Broadband Anti-reflective Coatings for Multi-junction Solar Cells

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A key issue for further improving efficiencies of the existing terrestrial and space solar cells is to enhance the anti-reflective coatings (ARC) used on top of cells and cover glasses. The theory of optical thin film filters and especially ARCs is well established [1] and all the physical relations relevant to ARC design can be found in most optics books. The focus of improving ARCs has transferred more to material development [2] and nano-patterning by lithography [3] for finding the best possible conditions for near-zero reflectivity designs.

This study focused on thin film ARCs on III-V semiconductor solar cells intended for space applications and concentrated photovoltaics. Two different thin film coatings i) electron-beam evaporated magnesium fluoride (MgF_2) and ii) silicon dioxide (SiO_2) deposited with plasma-enhanced chemical vapor deposition (PECVD) were studied. Optical properties, mainly refractive index, of the materials were controlled by varying the deposition conditions. All the investigated films were used as the low index layer material in a double or triple layer ARC. The high index material for this study was electron-beam evaporated titanium dioxide (TiO_2). Four different ARCs were simulated with Essential Macleod [4], fabricated and evaluated.

The refractive index of MgF_2 film was found to be adjustable with the deposition temperature showing linearly decreasing trend when temperature increased. Strong temperature dependency was also observed for PECVD-grown SiO2. Nanoporous SiO_2 with low refractive index was obtained at low-temperature. The ratio of precursor gases in PECVD had also a major impact on the SiO_2 film structure and refractive index.

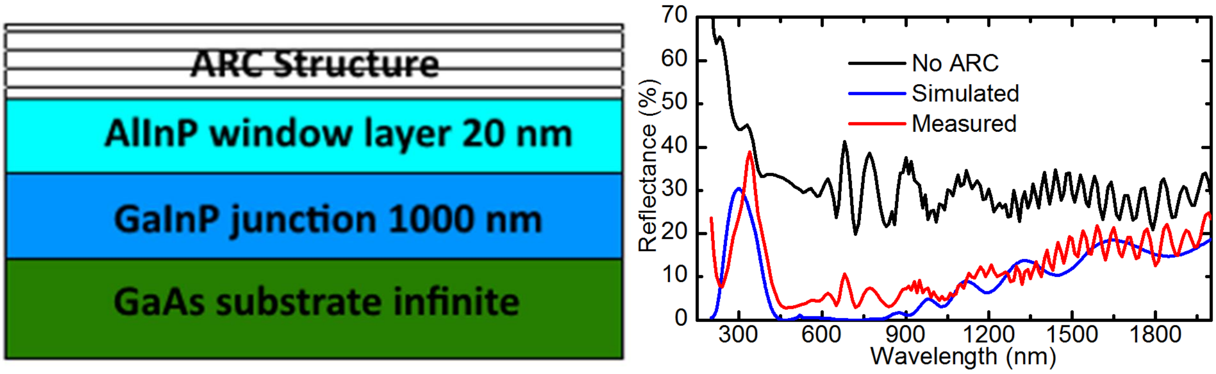

FIG. 1: (a) Layer structure for Essential Macleod simulation. (b) Simulated and measured reflectance of nanoporous SiO_2/TiO_2 ARC on GaInP/GaAs/GaInNAsSb multijunction solar cell.

After finding suitable fabrication conditions, five different ARCs were applied on GaInP/GaAs/GaInNAsSb multi-junction solar cells, converting light to electricity from UV down to 1 eV. As an example, measured and simulated reflectance spectrum for nanoporous SiO_2/TiO_2 ARC is presented in Fig. 1 (b). All the coatings reduced the reflectance significantly, with major differences appearing at the UV range, and 30 % increase in solar cell current was achieved. Thin film optical properties, and interdependencies on fabrication conditions and AR coating operation will be discussed in more detail. Future prospects are to widen the research to ion-beam sputtered materials and combine thin-film coatings to nanostructuring that has recently been proposed as a next step for ARCs of next-generation multi-junction solar cells. [5]

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