Aluminium oxide ALD graphene encapsulated photodetectors

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Summary

Graphene's outstanding optoelectronic properties are ideal for advanced technologies, but its instability in ambient conditions limits practical applications. By encapsulating graphene with aluminum oxide (Al_2O_3), we significantly enhance its long-term stability. Our field-effect transistors demonstrate consistent performance for over a month and improved resilience to elevated temperatures. This advancement paves the way for durable, high-performance photodetectors suitable for both ambient and harsh environments.

Methodology

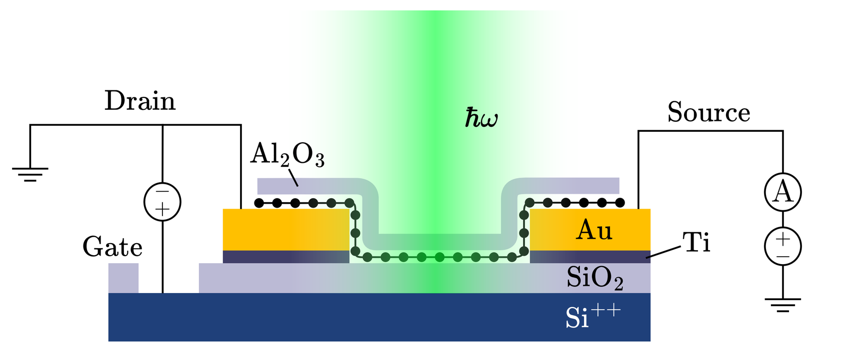

Figure 1. Side view of an ALD encapsulated graphene field-effect sample with a doped silicon back gate [1]. The gold pads serve as source and drain terminals, exposed by TMAH etching. Voltage is applied between the drain and source, with current monitored through the channel. Thicknesses of Au, and Ti are 55 nm and 5 nm, respectively. [2]

Responsivity ($\mathcal{R}$) was calculated from the photocurrent (I_{ph}) and the incident power (P):

$$\mathcal{R} = \frac{I_{ph}}{P} \propto I_{ph}, \tag{1}$$

where P is determined by measuring the light spot power and scaling it by the sample-to-spot area ratio, approximately 0.19.

Results

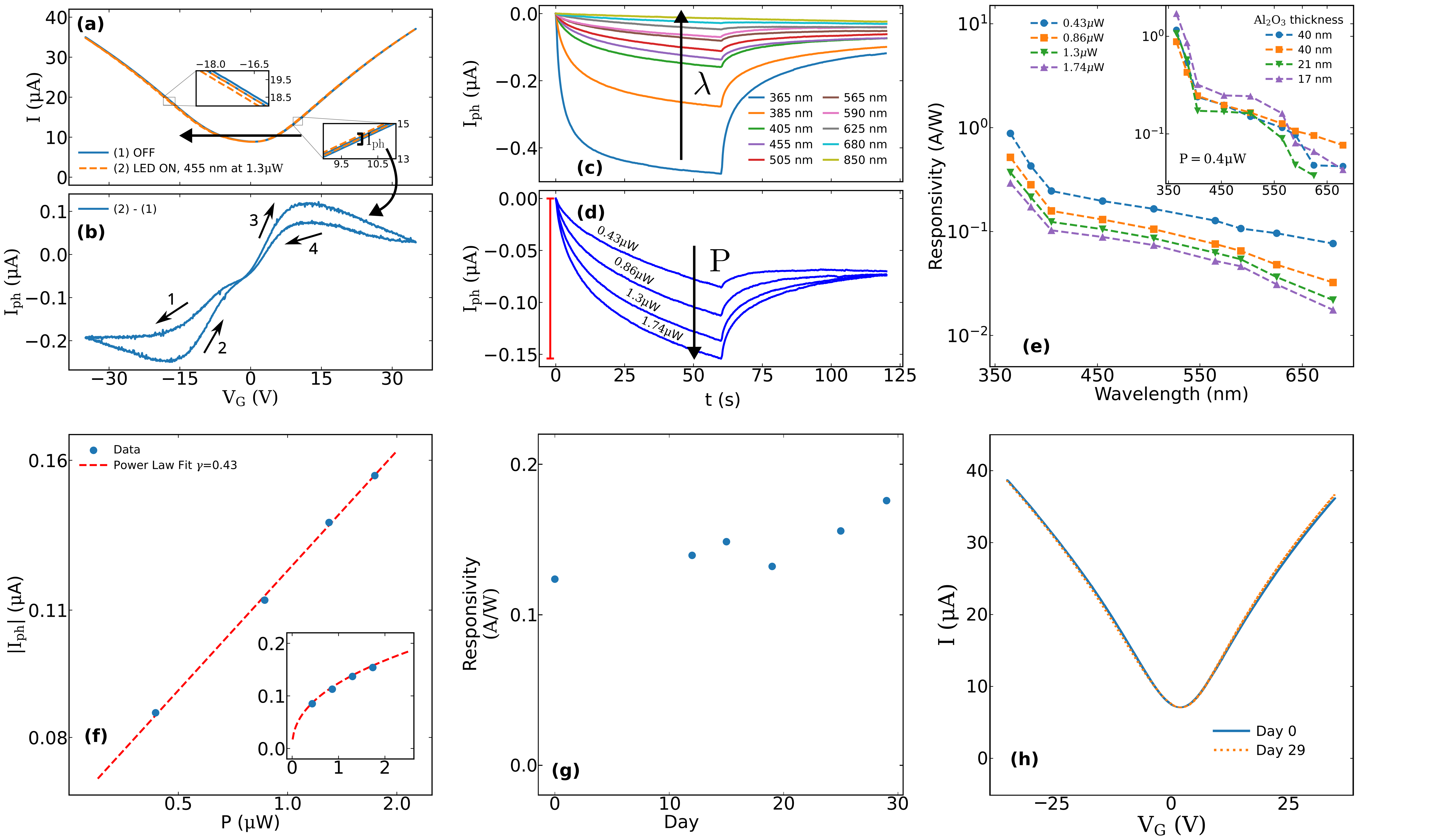

Figure 2. (a) Transfer curves for Sample 2 in dark (blue) and under 455 nm illumination (orange), showing a leftward shift in the Charge Neutrality Point (CNP) due to photogating. (b) Difference between illuminated and dark curves, indicating minimal hysteresis. (c) Photocurrent versus wavelength at a fixed power of 1.3 μW and gate voltage of -15 V. (d) Photocurrent over time under 455 nm illumination at varying powers, maintaining a gate voltage of -15 V. (e) Responsivity of Sample 2 across different wavelengths and comparison with Samples 1-4 at 0.4 μW and -15 V. (f) Photocurrent as a function of incident power for Sample 2, following a power-law fit with exponent $\gamma = 0.43$. (g) Stability of Sample 9's photoresponse over multiple days under consistent illumination and gate voltage. (h) Comparison of Sample 9's transfer curves before and after the stability test.

- Transfer curves for Sample 2 shift left under 455 nm illumination at 1.3 μW, maintaining shape, indicating photogating.
- Responsivity is ∼3× higher in the hole regime (negative photocurrent) than in the electron regime (positive photocurrent).
- Small hysteresis observed, suggesting enhanced gating
- Photocurrent increases from 850 nm (no response) to 365 nm (largest response).
- Photocurrent follows power-law $|I_{ph}| \propto P^{0.43}$, indicating dominant photogating effect [3].
- Persistent photocurrent observed, suggesting deep traps in SiO_2 contribute to photogating.
- Responsivity increases with decreasing wavelength; highest at 365 nm and lowest power.
- Sample 6 achieves up to 4 A/W responsivity.
- Sample 9 maintains stable photoresponse over 29 days with no >10% degradation; stable under temperatures up to 93.4 °C.

Conclusion

- Al_2O_3 layers ensure stable and reproducible photoresponse over long periods and air exposure.
- Photogating is observed, with slow responses indicating deep traps in the SiO_2 layer.
- Results are consistent across a wide wavelength range (NUV to NIR).
- Al_2O_3 does not actively contribute to photogating but enhances stability and reproducibility at temperatures up to 107 °C.
- Performance can be tuned by varying the thickness of SiO_2 and Al_2O_3 layers.
- Durable and consistent gFETs are ideal for real-life applications in harsh environments, such as radiation detection and aerospace.

Acknowledgements

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References

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