Design and optical analysis of high efficiency 100 nm GaAs ultrathin solar cell

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Ultrathin solar cells are a new class of devices that take advantage of light trapping mechanisms to reduce material costs while maintaining a reasonable level of sunlight absorption and thus high efficiencies[1]. Beyond cost advantages, these devices offer several benefits, such as flexibility, low weight and endurance to harsh environments, attending applications such as agro-PV, vehicle integrated-PV and spatial-PV. One of the most used strategies for light trapping in ultrathin solar cells is the use of subwavelength diffraction gratings to scatter and couple light to resonant modes, as it was demonstrated by Chen *et al* for a 200 nm GaAs solar cell[2]. In that work they were able to show a high short-circuit current equivalent to around 80% of the maximum achievable value with a reduction of one-order of magnitude in the absorber thickness compared to usual devices. The same strategy has already been used for other materials such as silicon and CIGS, but there is plenty of room for improvement.

In this work, we discuss design pathways and optimization procedures to achieve high optical path enhancement factors in ultrathin GaAs solar cells. We show the results of our optimization strategy for a 100 nm GaAs solar cell in which we were able to demonstrate a total absorption of 92.5% for the solar photons above the bandgap energy. After accounting for parasitic absorption, the estimated short-circuit current of this device is 26.4 mA/cm^2, significantly beyond the current state-of-the-art for similar thicknesses. We will also discuss routes towards even higher currents by engineering the periodic patterns using non-symmetric structures to maximize the distribution of energy into diffraction orders that couple to guided modes and how this approach could enable new conversion schemes such as hot carrier solar cells.

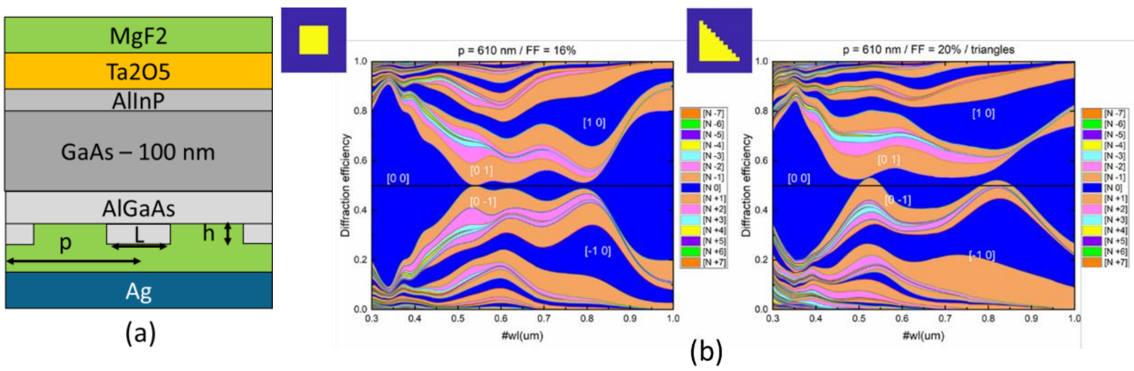

Figure: *(a) Layer structure used in the optical optimization for the 100 nm GaAs solar cell showing the parameters of the square diffraction grating (p, L, h) and (b) diffraction efficiency spectra for the present orders in gratings with two different patterns: square and triangle. FF =* L^2/p^2 *is the fill factor.*

References:

[1] I. Massiot, A. Cattoni, S. Collin, "Progress and prospects for ultrathin solar cells", Nature Energy 5, 959–972, 2020.

[2] H. L. Chen *et al*, " A 19.9%-efficient ultrathin solar cell based on a 205-nm-thick GaAs absorber and a silver nanostructured back mirror", Nature Energy 4, 761–767, 2019.