Composite semiconductor nanocolumnar ZnO/CdTe films

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Several approaches have been investigated to develop *Eta*-solar cell, a new solid state photovoltaic device based on an intrinsic semiconductor Extra Thin Absorber (*Eta*) sandwiched between two strongly interpenetrating transparent (wide band gap) semiconductors [1-3]. The key feature of this type of device is an extreme surface enlargement, by a factor 100 or larger relative to dense films, that allows the reduction of the absorber thickness in the same order of magnitude. Electron-hole pairs photogenerated in the absorber do not need to travel over large distances before being separated and collected since the absorber is very thin (few tenths of nanometer) and is «soaked» in the (p-i-n) junction electric field of the two wide band gap semiconductors. This helpfully relaxes the constraints on the absorber electronic quality (recombination centers). A promising approach based on a composite ZnO/semiconducting absorber columnar nanostructure has recently been proposed [4]. The ZnO is a 3.4 eV wide band gap n-type semiconductor. The initial thin film obtained by electrodeposition on (F:SnO2) conductive glass, is constituted of free standing monocrystalline ZnO columns with a 10 to 100 fold surface area enhancement compared to a flat surface. This type of morphology is therefore very suitable for the design of *Eta*-solar cells. We have recently shown that coating the columns with a-SiH results in a low reflectivity and high light trapping efficiency [4]. In this paper, a new composite structure based on ZnO/CdTe is proposed. The advantage of using CdTe instead of a-SiH as an absorber stands in its direct energy gap of 1.56 eV, resulting in an absorption coefficient for visible light of more than 10^5 cm^{-1}, allowing the deposition of a thinner layer to absorb a large part of light above the bandgap.

The CdTe deposition was performed by vapor phase epitaxy (VPE), under dynamical vacuum. The VPE growth was carried out at the evaporation temperature of ~775ºC, in a Mo crucible heated by Joule effect. The VPE source was made of a CdTe polycrystal, previously grown by the travelling heater method. The glass/SnO_2/ZnO substrate was located at 14 cm from the evaporation crucible, and no heating system for the substrates was used. The evaporation time was varied between 1.5-2 min, in order to obtain deposition of different thicknesses

Fig. 1 shows that the 40-75 nm thick CdTe layer is lining the ZnO nanocolumns as a continuous film with conformal coverage. The polycrystalline CdTe layer is a mixture of cubic and hexagonal crystalline phases. The optical properties are similar to those of bulk CdTe with a 1.56 eV direct band gap optical transition (Fig. 2). The effective reflectance of the ZnO/CdTe nanostructure calculated between 400 and 800 nm is equal to 7.7 % (Fig. 3) and the calculated effective absorption close to 90 % indicates a very efficient light trapping effect. The composite nanocolumnar ZnO/CdTe structure has considerable potential for use in photoelectric thin film devices. To finalize the *Eta*-solar cell structure, chemical deposition of CuSCN, a wide band gap p-type semiconductor (3.2 eV) on the columnar ZnO/CdTe nanostructure has been undertaken.

References

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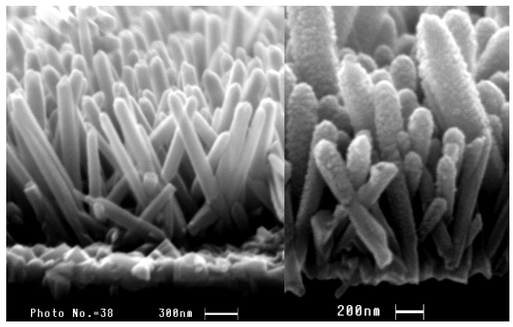

Fig. 1 Plane-view electron micrographs. (On the left) ZnO film constituted of free standing columns on conductive glass. (On the right) the composite ZnO/CdTe nanocolumnar film.The CdTe layer is 40 nm thick.

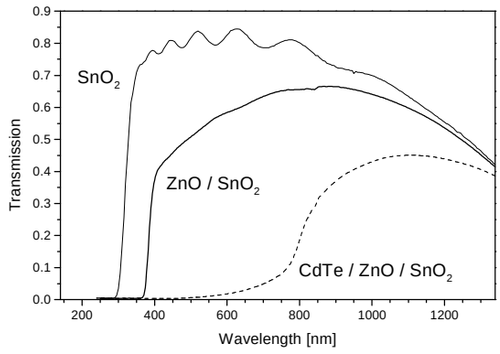

Fig. 2. Transmission spectra of the (F:SnO_2) conductive glass, the electrodeposited ZnO film and the nanocomposite ZnO/CdTe film. The CdTe layer is 75 nm thick.

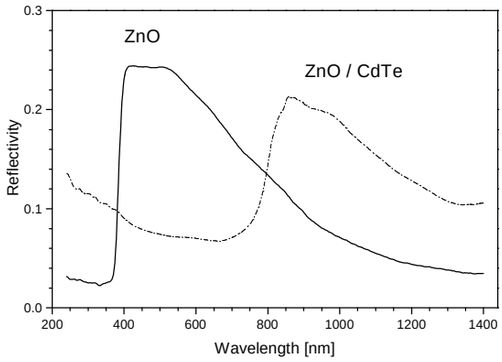

Fig. 3. Total reflectivity spectra of ZnO and ZnO/CdTe films on conductive glass.