The numerical simulation of graded band gap CdSeTe thin film solar cell

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INTRODUCTION

Cadmium telluride is widely used in the solar cell technology. The band gap of the compound is in good agreement with solar radiation spectrum. Throughout the visible light range, CdTe is characterized by high values of the absorption coefficient. However, the efficiency of CdTe use in photovoltaics is influenced by a significant surface recombination coefficient and a rather short lifetime of the carriers.

The band gap of $CdSe_yTe_{1-y}$ solid solution changes nonlinearly with the change in selenium content. Pure CdSe has a band gap of about 1.7 eV. As the selenium content decreases, the band gap decreases to approximately 1.4 eV at y = 0.5-0.6, and then increases to 1.45 eV for CdTe. The use of graded band-gap ternary compound with variable concentration of selenium in solar cell formation can be implemented in different ways:

It is possible to form a layer on the surface with a wide band gap, and then gradually reducing the selenium content with the film depth, we will get a structure with a built-in electric field, which, on the one hand, will more effectively separate charge carriers directed by the field through p-n junction and the effect of surface recombination is reduced due to the generation of carriers not on the surface but in the structure bulk.

Reducing the band gap reduces the open circuit voltage and fill factor. However, narrow band allows a more efficient use of the long-wavelength range of the solar spectrum. As a result, the short-circuit current increases.

METHODS

We considered graded bandgap structure of p-$CdSe_yTe_{1-y}$ with varying selenium concentration at upper interface and at metallurgical interface. CdS was taken as window layer and ITO layer as TCO. The cell characteristics were determined in the next steps [1]. We solved the Poisson equation with proper boundary conditions for all regions. Minor carrier concentration distribution was derived from continuity equations for p- and n-regions. Generation rate was determined by summarizing the number of photons absorbed in a nanometer of wavelength change for AM1.5 spectrum. Absorption coefficient of CdTe was the only function of incident light wavelength, whereas the coefficient of CdSeTe was the function of wavelength and depth *x*. Recombination losses were by Shokley-Hall-Read and surface recombinations. For comparison the identical calculations were performed for uniform band gap structures.

We concentrated our attention on different profiles of band gap of active layer in simulation of solar cell characteristics. The parameters used in calculations and attributed to TCO and n-type layer were constant [2-4]. The thickness of TCO was calculated before the main calculation start and the result supplying minimal light reflection was taken into account (80 nm). Acceptor density entered into the program for uniform band gap of active layer as variable and the value supplying maximum cell efficiency (10^{15} 1/cm^3) was used in the further simulations.

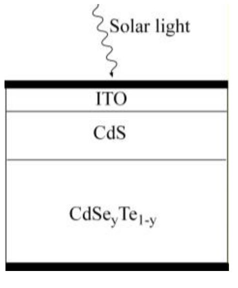


Fig. 1 – Simplified model of graded band gap solar cell

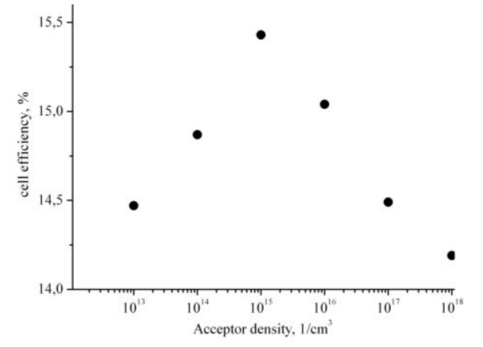


Fig. 2 – Solar cell efficiency for uniform band gap (1.45 eV)

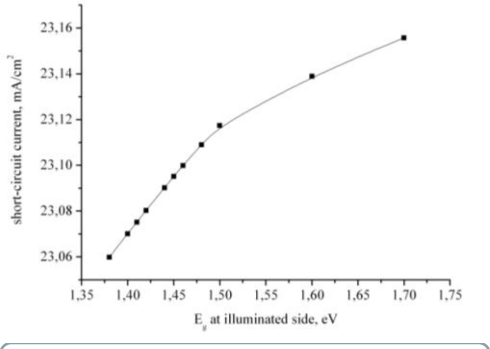
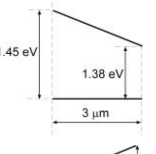
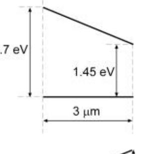
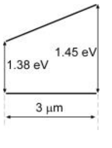
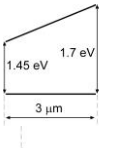
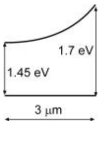
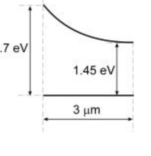


Fig. 3. Short-circuit current density as a function of band gap at illuminated side

RESULTS

The results for linear and parabolic profiles of active layer band gap are presented in Table 1. Low efficiencies of solar cells with increasing band gap inside of active layer can be caused by significant influence of recombination processes into the surface region and by internal electric field that slows down the minority carriers. The highest efficiency for linear profiles (17.71 %) we achieved when both factors were satisfied, namely, accelerating internal field and low level of absorption at the surface, that supplied effective partition of minority carriers into the cell. Absorption spectrum widening into long-wave region did not appreciable gain. The parabolic profile of band gap leads to slightly increased cell efficiency in comparison with linear case due to rapid field gradient in surface region. The parabolic profiles with local minimum inside the absorbing layer have lower efficiency owing to the appearance of regions with reverse direction of internal field. For uniform band gap (1.45 eV) we get the efficiency 15.43 that loses to the one for gradient structures.

Table 1. Solar cell characteristics for different profiles of band gap

Band gap profile	Cell efficiency	Band gap profile	Cell efficiency
	15.84		17.71
	14.37		15.23
	15.14		17.77

CONCLUSIONS

On the basis of numerical simulation we determined key parameters for achievement of highest cell efficiency. The most favourable carrier concentration is 10^{15} 1/cm^3. Graded band gap active layer with parabolic profile supplies the best result among the other types of grading and in comparison with uniform one.

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