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Monolithic Graphene Transistor Biointerface

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We report monolithic integration of graphene and graphite for all-carbon integrated bioelectronics. First, we demonstrate that the electrical properties of graphene and graphite can be modulated by controlling the number of graphene layers, and such capabilities allow graphene to be used as active channels and graphite as metallic interconnects for all-carbon bioelectronics. Furthermore, we show that monolithic graphene-graphite devices exhibit mechanical flexibility and robustness while their electrical responses are not perturbed by mechanical deformation, demonstrating their unique electro-mechanical properties. Chemical sensing capability of all-carbon integrated bioelectronics is manifested in real-time, complementary pH detection. These unique capabilities of our monolithic graphene-graphite bioelectronics could be exploited in chemical and biological detection and conformal interface with biological systems in the future.

Bio-electronics faces challenges associated with the mismatch between the hard, planar surfaces of conventional electronics and the soft, 3-dimensional (3D) tissues of biological systems [1]. Brain-machine interface presents the most significant challenges, in that the brain is very soft (elastic modulus <500 Pa) unlike rigid conventional electronics (>100 GPa) [1]. Superb electromechanical properties of graphene, where more than 20% of elastic deformation is achievable without perturbation of the electrical properties [2-4], have been recently explored as flexible electrode materials. Practical applications, such as graphene-based transparent electrodes [5], have been implemented, demonstrating potential for flexible touch screens. Such unique electromechanical properties can be applied to biological systems, in particular the biointerface, where mechanical flexibility and electrical functions (e.g. stimulation and detection) of graphene membrane can be fully utilized.

Here we demonstrate an unconventional approach for the single-step synthesis of monolithically-integrated electronic devices based on graphene and graphite for all-carbon bio-electronics. These fully-formed all-carbon structures were transferrable onto both rigid and flexible substrates (Figure 1). The integrated transistor arrays were used to demonstrate real-time, multiplexed chemical sensing, and furthermore, flexible and conformal interface for bio-electronics.

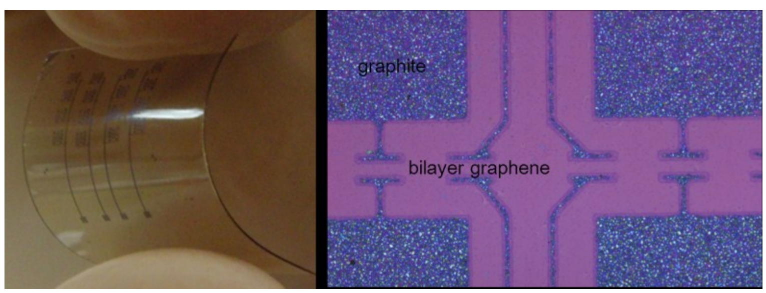

Figure 1. Flexible and conformal monolithic graphene-graphite bioelectronics.

REFERENCES

[1] D. E. Discher, P. Janmey and Y. Wang, "Tissue cell feel and respond to the stiffness of their substrate," *Science*, vol. 310, pp. 1139-1143, Nov. 2005.
[2] A. K. Geim, "Graphene: status and prospects," *Science*, vol. 324, pp. 1530-1534, Jun. 2009.
[3] K. S. Kim *et al.*, "Large-scale pattern growth of graphene films for stretchable transparent electrodes," *Nature*, vol. 457, pp. 706-710, Feb. 2009.
[4] J.-U. Park, S. Nam, M.-S. Lee and C. M. Lieber, "Synthesis of monolithic graphene-graphite integrated electronics," *Nature Mater.*, vol. 11, pp. 120-125, Feb. 2012.
[5] S. Bae *et al.*, "Roll-to-roll production of 30 inch graphene films for transparent electrodes," *Nature Nanotech.*, vol. 5, pp. 574-578, Aug. 2010.

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