Broadband photodetection in CVD graphene enabled by solid-state doping with α-$RuCl_3$

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Abstract: Graphene is a promising platform for broadband and high-speed photodetection thanks to its gapless band structure and ultrafast carrier dynamics. However, efficient device operation typically relies on complex gating schemes to engineer p–n junctions required for photothermoelectric (PTE) detection.

Here, we demonstrate a scalable graphene photodetector based on large-area chemical vapor deposited (CVD) graphene, where a sharp lateral junction is created via solid-state charge transfer using α-$RuCl_3$. This approach enables the formation of an ultrasharp p–n junction without electrostatic gating, providing the required Seebeck coefficient asymmetry for efficient zero-bias PTE operation .

Using combined Raman–photocurrent mapping, we show that the photoresponse is maximized at the graphene/α-$RuCl_3$ interface, where the doping gradient is largest. A quantitative thermal transport model reproduces the spatial profile of the photocurrent and yields cooling lengths consistent with graphene PTE devices. The detector operates over a broad spectral range, from the visible to the terahertz, achieving a responsivity up to ~25 V/W, a noise-equivalent power of 200 pW $Hz^{-1/2}$ at 3 THz, and a response time of ~1.5 ns.

These results demonstrate that solid-state modulation doping with α-$RuCl_3$ provides a simple and scalable route to high-performance, zero-bias graphene photodetectors, bridging the gap between device performance and large-area integration for broadband photonic and optoelectronic applications.

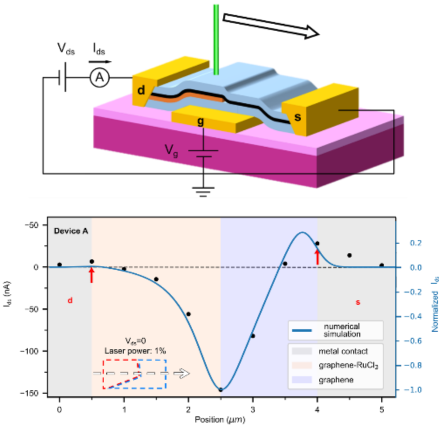

Fig. 1 **Figure 1.** Top: Schematic of the graphene/α-$RuCl_3$ heterostructure device. Charge transfer from α-$RuCl_3$ induces strong p-type doping in the covered region, forming a sharp lateral junction with nearly intrinsic CVD graphene. Under optical excitation, the resulting Seebeck coefficient asymmetry generates a photothermoelectric (PTE) current at zero bias. Bottom: Spatially resolved photocurrent profile acquired under laser illumination, showing a maximum response at the graphene/α-$RuCl_3$ interface. The experimental data are well reproduced by a thermal transport model (blue line), confirming the PTE origin of the photoresponse..

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