Defect Spectroscopy on Damp-Heat Treated ZnO/CdS/Cu(In,Ga)(S,Se)$_2$/Mo Heterojunction Solar Cells

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The changes of defect characteristics induced by accelerated lifetime tests on solar cells of the heterostructure ZnO/CdS/Cu(In,Ga)(S,Se)$_2$/Mo are investigated. Encapsulated modules were shown to be stable against water vapor and oxygen under outdoor conditions, whereas the fill factor and open-circuit voltage of non-encapsulated test cells are reduced after prolonged damp heat treatment in the laboratory, leading to a reduced energy conversion efficiency. We subjected non-encapsulated test cells to extended damp heat exposure at 85 °C ambient temperature and 85% relative humidity for various time periods (6 h, 24 h, 144 h, 294 h, and 438 h). In order to understand the origin of the pronounced changes of the cells, we applied temperature-dependent current-voltage and capacitance-voltage measurements, admittance spectroscopy, and deep-level transient spectroscopy. We observed the presence of electronic defect states which show an increasing activation energy due to damp heat exposure. The corresponding attempt-to-escape frequency and activation energy of these defect states obey the Meyer-Neldel relation. We conclude that the response originates from an energetically continuous distribution of defect states in the vicinity of the CdS/chalcopyrite interface. The increase in activation energy indicates a reduced band bending at the Cu(In,Ga)(S,Se)$_2$ surface. We also observed changes in the bulk defect spectra due to the damp-heat treatment. – PACS: 73.20.hb, 73.61.Le

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