Photoresponse in epitaxial graphene with asymmetric metal contacts

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Abstract: We report photoresponse observations in epitaxial graphene (EG) devices with asymmetric metals (Au, Al) contacted in planar Au/EG/Al device format. The transient photocurrent measurements on the zero-bias device show photocurrent maxima at the Au/EG contact and minima at the EG/Al contact. This observed significant difference between the two types of junctions is responsible for the overall efficient device photoresponse. We have also found that the number of EG layers influences the photocurrent magnitude and response time regardless of incident photon energy or intensity. An external photoresponsivity (or efficiency) of ~ 31.3 mA W^{-1} is achieved with a biased Au/EG/Al photodetector at excitation wavelength of 632.8 nm.

Results and discussion

Materials & Characterizations

- Epitaxial graphene (EG) on semi-insulating 4H-SiC substrates

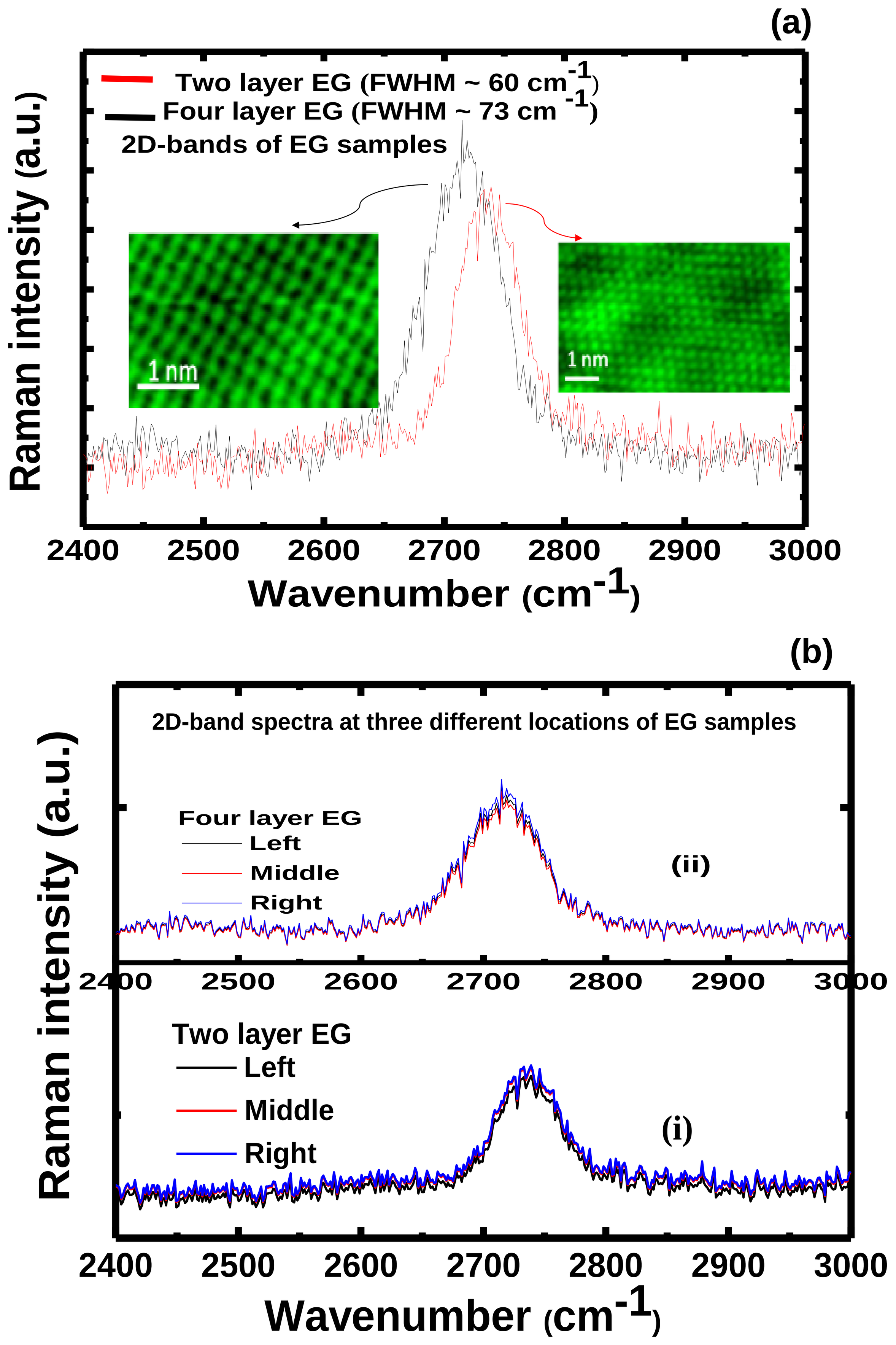

Figure1. (a) The Raman 2D-band of EG samples having width (FWHM) ~ 60 cm^{-1} and 73 cm^{-1} that indicates the thickness ~ two and four layers. The inset shows the corresponding STM images of 2-layer and 4-layer EG (b) 2D-band spectra at different positions (left-middle-right) acquired on 0.05 mm x 2 mm area devices with (i) two layer EG (ii) four layer EG. The measured 2D-band at several points (> 20 points on each device) showed no significance variation in intensity or width indicating fair layer thickness uniformity (two and four layers) in each device.

Device fabrication & photoconductive characteristics

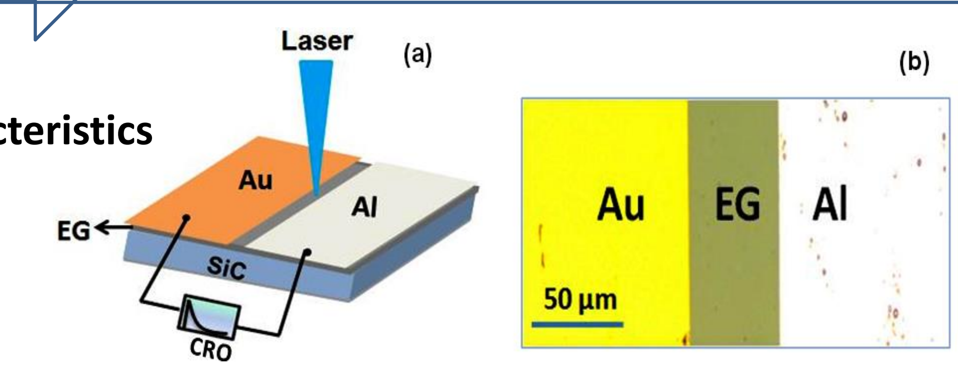

Figure 2. (a) Schematic view of zero-bias Au/EG/Al device connected to a cathode ray oscilloscope (CRO). (b) Optical micrograph of the EG device contacted with Au (yellow) and Al (white) metals.

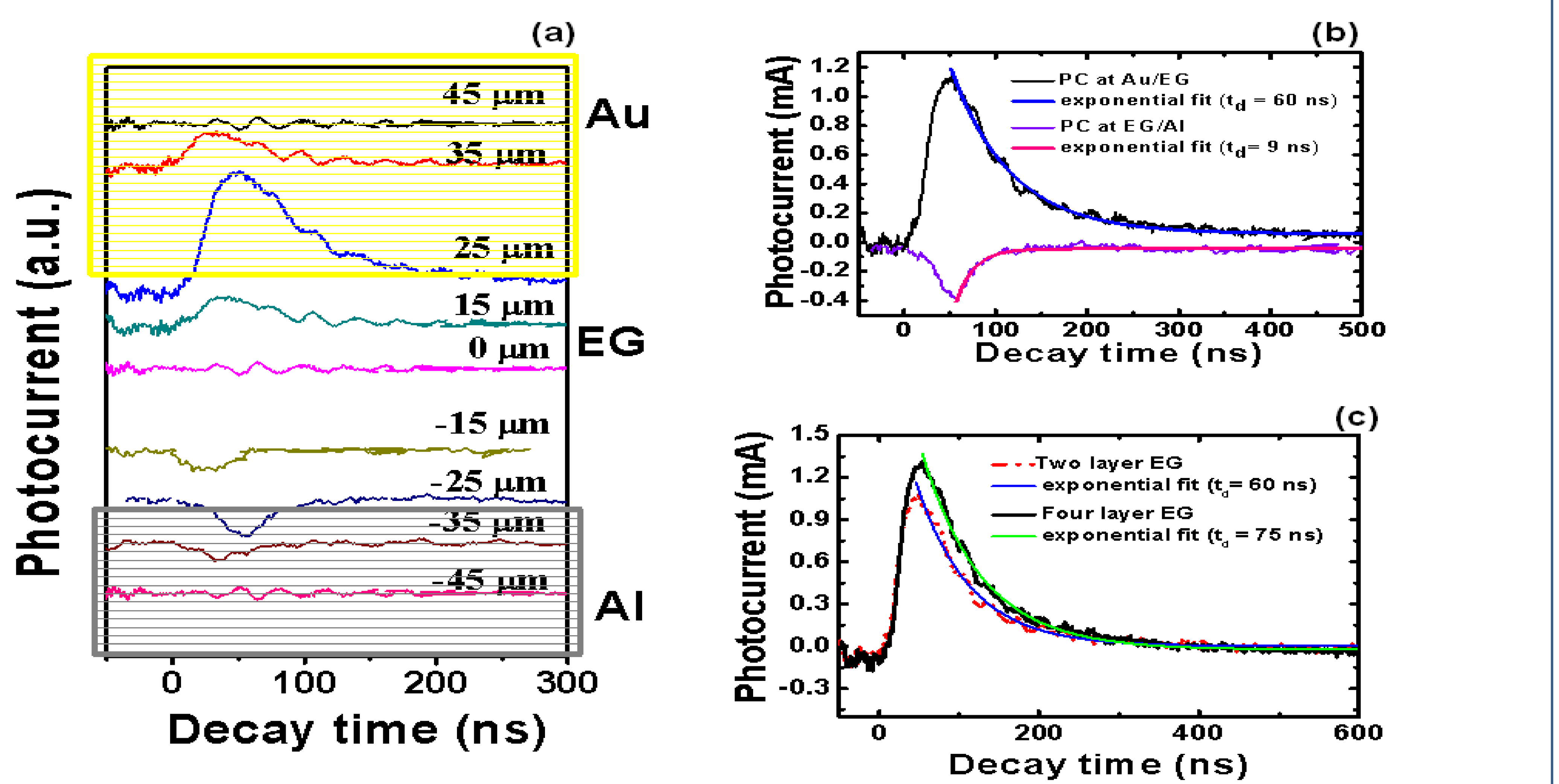

Figure 3. (a) Photoresponse of the Au/EG/Al device at different positions excited with laser pulses (photo scan from Au to Al electrode). (b) Plot of maximum photocurrent (PC) near Au/EG and EG/Al contacts. (c) Photoresponses (maximum photocurrent) in devices with two and four layers of EG. Laser pulse duration: 7 ns, wavelength: 532 nm, and fluence: 0.94 mJ

- ✓ Significance difference in photocurrent magnitudes at Au/EG & Al/EG junctions → overall efficient photoresponse
- ✓Number of active EG layers having influence on device photoresponsivity and response time
- ✓Fast, efficient and low power consuming EG based photodetectors via asymmetric metalization scheme
- ✓Device compatibility with wafer-scale CMOS electronics

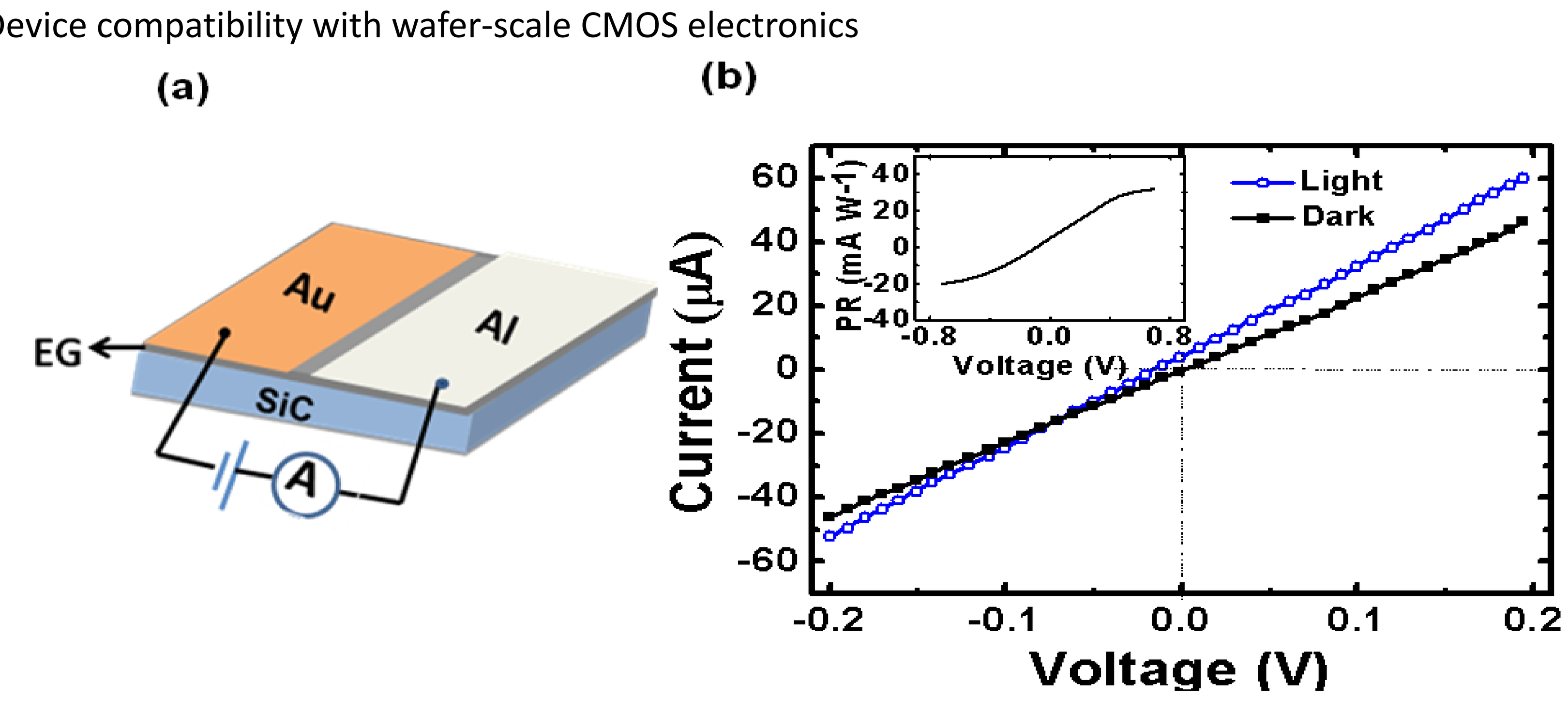

Figure 4. (a) Schematic of biased Au/EG/Al device.
(b) I-V characteristics (active EG~ 4-lyares) with and without light illumination at 632.8 nm wavelength.
The inset shows the measured external photoresponsivity (PR) as the function of the bias voltage.
The I-V curves in black and blue represent dark and photocurrent respectively.

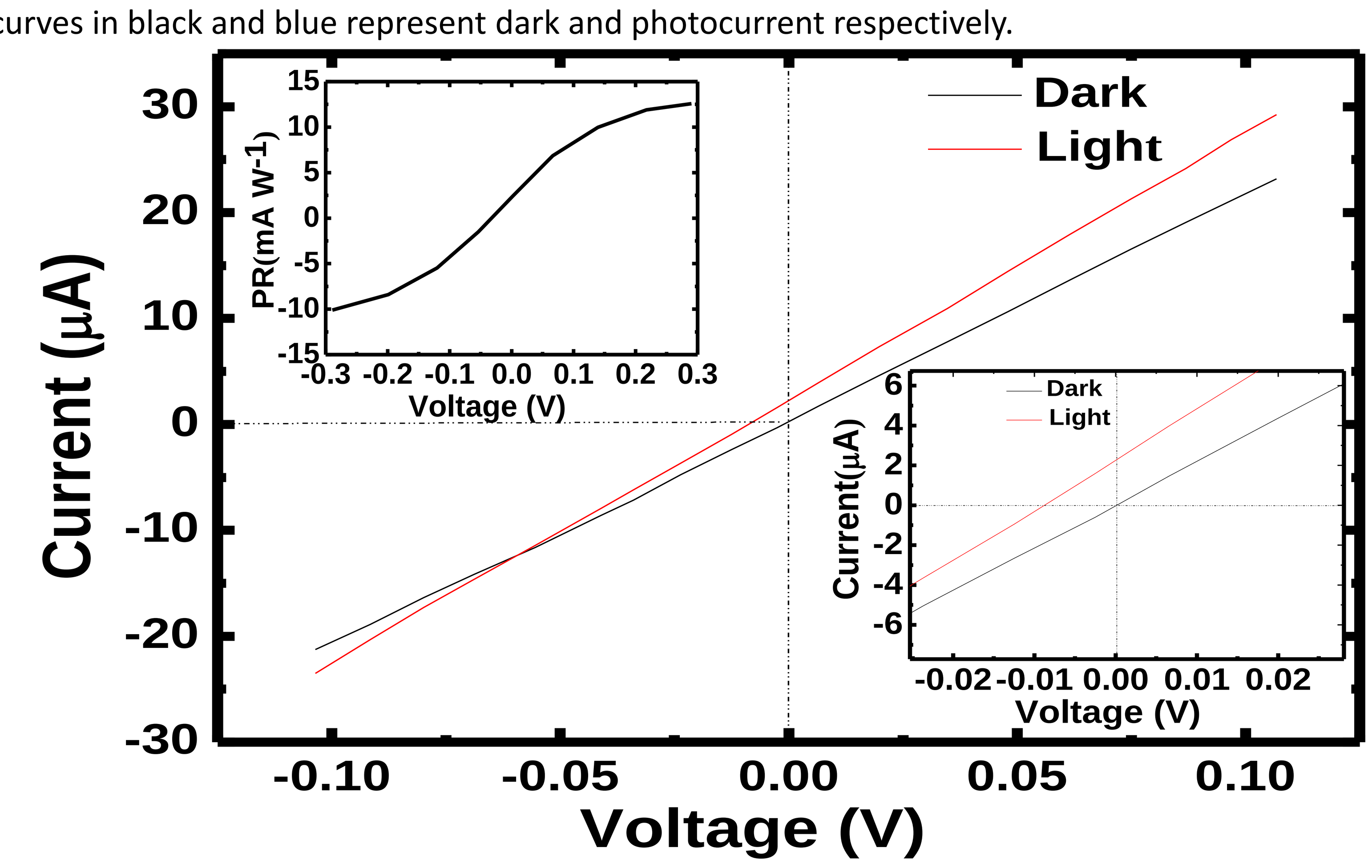

Figure 5. I-V characteristics (active EG ~ two layers) of Au/EG/Al device with and without light illumination at 632.8 nm wavelength (Power = 0.96 mW). The top-left inset shows the external photoresponsivity (PR) in the asymmetric Au/EG/Al device, and the bottom-right inset shows the zoom-in view around V_{bias} = 0 V , which clearly indicates the photoresponse at 0 V.

Conclusion

In summary, we have demonstrated the photoresponse in epitaxial graphene devices with asymmetric Au and Al metallization scheme. The zero-bias device photoresponse directly observed in digital oscilloscope shows significance differences in photocurrent magnitudes near the Au/EG and EG/Al contacts, resulting in significantly higher device photoresponse efficiencies. Specifically, we found that the number of layers in EG further I nfluences the photocurrent magnitude and response time regardless of incident photon energy or intensity. The maximum external photoresponsivity ~ 31.3 mA W^{-1} at a bias voltage ~ 0.7 V under illumination with 632.8 nm wavelength was estimated. The finding shows that graphene devices with asymmetric metal contacts can be used as photodetector that is fast, efficient and with low power consumption.

References

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