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Synthesis and characterization of graphene using PECVD and its field emission applications

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Graphene is a two dimensional structure of sp2 hybridised carbon atoms arranged in a hexagonal honeycomb like pattern. Its extraordinary and exciting electrical, optical and mechanical properties have made it a focal point of contemporary research in material science and have earned it the status of wonder material of 21st century. Our objective is to synthesis graphene sheets in a controlled manner in terms of number of layers and to observe for its properties like electrical conductivity, absorbance, transmittance and field emission which could be exploited in development of modern age opto-electronic devices. We have successfully synthesised high quality graphene on copper (Cu) coated silicon (Si) substrate at very large area using plasma enhanced chemical vapour deposition (PECVD) method at temperature as low as 600°C. SEM and TEM images showed the surface morphology of as grown samples is quite uniform having single layered graphene (SLG) to few layered graphene (FLG). The G and G' peaks of stokes phonon energy shift obtained in Raman spectroscopy confirmed that the sample consisted of a number of SLG's and FLG's. The field emission characteristics of as-grown graphene samples studied in planar diode configuration at room temperature depict that the as grown graphene is good field emitter with low turn-on field, higher field amplification factor and long term emission current stability. Other techniques such as low pressure chemical vapour deposition (LPCVD) and modified Hummer's methods have also been employed for successful synthesis of graphene and r-GO (reduced graphene oxide). The optical studies of these samples show that our samples had more than 90% optical transparency to visible light making it useful for opto-electronic applications.

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Graphene based heterostructures used for high performance broadband photodetectors

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Graphene has recently emerged as a potential candidate to address the shortcomings of traditional IV and III-V semiconductors for fast and broadband photodetectors. Graphene photodetectors can convert light into electrical signal over a broad electromagnetic spectrum from ultraviolet (UV) to terahertz (THz) range. However, the intrinsic optical responsivity of pure graphene-based transistors is usually poor (~10-2 AW-1) due to its relatively low absorption cross-section, fast recombination rate and the absence of gain mechanism. This has led to the formation of heterostructures of graphene with other gain materials that have a band gap, owing to the enhanced device performance in terms of photoresponsivity and photoconductive gain in these hybrid structures. Here, we reported novel photodetectors based on graphene-Bi_2Te_3, graphene-M_0Te_2, and graphene-black phosphorus heterostructures and their application for broadband photodetectors. Our results show that the graphene-Bi_2Te_3 photodetector not only shows greatly enhanced responsivity (up to 35 AW-1 at 532 nm) and an ultra-high photoconductive gain, but also has the capability for broadband photodetection from visible to near-infrared (NIR) wavelengths. We also demonstrated that graphene-M_0Te_2 hetero structure photodetector achieves a high responsivity of ~970.82 AW-1 (at 1064 nm) and broadband photodetection (visible-1064 nm). Additionally, flexible devices based on the graphene-M_0Te_2 hetero structure also retains a good photodetection ability after thousands of times bending test (1.2% tensile strain), with a high responsivity of ~60 AW-1 at 1064 nm. Finally, we show that the graphene-black phosphorus heterostructure photodetector shows an ultrahigh responsivity of 3.3×103 AW-1, high photoconductive gain (1.13×109), ultrafast charge transfer (41 fs), polarization dependent photocurrent response, and long term stability at telecommunication band of 1550 nm wavelength. The high performance in NIR range demonstrated in this work paves the way for practical applications in remote sensing, biological imaging and environmental monitoring using 2D materials.

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