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High Speed Graphene Optoelectronic Devices Enabled Through Controlled Molecularly Doped Graphene

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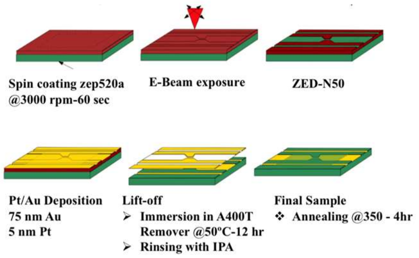
ABSTRACT

Ultra-fast graphene optoelectronic devices require a stable voltage-free doped graphene that is achieved through meticulous molecular surface adsorption in this work. The graphene film resistance is significantly reduced from 40 to less than 10 .

INTRODUCTION

- Presence of structural defects, surface wrinkles and poor adhesion to the substrate
- Diminished mobility and lack of systematic approach to keep a high mobility at different devices
- The biggest challenge to the application of graphene
- stable molecular surface adsorption with no structure change
- adsorption of electron acceptor molecules on graphene

METHODS



1. Epitaxial graphene Hall bars were patterned using electron beam lithography
2. Commercially available graphene on PMMA film transferred from the CVD grown graphene
3. Raman spectroscopy and optical microscopy confirms the presence of a monolayer graphene film.
4. The doping blend was spin-coated to achieve a uniform doping layer [1-2].
5. The last fabrication step is to define the graphene channel (Fig 2.c).

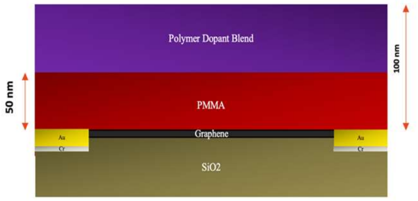


Fig 1. Cross-Section Schematic of the device structure. The graphene/PMMA layer is deposited on top of Au/Cr electrode followed by the dopant blend.

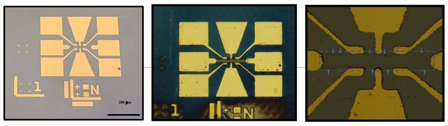


Fig 2. a) The final Au/Cr electrode array structure b) The graphene/PMMA is patterned between electrodes with the aid of oxygen plasma etchant c) The removal of PMMA and remained graphene between electrodes. The arrows indicate the boundaries of transparent graphene.

RESULTS

As shown below, the 2D peak ratio from a pristine graphene to the one with dopant blend thin film of 280nm is changed from 2:1 to 1:4 which is an 8 times difference. This simply means that the graphene structure is very sensitive to the dopant blend thickness to keep its carbon network coherence unaffected. Fig. 4 shows that slope of I-V curve which is inversely correlated to the resistance value is indeed increased upon doping by the dopant blend in this study. Significant resistance reduction in graphene thin film as a result of controlled surface molecular doping reinforces the promising effect of chemical doping in graphene optical modulators as well as switches where voltage induced doping is impossible.

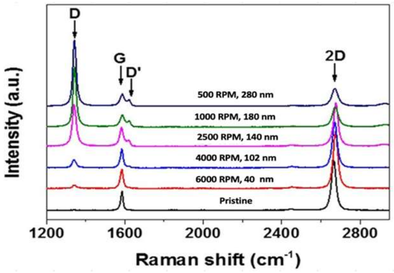


Fig 3. Raman spectrum comparison of pristine and doped graphene at different spin-coating speed resulting in different thickness

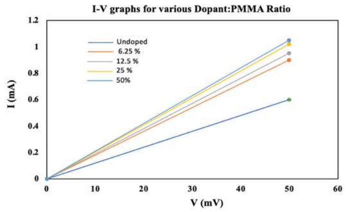


Fig 4. The I-V curve of pristine and doped graphene with different molecular dopant to solvent ratio

CONCLUSIONS

Significant resistance reduction in graphene thin film as a result of controlled surface molecular doping reinforces the promising effect of chemical doping in graphene optical modulators as well as switches where voltage induced doping is impossible.

REFERENCES

[1] He, H., Kim. et. al, Uniform doping of graphene close to the Dirac point by polymer-assisted assembly of molecular dopants. *Nature Communications*, (2018), 3–9.

[2] Li, X. et. al, Synthesis of Nitrogen-Doped Graphene via Thermal Annealing Graphene with Urea Synthesis of Nitrogen-Doped Graphene via Thermal Annealing Graphene with Urea, *325*.

[3] Yager, T. et. al, (2015). Low contact resistance in epitaxial graphene devices for quantum metrology, *087134*(August). https://doi.org/10.1063/1.4928653

[4] Zhang, H. et. al, (2016). Enhanced all-optical modulation in a graphene-coated fiber with low insertion loss. *Nature Publishing Group*, (March), 2–6. https://doi.org/10.1038/srep23512

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