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The use of vacuum evaporation for production of the Cu_xS absorber layer in thin-film CdS solar cells

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Abstract. Vacuum evaporation has been investigated as an alternative to the more commonly employed chemiplating technique for Cu_xS film formation in CdS/ Cu_xS solar cells.

The desired chalcocite phase has been found to be the dominant phase in the Cu_xS layers deposited at very low rates. The greater control provided by the evaporation technique, compared with the chemiplating process, is found to yield improved reproducibility as well as improved characteristics of the resultant solar cells.

Uncertainties concerning the long-term operational stability of $\text{Cu}_x\text{S}/\text{CdS}$ thin-film devices still hamper their commercial exploitation. These uncertainties are associated mainly with the Cu_xS layer, the properties of which are highly sensitive to composition. The phase required for the absorber layer is the chalcocite (Cu_2S) phase but the usual chemical exchange process for forming the Cu_xS layer results in non-uniform stoichiometry and thickness. This process also provides a $\text{Cu}_x\text{S}/\text{CdS}$ junction area that is much larger than the planar area of the cell, leading to reduced open-circuit voltage [1]. To overcome these problems, we have investigated an alternative Cu_xS film formation process using vacuum evaporation.

A single-source evaporation process was employed. The Cu_xS powder was placed in a conventional tungsten–alumina crucible and substrates of plain glass, ITO-coated glass or polycrystalline CdS films were located vertically above the source, in a holder that could be heated independently up to 300 °C.

Due to the different vapour pressures of the constituent elements, the source powder tends to become rich in Cu during the evaporation, leading ultimately to the appearance of elemental Cu in the resultant Cu_xS films. For films formed using high deposition rates and high substrate temperatures (>200 °C), SEM micrographs revealed the presence of Cu nodules. The presence of excess Cu is expected to enhance the formation of highly stoichiometric Cu_2S , and x-ray diffraction studies have confirmed that Cu_2S is the predominant phase in the layers that yield additional diffraction lines characteristic of copper. However, the presence of Cu nodules is not beneficial in layers used as absorber layers in solar cells, but it was found that these nodules could be avoided by performing the evaporation at a very slow rate (<150 Å min⁻¹).

Due to the conductivity of Cu_xS being governed mainly by Cu vacancies, the resistivity was found to increase significantly as the Cu/S ratio was increased and the layers deposited onto CdS were less resistive than those on glass due to the diffusion of Cu

from the Cu_xS into the underlying CdS substrate. This diffusion generated a semi-insulating region in the near-surface region of the CdS layer as is required for good photovoltaic behaviour [1]. Further improvement in the characteristics of the completed photovoltaic cells could be obtained by post-fabrication annealing treatments. However, the main benefits arising from the formation of the Cu_xS layer by vapour deposition are the improved reproducibility of the cell characteristics and the increased open-circuit voltage (by up to 60 mV) due to the creation of a more nearly planar junction.

Reference

- [1] Rothwarf A 1980 *Solar Cells* **2** 115–40