OPTIMIZATION OF GRIDLINE ARCHITECTURE IN THE NEXT GENERATION OF HIGH EFFICIENCY MULTI-JUNCTION SOLAR CELLS AT SPECTROLAB

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Abstract

Solar cell efficiency is extremely leveraging for reducing the levelized cost of energy (LCOE) in CPV systems. Spectrolab has been on a path to continuously improve the efficiency of its multi-junction III-V solar cells, and has developed and introduced four generations of multi-junction solar cells for terrestrial concentrator photo-voltaic applications over the past four years with continuous improvement in the conversion efficiency from 37% for C1MJ to 40% for C4MJ. This continuous increase in conversion efficiency has been achieved by progressing on two parallel fronts – i) improvements in the cell design and quality of epitaxial layers, and ii) improvements in wafer fabrication processes, including optimization of the metal gridline architecture. In this paper, we will discuss the various factors related to the optimization of gridline design and the wafer fabrication processes that have impacts on the electrical performance of the solar cells.

From wafer fabrication point of view, design and fabrication of metal gridlines have arguably the largest impact on the solar cell performance. Optimization of the gridline architecture is extremely important to achieve high efficiency since a proper balance between minimization of the metal coverage of the surface of the cell (so as to reduce obscuration area) and maintaining sufficiently high electrical conductance of the grid structure (to be able to carry several amperes/cm^2 of current generated by concentrated sunlight) needs to be achieved. We have, hence, developed an extensive mathematical model to out to find optimum gridline parameters such as base width, thickness (height) and inter-gridline spacing as a function of cell area, level of light concentration, shape of the gridlines etc. Furthermore, a separate model was developed to investigate the effects of non-normal angles of light incident on the solar cell. Estimation of the effects on non-normal light incidence is extremely important for high concentration photo-voltaic (HCPV) systems, since in most of the advanced HCPV systems a large fraction of the light incident on the cell through the secondary optical elements arrives at angles significantly different from normal. Hence, a solar cell design optimized for theoretical normal light incidence does not perform optimally for most HCPV systems. We have utilized these tools to further optimize our existing C3MJ+ and C4MJ lattice-matched and metamorphic cell architectures. In this paper we apply these tools to optimize the gridline design in several real-life HCPV systems and discuss the differences in cell performance as a function of light incidence angle.