ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 4, Issue 9, September 2017

Review on Graphene Sensor for Human Health

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Abstract: This paper reviews graphene's potential as a material for making different types of sensors. Graphene is a monolayer of carbon atoms that exhibits some remarkable electronic and mechanical properties and many of these properties are suitable for applications with sensors. The review attempts to be comprehensive with mass and strain sensors in sensor types covering chemical and electrochemical sensors, magnetic and electrical field sensors, and optical sensors as well. An indication of its versatility and importance is the fact that grapheme offers some advantages over this whole range of sensing modalities. Graphene has emerged as one of the strongest post-silicon technological candidates. One of graphene's most important applications in the foreseeable future is the sensing of particles of gas molecules, biomolecules or various chemicals or the sensing of particle radiation, such as alpha, gamma or cosmic particles. Several unique graphene properties, such as its extremely small thickness, very low mass, large surface-to-volume ratio, very high absorption coefficient, high load carrier mobility, high mechanical strength and high Young's modulus make it exceptionally suitable for sensor making.

Keywords: Carbon electronics, Chemical sensors, Graphene, Magnetic sensors, Optical sensors, Mass and strain sensors,

INTRODUCTION

Graphene is a 2D structure consisting of bonded carbon atoms in a hexagonal lattice which was not thought to exist in its freestanding form until Geim and Novoselov were isolated in 2004. It is an outstandingly stable material with high mechanical strength and fascinating electronic properties [1]. Nanostructures based on graphene are thought to have tremendous potential for developing sensors of different types. This is partly due to the fact that each atom in the structure interacts directly with the sensing environment, and partly because of the ease with which this interaction can modify the grapheme's electronic properties. Graphene, however, has a range of unique physical properties that can be exploited in many different types of sensing applications including optical sensors, magnetic and electrical field sensors, strain and mass sensors, as well as chemical and electrochemical sensors [2].

The mechanical exfoliation technique was initially used to make samples of high-quality single crystal grapheme and this still provides the best quality single crystal material for use in laboratory-scale experiments. By this method, samples with mobility greater than 100 000 cm2V-1s-1 can now be produced freely, although typical mobility is 5000–15 000 $cm^2V^{-1}s^{-1}$ for captive samples as prepared on a SiO_2 surface. Naturally, in order to live up to its reputation as a potential sensor material, graphene must be manufactured on a commercial scale in large areas. A full discussion will be given now on the manufacturing techniques.

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RELEVANT ELECTRONIC AND MECHANICAL PROPERTIES

Graphene's electronic structure was first described as a theoretical building block to describe graphite, in 1946. Graphene's valence and conduction bands are conical valleys which touch at the Brilluoin zone high-symmetry K and K ' points as illustrated in figure 1. Near those points the energy varies linearly with the momentum magnitude, i.e. a linear dispersion relationship follows. Consequently, electrons have been shown to behave as quasi-relativistic particles, and the Dirac equation should describe them. Graphene electrons velocity is about 106 m / s, about 300 times slower than light velocity (photons).

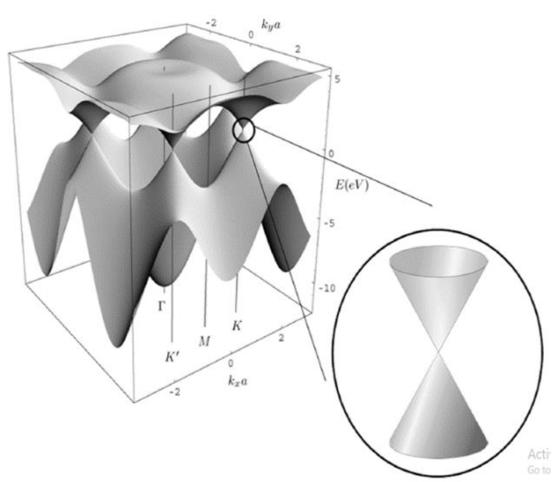

Fig.1: Band Structure of Single-layer Graphene showing the Linear Dispersion at the Dirac Point

In bilayer graphene the stacking of the AB (Bernel) between the two layers of graphene makes the two carbon atoms inequivalent and results in two graphene sublattices.If the inversion symmetry between the two layers is broken, then at the Dirac point, as illustrated in Figure 2, an energy gap between the low-energy valence and the conduction bands forms. This can be achieved through a transverse electric field, for example. Using a dual-gate configuration, the two key semiconductor parameters, the electronic band gap and the carrier doping concentration can also be tuned independently.

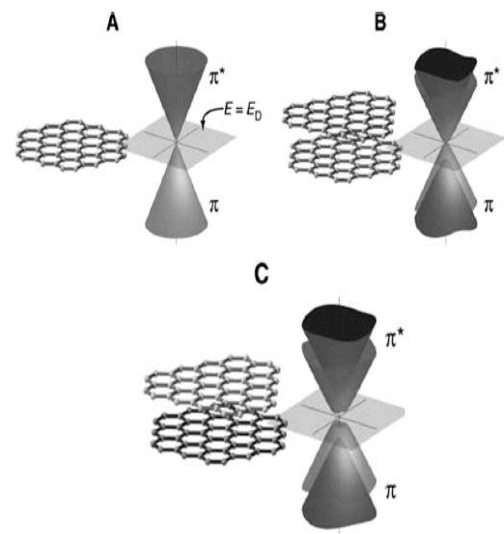

Fig.2: Electronic structure of (A) monolayer, (B) symmetric double layer, and(C) asymmetric double layer of grapheme

Nano-indentation of suspended graphene layers in an atomic force microscope (AFM)[4] performed direct measurements of the graphene's mechanical properties [3]. A Young's modulus of 0.5 TPa and 340 Nm-1 and -690 Nm-1, respectively, second- and third-order elastic stiffness were measured. Graphene's breaking stiffness corresponds to 1 TPa, and its inherent strength is 130 GPa. The combination of extraordinary mechanical and electrical properties suggests that graphene would find applications as mass sensors based on a resonator.

1. Chemical Sensor:

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As discussed earlier, graphene offers the best volume-to-surface ratio of any material, to the extent that each graphene atom is exclusively a surface atom. That implies that each graphene atom is a viable target for reactive species. The strength of this interaction could vary from weak van der Waals to strong covalent chemical bonding over the whole range to some extent, all of these interactions will disrupt the pristine nature of the structural and electronic graphene system, which then forms the basis for detecting such interactions / binding events.

Gas sensors based on graphene could take advantage of the change in graphene's electrical conductivity when gas molecules adsorb on the graphene surface and act as donors or electron acceptors [5]. Indeed, such sensitivity can be pushed to the ultimate limit of detecting a single gas molecule, i.e. graphene can measure the smallest quantity of resulting conductive change. One can attribute this ultimate sensitivity to a number of factors. Graphene is an extremely low-noise material even without carrier limits and even a few extra electrons can cause a noticeable change in the concentration of the carrier Graphene also allows the manufacture on mono crystals of four-sample devices which ensures that any influence of contact resistance is eliminated in limiting sensitivity.

2. Electrochemical Sensor:

Graphene may also be used in electrolyte gated configuration as a chemical sensor, as illustrated in Figure 3. In an electrolyte, in an electrolyte with a concentration of several millimolars, the electric-double layer acts as a top-gate insulator with a thickness as small as 1–5 nm. Compared to the best top-gate graphene field effect transistors (FETs)[6] with dielectric atomic layer deposition (ALD) such as HfO2 this is even thinner. A top-electrolyte gated graphene FET displays similar characteristics of ambpolar transfer as a back-gated device. It has been observed that with increasing pH, the Graphene FET's Dirac points shifted in a positive direction. This behavior indicates that using electrolyte gating, graphene FETs are able to detect the pH value by the electrical properties. Plotting the zero gate-bias conductivity as a function of pH reveals that an electrolyte gated graphene FET can achieve a sensitivity of up to 99 mV/pH. This is attributed to n- and p-charges induced by capacitive charging of the graphene / electrolyte interface which is ideally polarised.

FETs with suspended graphene have shown increased performance as sensors. In general, suspended graphene FETs possess superior carrier mobility and on-state transconductance [7]. The power of low-frequency noise decreases 12- and 6-times, respectively, for hole and electron carriers. In addition to aqueous media, electrochemical gating has also been shown in ionic liquids which have implications in graphene-based electrochemical sensors.

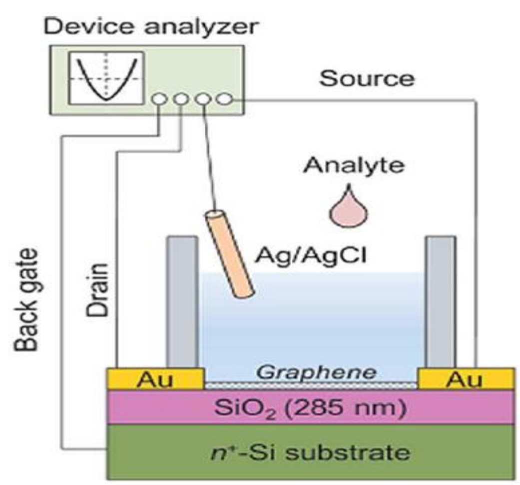

Fig. 3: Schematic Illustration of the Experimental setup for Electrolyte-Gated Graphene FETs

The sensitive response of graphene to surface charge or ion density, as demonstrated in the case of bovine

ISSN (Online) 2394-2320

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serum albumin (BSA), allows applications in solution-gated, ultrafast, ultralow noise biosensors or chemical sensors [8].

3. Electric Field Sensors:

Since the density of the carrier is so easily changed by an electric field applied to a graphene conductor, it makes an excellent sensor of electrical field. In fact, high-resolution spatial probes for electric field sensing using single electron transistor (SET)[9] and FET devices were used to map surface charges in conjunction with AFM techniques. Graphene offers some advantages but has not been used to date in these devices the big advantage is that a graphene SET system has been shown to work at room temperature, which would expand the useful temperature range of these high-resolution scanning techniques. Moreover, the fact that graphene is a monolayer means that it can be arbitrarily brought close to the surface to calculate the field close to the charging source where it is strongest, thereby giving a better signal-to-noise ratio and allowing for higher specific resolution than traditional heterostructure based DEG systems.

4. Magnetic Field Sensors:

Nevertheless, if we compare the room temperature Hall coefficient for a standard In As sensor with that for graphene, it does not appear that graphene is suitable for Hall effect The thickness of the conductive layer for the InAs RH = 4,310-6 mm / T is estimated to be 12 nm for the graphene RH = 0.3×10^{-6} mm/T but only 0.34 nm for the graphene. It gives the semiconductor unit a hall resistance of 1 kΩ/ T compared to only 358Ω/T. If we also include the facts that graphene can support current densities approaching 108 amps / cm2 and is not hidden under additional layers as is the case with traditional semiconductor 2 DEG systems, then it is clear that graphene has some significant advantages for Hall-effect sensing.

5. Mechanical Sensors:

5.1 Mass Sensor:

Sensing changes in mass due to adsorbed molecules have been of great interest in recent years due to their effect on the resonant frequency of a membrane or cantilever through monitoring the change in resonant frequency of the vibrating graphene when molecules are adsorbed or desorbed from its surface, mass sensors can be fabricated from graphene membranes[10] and cantilevers. Theoretical experiments using classical molecular dynamics to investigate the ability of graphene monolayers for mass sensing, using gold as the model of the adsorbed atom. It was found that tensile strain is needed over a useful range of operating temperatures to maintain the factor suitably high.

5.2 Strain Sensor:

In general, it has been shown that graphene-based transparent conducting electrodes can withstand enormous amounts of strain (up to 6 per cent) without any significant change in their electronic conductivity, indicating that graphene is not the perfect substrate for strain sensors. Nonetheless, theoretical calculations show that graphene asymmetric strain distributions result in band gaps being opened at Fermi level while graphene with a symmetric strain distribution is always a zero band gap semiconductor. Nevertheless, very large uniaxial strains are required to open any appreciable gap in the unit. The band gap regularly rises to its limit of 0.486 eV for a strain parallel to C-C bonds, as the strain increases up to 12.2 percent. Of strain perpendicular to C-C bonds, their band gap increases continuously to a maximum of 0.170 eV as the strain increases to 7.3%. Nevertheless, the opening of this band gap could be observed with Raman

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spectroscopy, or with a pseudomagnetic quantum Hall effect associated with strong gage fields expected in strained graphene.

CONCLUSION

From this analysis it is clear that graphene is applicable to a wide range of sensing modalities and in almost all of them provides advantages over more traditional materials. A lot of work remains to be done before industrial sensors can be put into practice. In particular, a source of high quality graphene on a wafer scale needs to be readily available.

One major application that doesn't require the availability of single crystal material is to provide transparent electrodes in a variety of optical sensors. Sensing electrodes for touch screens would, of course, possibly be one of the first significant commercial applications. A great advantage of graphene is its mechanical durability and, above all, its usefulness in the manufacture of extremely flexible touch screens for mobile electronic devices. It is clear that it is important to exploit improved substrates which allow the high intrinsic mobilities found in graphene. Such materials as boron nitride (BN) that can also be processed as monolayers demonstrate particular benefits here. Because graphene is applicable over such a wide range of sensing modalities, it may be useful to look for graphene sensors that can combine two or more methods. Although there is still more work to be done, the future for graphene sensing devices is indeed looking very exciting.

REFERENCES

[1] Y. Zhu et al., "Graphene and graphene oxide: Synthesis, properties, and applications," Adv. Mater., 2010, doi: 10.1002/adma.201001068.

[2] A. L. Da Róz, M. Ferreira, F. de Lima Leite, and O. N. Oliveira, Nanostructures. 2016.

[3] A. M. Díez-Pascual, M. A. Gómez-Fatou, F. Ania, and A. Flores, "Nanoindentation in polymer nanocomposites," Progress in Materials Science. 2015, doi: 10.1016/j.pmatsci.2014.06.002.

[4] R. Hiesgen and K. A. Friedrich, "Atomic force microscopy," in PEM Fuel Cell Diagnostic Tools, 2011.

[5] X. Liu, S. Cheng, H. Liu, S. Hu, D. Zhang, and H. Ning, "A survey on gas sensing technology," Sensors (Switzerland). 2012, doi: 10.3390/s120709635.

[6] V. Misra and M. C. Öztürk, "Field Effect Transistors," in The Electrical Engineering Handbook, 2005.

[7] S. Inal et al., "A high transconductance accumulation mode electrochemical transistor," Adv. Mater., 2014, doi: 10.1002/adma.201403150.

[8] D. W. Kimmel, G. Leblanc, M. E. Meschievitz, and D. E. Cliffel, "Electrochemical sensors and biosensors," Analytical Chemistry. 2012, doi: 10.1021/ac202878q.

[9] M. Fuechsle et al., "A single-atom transistor," Nat. Nanotechnol., 2012, doi: 10.1038/nnano.2012.21.

[10] M. Sillanpää, S. Metsämuuronen, and M. Mänttäri, "Membranes," in Natural Organic Matter in Water: Characterization and Treatment Methods, 2015.

[11] Vishal Jain, Dr. Mayank Singh, "Ontology Based Information Retrieval in Semantic Web: A Survey", International Journal of Information Technology and Computer Science (IJITCS), Hongkong, Vol. 5, No. 10, September 2013, page no. 62-69, having ISSN No. 2074-9015, DOI: 10.5815/ijitcs.2013.10.06.

[12] Vishal Jain, Dr. Mayank Singh, "Ontology Based Pivoted Normalization using Vector – Based Approach for Information Retrieval", IEEE Co-Sponsored 7th International Conference on Advanced Computing and

Communication Technologies (ICACCT), In association with INDERSCIENCE Publishers, UK, IETE and Technically Co-sponsored by Computer Society Chapter IEEE Delhi Section, held on 16th November, 2013, organized by Asia Pacific Institute of Information Technology SD India, Panipat, India.

[13] S.Balamurugan ,R.Madhukanth , V.M.Prabhakaran and Dr.R.Gokul Kruba Shanker, "Internet of Health: Applying IoT and Big Data to Manage Healthcare Systems," International Research Journal of Engineering and Technology (IRJET), Volume 3 issue 10, pp.732-735, e-ISSN: 2395 -0056, p-ISSN: 2395-0072, 2016

[14] V.M. Prabhakaran and Dr.Gokul Kruba Shanker S.Balamurugan ,R.P.shermy, "Internet of Ambience: An IoT Based Context Aware Monitoring Strategy for Ambient Assisted Living," International Research Journal Of Engineering and Technology(2016)