Optical optimization for III-V//Si multijunction solar cells

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III-V//Si Multijunction Solar Cells (MJSCs) provide a potential for high performance and low-cost photovoltaic device. After decades of efforts in investigation, and with the benefit from advanced technology in MOVPE and lifting off of the growth substrate, up to now, the highest conversion efficiency of mechanically stacked III-V//Si MJSCs is 32.45%[1] for GaInP//Si two junctions and 35.9%[1] for GaInP/GaAs//Si three junctions solar cells. At the same time, high quality single junction III-V cells approaching radiative limit have higher external radiative efficiency which allows them to benefit more from photo recycling effect from metal back reflector. So, besides further exploration in fabrication technology, getting higher efficiency in III-V//Si MJSCs by the method of optical optimization starts drawing more attentions. Referring to optical manipulation in this area, anti-reflection coating (ARC) layers[2], rear layers of top cells, intermediate layers between top and bottom cells, and the light trapping in bottom cells are the main issues.

Optical manipulation methods have been conducted by several groups which show promising results. ARC thickness optimization and textured surface are considered firstly. Besides this, Stephanie Essig's group[1] applied epoxy adhesion as the intermediate layer which provides relatively low refractive index and is good for photon recycling[3]. Low refractive index as intermediate layer provides narrow escape cone[4],most of anisotropic photons from radiative recombination could be reflected back. However, within escape cone, photons emitted pass the intermediate layer and be absorbed at bottom cell provide lower V_{oc}. This result top cell in III-V//Si MJSCs is ~2% lower in efficiency comparing with the record of single junction cell with metal back layer.

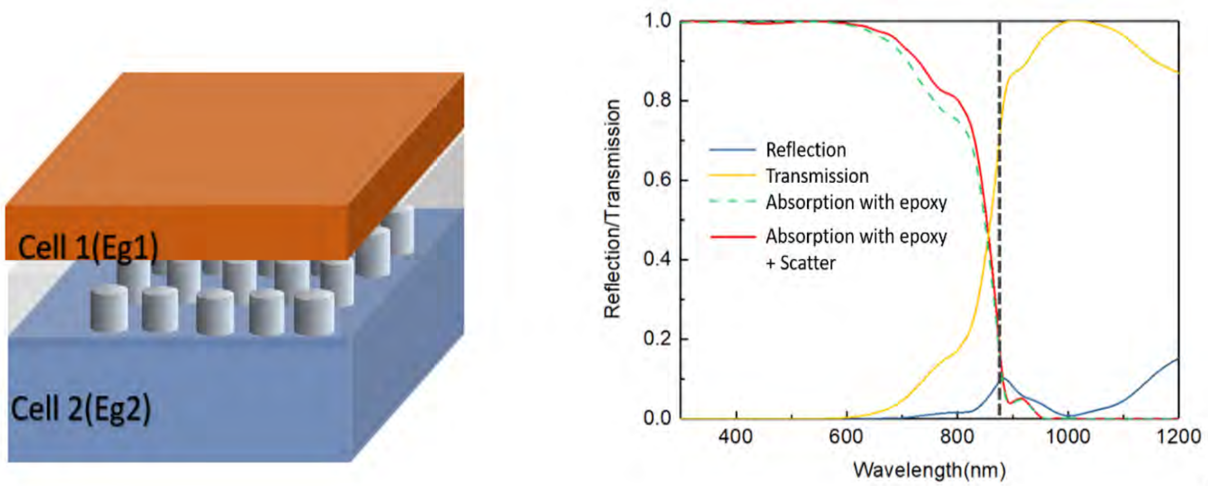

Figure 1. (a) Illustration of intermediate layer consist of scatter array and transparent epoxy. (b) Transmission, reflection and absorption spectra for III-V MJSCs with/without scatter.

Our work focus on maximize the utilization of photons emitted from radiative recombination through the optical optimization. Simulation of intermediate layer with epoxy and various nanostructures as angle and wavelength selective reflector have been conducted. GaAs and silicon are applied as the top and bottom cell, respectively. Metal or dielectric nanostructure as specific wavelength reflector to deal with the photons within the escape cone. Results indicated that epoxy as adhesive glue provided angle selective layer which results escape cone of ~24°. Within the escape cone, metal nanostructure and Si pillar array can reflect specific wavelength through carefully designed geometry parameters. Metal nanostructures show promising effect in wavelength manipulation by metal localized surface Plasmonics Resonance(LSPR). However, they will convert photo energy into heat and introduce more current losses. Dielectric scatter such as silicon disk showing narrow scatter wavelength with ignorable absorption is the promising candidate. Through carefully adjustment, photons at the bandgap of top direct-bandgap cell can be reflected back and be reabsorbed. Comparing with epoxy layer, the scatter will improve J_{sc} of the top cell by~1.5 mA/cm2 with an ignorable influence on the bottom cell. Our work provides a potential to further improve the efficiency of III-V//Si MJSCs which could be realized by nanoimprint or self-assemble technology.

References

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