Graphene Woven Structure for Sensing Applications

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Abstract

Sensing strain and vibration with soft materials in small scale has attracted increasing attention. Graphene has the potential for creating thin film devices, owing to its two-dimensionality and structural flatness. We demonstrated several interesting examples of potential applications of graphene woven structure in highly sensitive strain sensing (Figure 1) [1,2].

A rational strategy was proposed to fabricate flexible touch sensors easily and effectively with the full usage of the mechanical and electrical properties of graphene (Figure 2) [3]. The resistance of the woven structure was highly sensitive to macro-deformation or microdefect. Compared to commercial and traditional touch sensing, the graphene-on-polymer piezoresistor is structurally flexible that is demanded under special conditions and meanwhile makes the piezoresistor to have excellent durability.

Detection and analysis of volatile organic compounds as pollutants in the atmosphere and liquids are of great significance because of their detrimental effects. A polymer-coated graphene micro-tube piping structure with a cross-linked and interconnected channel network was synthesized for liquid sensing (Figure 3) [4]. Due to the capillary force, the interfaces of the 3D structures could speed up the penetration of solvents into the polymer, thus promoted distinct selectivity within seconds and significantly decrease the response time. Owing to their good selectivity, high sensitivity, rapid response and flexibility, and the ease of use of the sensors and the simplicity of the fabrication processes, the composites should be a good candidate for liquid sensing.

Torsion is another deformation occurring in everyday life, but was less well understood. In our previous study a torsion sensor was prepared by wrapping woven graphene fabrics around a polymer rod at a specific winding angle (Figure 4) [5]. The sensor showed an ultra-high sensitivity with a detection limit as low as 0.3 rad/m, indicating its potential application in the precise measurement of low torsions.

A flexible and wearable strain sensor was assembled by adhering graphene on polymer and medical tape composite film. The sensor exhibited the following features: ultra-light, relatively good sensitivity, high reversibility, superior physical robustness, easy fabrication, ease to follow human skin deformation (Figure 5) [6]. Some weak body motion were chosen to test the notable resistance change, including hand clenching, phonation, expression change, blink, breath, and pulse. A highly sensitive sensor for sound signal acquisition and recognition was further fabricated from thin films of special crisscross graphene woven structures. The ultra-high sensitivity of the sensor could realize fast and low frequency sampling of speech by extracting the signature characteristics of sound waves (Figure 6) [7]. Representative signals of 26 English letters, typical Chinese characters and tones, even phrases and sentences, were tested with obvious resistance changes. Furthermore, resistance changes of graphene sensor responded perfectly with sounds.

By future combining artificial intelligence with digital signal processing, the graphene based sensing system will represent a new smart tool to classify and analyze signals in wide potential applications in fields of the displays, robotics, fatigue detection, body monitoring, in vitro diagnostics, and advanced therapies.

References

[1] X. Li, P. Z. Sun, L. L. Fan, M. Zhu, K. L. Wang, M. L. Zhong, J. Q. Wei, D. H. Wu, Y. Cheng, H. W. Zhu*, Sci. Rep., **2** (2012) 395.
[2] X. Li, R. J. Zhang, W. J. Yu, K. L. Wang, J. Q. Wei, D. H. Wu, A. Y. Cao, Z. H. Li, Y. Cheng, Q. S. Zheng, R. S. Ruoff, H. W. Zhu*, Sci. Rep., **2** (2012) 870.
[3] X. Lee, T. T. Yang, X. Li, R. J. Zhang, M. Zhu, H. Z. Zhang, D. Xie, J. Q. Wei, M. L. Zhong, K. L. Wang, D. H. Wu, Z. H. Li, H. W. Zhu*, Appl. Phys. Lett., **102** (2013) 163117.
[4] T. T. Yang, H. Z. Zhang, Y. Wang, X. Li, K. L. Wang, J. Q. Wei, D. H. Wu, Z. H. Li, H. W. Zhu*, Nano Res., **7** (2014) 869–876.

[5] T. T. Yang, Y. Wang, X. M. Li, Y. Y. Zhang, X. Li, K. L. Wang, D. H. Wu, H. Jin, Z. H. Li, H. W. Zhu*, Nanoscale, **6** (2014) 13053-13059.
[6] Y. Wang, L. Wang, T. T. Yang, X. Li, X. B. Zang, M. Zhu, K. L. Wang, D. H. Wu, H. W. Zhu*, Adv. Funct. Mater., **24** (2014) 4666–4670.
[7] Y. Wang, T. T. Yang, J. C. Lao, R. J. Zhang, Y. Y. Zhang, M. Zhu, X. Li, X. B. Zang, K. L. Wang, H. Jin, L. Wang, H. W. Zhu*, Nano Res., in press (2015).

Figures

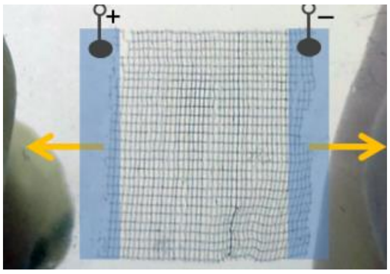

Figure 1. Graphene woven structure

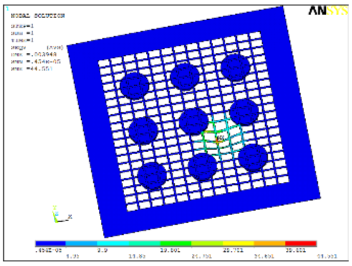

Figure 2. Touch senor

Figure 3. Liquid sensor

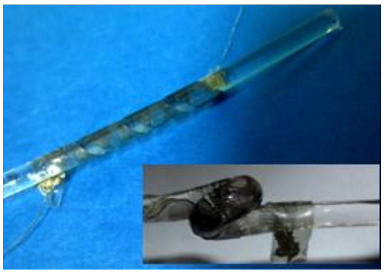

Figure 4. Torsion sensor

Figure 5. Skin sensor

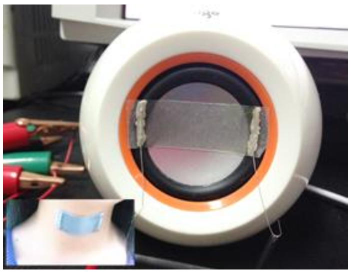

Figure 6. Sound sensor