OPTIMIZATION OF CDS LAYER PROPERTIES FOR ENHANCED PERFORMANCE OF THIN-FILM SOLAR CELLS

Yu Rongfeng, Leliuk S.Yu., Minakova K.O., Kirichenko M.V., Zaitsev R.V.
National Technical University «Kharkiv Polytechnic Institute», Kharkiv

Thin-film solar cells based on CdTe and Cu(In,Ga)Se_2 (CIGS) are promising for large-scale terrestrial energy production due to low cost and high efficiency. A key component is the wide-bandgap cadmium sulfide (CdS) buffer layer, which influences p-n junction formation, carrier separation, and minimizes interface recombination. This research analyzes CdS thin films deposited by vacuum thermal evaporation and the "hot wall" method, focusing on their structural, optical, and electronic properties. The vacuum method limits substrate temperature to ~200°C due to sulfur volatility, while the "hot wall" method allows heating up to 450°C, enabling near-equilibrium growth. A known temperature-dependent relation describes the vapor pressure of CdS during evaporation.

$$\lg P = -A/T + B, \quad (1)$$

where A = 10460 and B = 6.3 within the temperature range 600–900°C [1].

X-ray diffraction analysis revealed that films deposited at higher substrate temperatures exhibited improved crystallinity, with reduced microstrain and larger grain size. These factors enhance charge carrier mobility and reduce recombination at grain boundaries. Optical characterization showed that the transmission spectra and the bandgap energy of the CdS layers are strongly dependent on deposition parameters and film thickness. The absorption coefficient α was calculated using the Bouguer–Lambert law:

$$\alpha = \ln((1 - R)/T) / t, \quad (2)$$

where T is the transmission, R is the reflection coefficient, and t is the film thickness.

The bandgap energy E_g was determined using T_{auc} plots from spectral measurements:

$$(\alpha h\nu)^2 = A(h\nu - E_g), \quad (3)$$

demonstrating that increasing film thickness from 880 Å to 2550 Å results in a bandgap decrease from 2.33 eV to 1.96 eV [1]. This correlates with an increased absorption coefficient and reduced reflectivity, indicating improved optical absorption in the visible range. The study showed that CdS layers deposited using the "hot wall" method exhibited fewer recombination-active defects and improved band alignment at the heterointerface in CdS/CdTe and CdS/CIGS structures [2, 3]. Based on these results, optimized substrate temperatures, annealing regimes, and thickness control were recommended to enhance film quality. Overall, precise control of deposition parameters significantly improves charge carrier transport and reduces recombination, leading to better solar cell performance.

References

1. V.A. Mikhailov, S.Yu. Ratinov, Vacuum deposition of CdS films and their structure, Semiconductors, 2007, Vol. 41, pp. 123–128.
2. N.M.R. Peres, F.D. Klironomos, S.W. Tsai, J.M.D. Lopes dos Santos, A.H. Castro-Neto, Electromagnetic response of chemically substituted graphene, arXiv:0705.0304v1 [cond-mat.mtrl-sci], 2007.
3. A.H. Castro Neto, F. Guinea, N.M.R. Peres, K.S. Novoselov, A.K. Geim, *The electronic properties of graphene*, Rev. Mod. Phys., 2009, Vol. 81, pp. 109–162.