

Studies of Cadmium Sulphide as a “buffer layer” for thin films solar cells



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Abstract

Cadmium sulphide (CdS) thin films are important materials used extensively as the window layer in CdTe/CdS solar cell devices. These films appear to be the best available partner for the CdTe/CdS solar cells due to its ability to transmit maximum amount of light to the active layer. CdS films make n type region for the heterojunction solar cells and serve as a buffer layer for the device due to its wide band gap of 2.42 eV, which is almost 1 eV higher than the bandgap of the absorber layer i-e CdTe. The choice of the buffer layer is constrained by the optical and electrical characteristics of the material as well as compatibility with the fabrication process. For the development and optimization of such optoelectronic devices, CdS thin films require comprehensive optical characterization

Experimental studies

The CdS thin films were deposited on a glass and (100) silicon substrates using the vapor-phase condensation method. The growth temperature T_s was 200°C, evaporation temperature of the pre-synthesized compounds CdTe change within $T_E = (800 - 900)^\circ\text{C}$. The thickness of the thin films was determined by deposition time $\tau = (60-420)$ sec (Table I). Structural properties and cross-section images of the film was investigated by scanning electron microscopy Vega3 Tescan and using the Atomic Force Microscope CSM Instrument. The film thicknesses, d , measured with an 2D Profilometer Bruker Dektak XT.; Optical transmission spectra were measured in the wavelength range of 190 – 1500 nm using Agilent Technologies Cary Series UV-Vis-NIR Spectrophotometer. The chemical composition of the obtained films was investigated by SEM using the method Energy-dispersive X-ray spectroscopy (EDS).

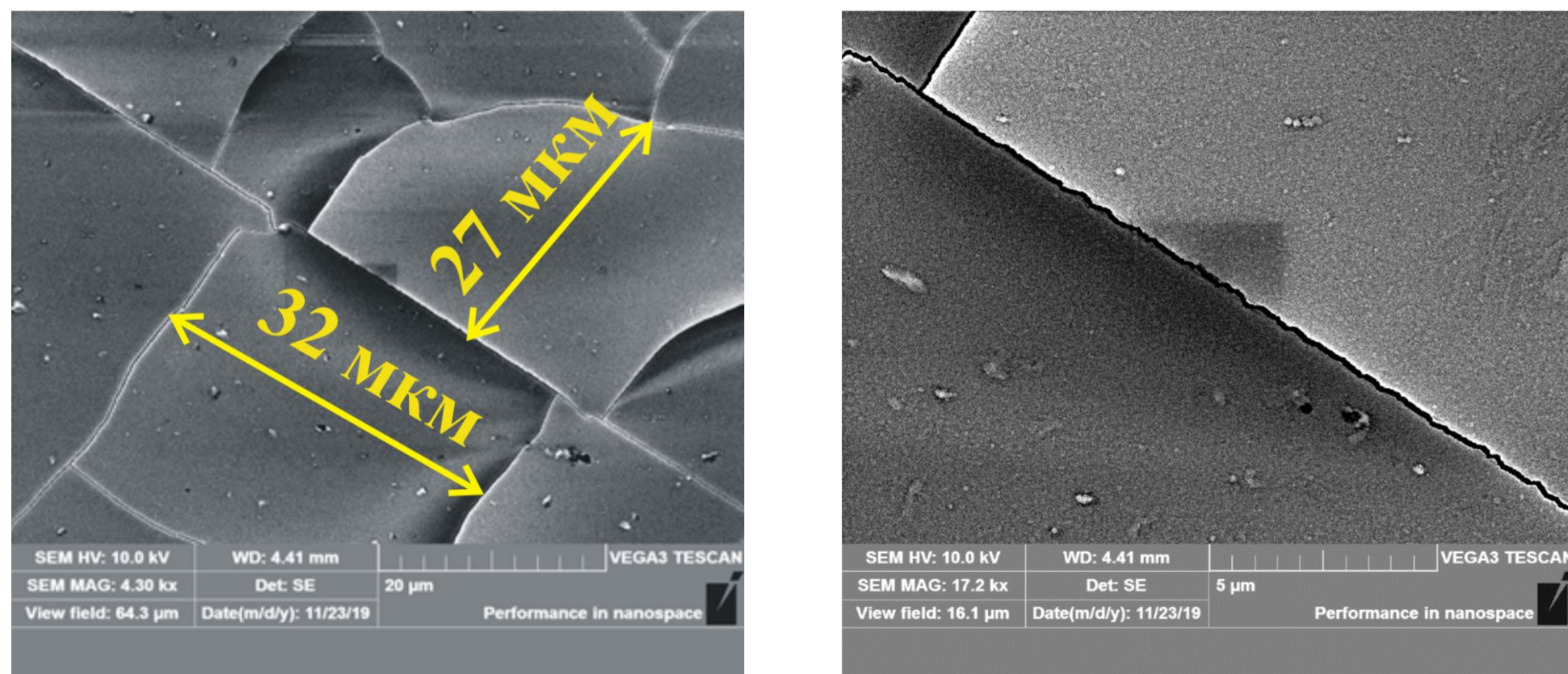


Fig.1. SEM-image of CdS (sample 2b) Substrate temperature $T_s = 200^\circ\text{C}$, evaporation temperature $T_v = 880^\circ\text{C}$, deposition time $\tau = 60$ c, film thickness $d = 420$ nm.

Morphology

As can be seen (Fig.1), the surfaces of films of smaller thicknesses have a "scale" structure, ie, condensate is formed on the surface of the film in the form of individual plates. The size of these plates and their very presence is directly determined by the deposition time. In particular, it could be concluded that an increase in the deposition time leads to a decrease in the lateral size of the "scales": from about 30 μm at a deposition time of 60 s to ~ 20 μm at a deposition time of 90 s. Given that the surface platinum decreases in size, we can assume that with increasing deposition time, the process of their fusion begins. A further increase in the deposition time leads to blurred outlines of such plates, and for the thickest films it is absent. This hypothesis is supported by the fact that for small film thicknesses there is a combination of such plates in certain complexes.

Conclusions

Analysis of the optical properties of CdTe thin films was performed and their comparing after the addition of an “buffer layer” of CdS has been investigated. Optical transmission spectra of thin films were examined with use of Swanepoel method. It was found that the thin layer of CdS causes significantly increase in the absorption properties of the films. The optimal thickness of the CdS layer for the best values of the efficiency of the CdS / CdTe heterojunction 16,2% was optimized in the SCAPS software for simulation of the optical parameters.

Optical properties

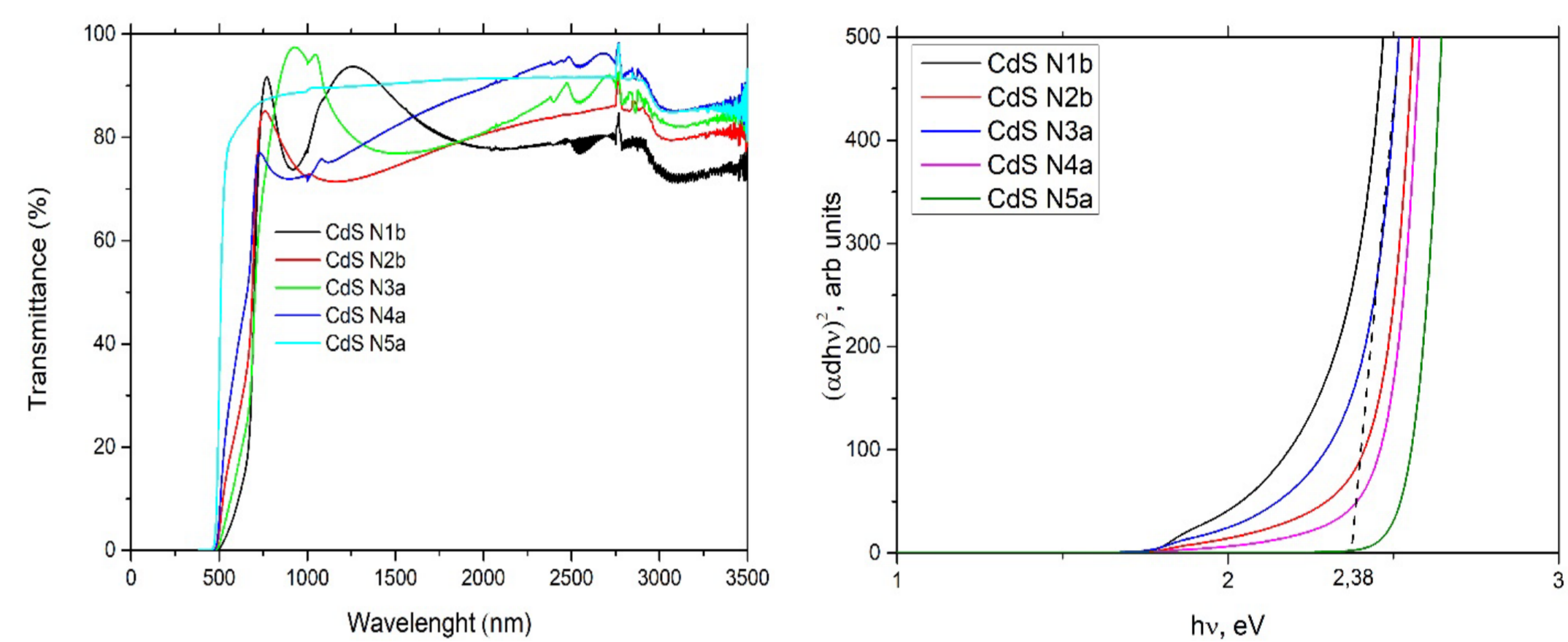


Fig.2. Optical transmission of CdS / glass thin films (a) and optical band gap (b).

The optical properties of CdS thin films were investigated as a function of wavelength transmission.. Films of different thickness deposited on a glass substrates were used for the study. Can be see the periodic highs and lows due to interference, which also indicates the high structural perfection of thin films. In fig. 2 presents the spectrum of optical transmission of thin CdS films on a glass substrate (a) and the determined width of the band gap (b). The spectral dependence of the absorption for CdS films on the Tauc graph shows the presence of a fundamental absorption limit ($E_g = 2.38$ eV). The linear nature of the dependences $(\alpha hv)^2 = f(hv)$ indicates the formation of the absorption edge by direct interband optical transitions.

SCAPS simulation

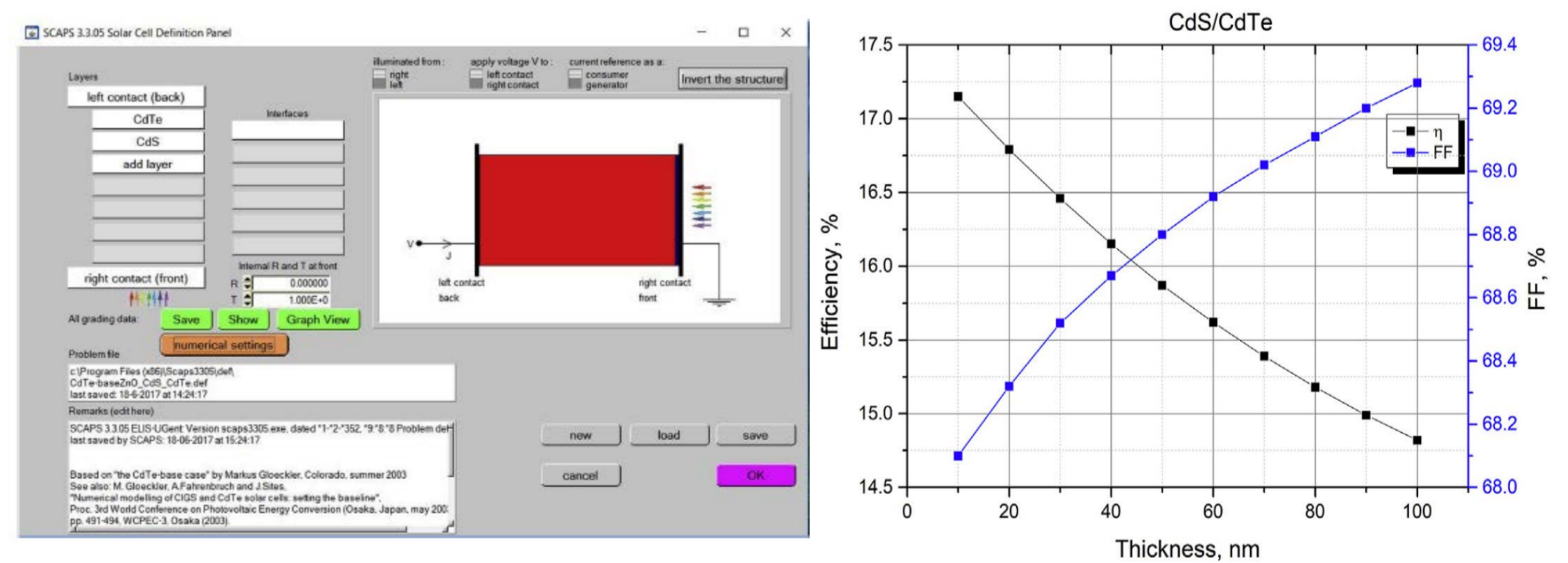


Fig.3. Variation of the efficiency η and FF of the CdS / CdTe heterojunction as a function of the thickness of the "window layer" of CdS ($d_{CdTe} = 3$ μm).

In this work, modelling and simulation for thin film CdS/CdTe solar cell solar cell were done using a one dimensional solar cell simulation software SCAPS-1D. Experimentally, the thickness of the window layer CdS ranged from 10 to 100 nm, while other parameters of the absorption layer CdTe with a thickness $d = 3$ μm were constant. In fig. 3 shows part of this range, namely from 10 nm to 100 nm. A CdS layer thickness of 50 nm is the technologically minimum limit for the open evaporation method, and this value has the best efficiency for the entire thickness range. Reducing the thickness of the CdS window layer directly leads to an increase in the performance of the solar cells of the CdTe absorption layer by reducing the absorption losses occurring in the window layer, as well as a possible increase in short-circuit current. Moreover, reducing the thickness of CdS increases the possibility of diffusion of CdS to CdTe in the manufacturing process of solar cells. Such diffusion between the window layer and the absorber layer can reduce the deformation caused by the mismatch of the lattice, and thus causes a reduction in defects in the interface.

