Quantitative Photocurrent Decomposition in Epitaxial Graphene/6H-SiC Photodetectors

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Silicon carbide arises as promising material for ultraviolet (UV) photodetection in harsh environments—the wide bandgap (2.2-3.25 eV), high thermal conductivity, and chemical stability make it naturally suited for solar-blind UV sensing required in application ranging from combustion control and space-borne instruments to emerging quantum technologies [1]. The metal-semiconductor-metal (MSM) configuration is attractive for its fabrication simplicity and low parasitic capacitance, but conventional metal electrodes introduce optical shadowing that directly hampers quantum efficiency—a fundamental trade-off between field topology and optical access [2]. Epitaxial graphene (EG), grown on SiC by thermal decomposition, offers an alternative: it forms a Schottky contact with SiC without a prior transfer, absorbs only ~0.67% of incident broadband light and is thermally stable at wide range of temperatures. Despite these advantages, only a handful of EG/SiC MSM structures have been reported, and no experimental UV photodetector based on V-doped semiinsulating 6H-SiC with EG electrodes has been demonstrated to date.

We develop a Ramo–Shockley [3] simulation framework that quantitatively decomposes the spatially resolved photocurrent of EG/6H-SiC MSM photodetectors into bulk SiC (IQE ≈ 9 × 10^{-6}) and graphene IPE (~3%) contributions with a complete uncertainty budget (Fig. 1). Comparing graphene with simulated gold equivalents of identical field topology yields +-2-3 times signal gain from electrode transparency alone. At UV wavelengths, graphene IPE drops below 0.01% of total photocurrent, making EG a spectrally neutral transparent contact that decouples electrode design from optical shadowing

References:
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[2] S. Jang et al., J. Electrochem. Soc. 154 (2007) H830.
[3] Z. He, Nucl. Instrum. Methods Phys. Res. A 463 (2001) 250.

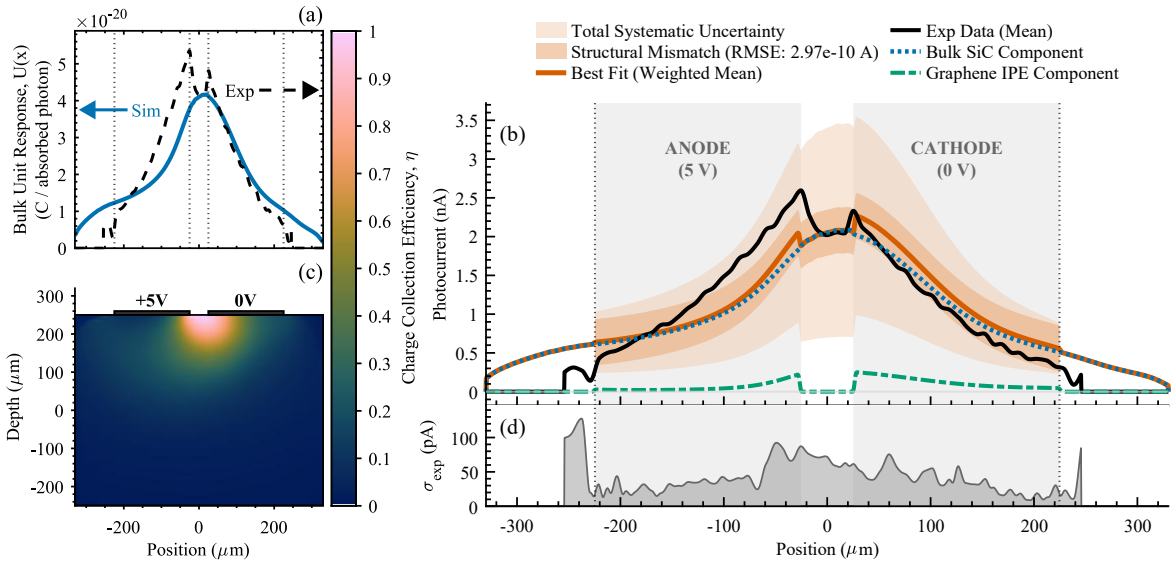

Fig. 1: Modeling of the device (200 μm electrode width, 100 μm gap, at 5 V bias, 532 nm excitation) and the photocurrent decomposition pipeline. (a)—overlay of the experimental photocurrent profile (black dashed, right axis) against the bulk unit response profile U(x) (solid blue, left axis), representing the expected induced charge per absorbed photon at position x; (b)—result (vermillion) of the U(x) scaled by incident laser flux and fitted to experiment (black), accompanied by shaded bands indicating structural mismatch (RMSE, darker) and total systematic uncertainty (lighter), and separate bulk SiC (blue dotted) and graphene IPE (bluish green dashed) contributions are shown; (c)—CCE map obtained via Shockley-Ramo trajectory tracking in a numerically solved Laplace field of photogenerated electron-hole pairs injected as spatial delta functions; (d)—the standard deviation of experimental photocurrent across the multiple scan lines at each spatial position x.