Enhancing the efficiency of silicon-graphene solar cell with SOI

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Ultrathin solar cells offer flexibility and require significantly less material, but their reduced thickness limits light absorption. To overcome this challenge, we explore a planar cell structure by optimizing the optical field and electronic transport in a single Schottky junction between silicon and graphene. Optimizing the optical field enhances light absorption, particularly at the wavelengths most effectively absorbed by silicon. The graphene electrode, with its high carrier mobility and tunable work function, minimizes recombination losses and improves charge collection compared to conventional metal contacts. By taking advantage of the formation of optical standing wave, the optical field maximum can be positioned at the Schottky junction by optimizing the thicknesses of both the silicon and silicon dioxide layers in the silicon-on-insulator (SOI) substrates. Transfer matrix calculations show an eight-fold increase in optical field intensity at the Schottky junction, as shown in Figure 1a, which compares the normalized optical intensity in different cell structures (Si bulk/G and SOI/G) at a wavelength of 700 nm. This enhancement leads to improved absorption in the optimized configuration. Simulations of photogeneration and electronic transport show the effect of the optical enhancement. The simulations predict a short-circuit current density of 1 mA/cm², indicating efficient photogeneration despite a 1000-fold reduction in active layer thickness compared to standard silicon cells. The IV characteristics, shown in Figure 1b, reveal that photocurrent generation is influenced by shunt resistance. This reduces the effective photocurrent and needs further improvement. Nonetheless, the combination of a planar structure and optimized optical field presents a promising route to enhancing ultrathin solar cells and improving efficiency.

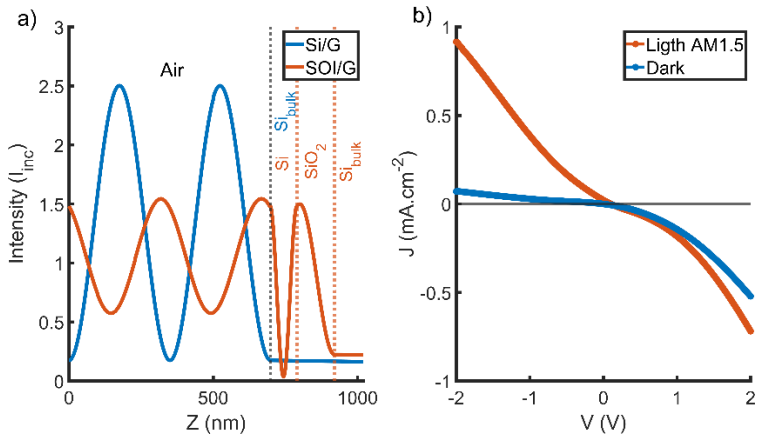

Figure 1: Time averaged optical field intensity across the SOI (blue) and bulk Si (red). The intensity is normalized to the amplitude of the incident field (wavelength 700 nm). The blue lines indicate the Si and SiO_2 layer of the SOI substrate/ The gray line shows the interface with graphene, for both SOI/G and Si/G samples. (a), and current density measurement with and without illumination (AM1.5) of a SOI/G cells (Si: 88 nm, SiO_2: 145 nm, n-type Si #1e14 (1/cm³)) (b)