS/CdTe solar cells with different substrate temperatures are shown in Figure 2. The thickness of the deposited CdS film in all cases was 0.32 μm. The analysis of the EQE (λ) curves showed that this small variation of the substrate temperature of the CdTe layer does not have a strong influence on the form of quantum efficiency spectra, but has the most influence on the carrier generation and collection. The quantum efficiency (EQE) for all the solar cells is reasonably good for wavelengths between 520 nm and 845 nm. The device obtained at a substrate temperature of 320°C has a high collection in the visible region of the spectrum. Thus, the substrate temperature for the deposition of the CdTe layer has a striking effect on the cell performance of the solar cells. The current density-voltage (J-V) characteristics of ZnSe/CdTe thin film HJs solar cells dependence on the ZnSe layer thickness is illustrated in Figure 3. The highest efficiency was achieved for ZnSe/CdTe thin film HJs with a thicker ZnSe buffer layer. The external quantum efficiency (EQE) (Figure 4) for these cells shows that the shape of these characteristics depends on the ZnSe layer thickness. In the case of the samples with a thicker ZnSe film, most of the space charge is situated in CdTe and in a solid solution layer formed at the interface due to the diffusion of the component elements, and the EQE is determined by the electron-hole generation in them.

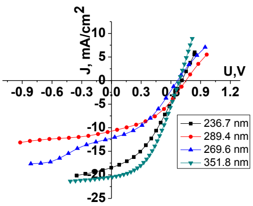

Fig. 3. Current-voltage characteristics of the ZnSe/CdTe solar cells with different thicknesses of ZnSe window layer

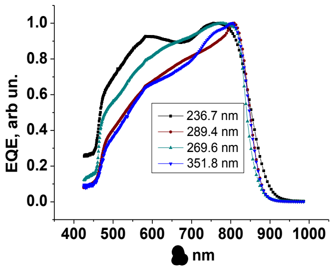

Fig.4. External quantum efficiency of the ZnSe/CdTe solar cells with different thicknesses of ZnSe window layer.

The redistribution of the electron-hole pair generation occurs with the decrease in the thickness of the ZnSe thin film. Figure 5 shows current density-voltage characteristic of a p-ZnTe/n-CdTe thin film HJS. The highest efficiency for ZnTe/CdTe thin film HJs is ~ 4%. The FF is also small as in the case of the other two thin film HJ cells. The EQE spectra of these thin film heterojunction solar cells are given in Figure 6. The most effective separation of charge carriers occurs in the ZnTe/CdTe cell with a thinner ZnTe film. This can be judged from the form of the EQE spectra.

CdTe thin-film photovoltaic heterojunctions in II-VI compounds with the structure of “glass/SnO2 film/CSS window (CdS, ZnSe, ZnTe)/CSS CdTe film” were fabricated at a CdTe

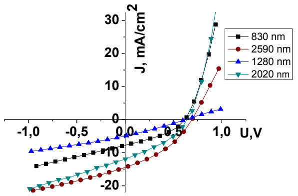

Fig. 5. Current-voltage characteristics of the ZnTe/CdTe solar cells with different thicknesses of the ZnTe window film

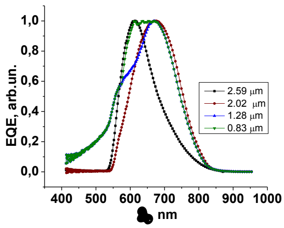

Fig. 6. External quantum efficiency of the ZnTe/CdTe solar cells with different thicknesses of the ZnTe window film

substrate temperature lower than 350°C. Besides the technological parameters of this method, an activation treatment with chlorine is crucial in manufacturing the CdTe photovoltaic devices with CdS and ZnSe window layers. The higher open-circuit voltages are achieved when CdS layers are used as a window layer. This indicates the importance of cross diffusion of the Te/S and Te/Se across the CdS/CdTe and ZnSe/CdTe interfaces, respectively.