Advanced Transmission Electron Microscopy for the Development of High-Efficiency Solar Cells

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High-efficiency multi-junction solar cells based on hetero-epitaxial III-V compound semiconductor layers reach currently highest solar-electric conversion efficiencies of more than 46% under concentrated sunlight (1). Such cells are fabricated by metal-organic vapor phase epitaxy (MOVPE) and are primarily used in terrestrial concentrator photovoltaics, in power generation for satellites and spacecraft and for solar generation of hydrogen (e.g., ref. 1). Being important also for their integration with cells based on Ge and Si, the challenges in heteroepitaxial layer growth of different III-V semiconductor materials are the reduction of crystal defects and the control of layer strains, caused by the differences in lattice constant and thermal expansion. Successful approaches used for processing technologies are the direct epitaxial growth on substrates involving buffer layer concepts (2, 3), and the layer transfer combined with semiconductor wafer bonding (4-7). The imaging and spectroscopic methods of advanced and in situ transmission electron microscopy (S)TEM are instrumental in developing concepts for engineering and controlling layer strains and in understanding electrical properties of interfaces and their behaviour during thermal processing, thus contributing relevant analytical information for the development of successful processing technologies in solar cell fabrication. Current developments, aiming at solar cell efficiencies of 50 % and more, explore new combinations of materials systems and employ novel approaches for high-resolution characterization of electrical interface properties.

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