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Gamma ray radiation effects on hBN encapsulated Graphene Field Effect Transistors

In the advent of emerging technologies graphene with its unique properties of flexibility, high mechanical strength, high thermal conductivity, structural stability along with high mobility, and optical transparency provides a foundation for boundless applications especially in the development of X-Ray-, THz- IR-, UV-, visible light-, chemical/ bio-sensors. It is then imperative to study the mechanisms that arise in graphene-based composite/hybrid devices under various radiation harsh environments. Radiation on graphene can cause formation of defects, displacement of its tightly packed stable structure. However, most damage under high energy radiation occurs in the substrate creating defects at the interface of graphene and substrate such as traps, tunneling sites, generation/ recombination sites, and compensators [1].

Graphene field effect transistors (GFETs) provide an adept vehicle for investigation of radiation effects as the field effect mobility and charge neutrality (Dirac) point are highly sensitive to unintentional doping from surrounding environment traps, fixed charges at oxide/substrate interface. Prior studies have shown that Gamma radiation in GFETs can cause electrically active defects in the substrate, increase trap density at the interfaces [2] while affecting the lattice of graphene itself exhibiting p-doped behavior. Encapsulation of graphene in 2Dmaterial such as hexagonal boron nitride (hBN) can isolate it from moisture rich ambient air, provide supporting substrate, passivating dielectric and due to the relatively inert nature of the hBN/graphene interface there are less dangling bonds or charged surface traps. But under X-ray irradiation, charge trapping is observed at or near hBN/graphene interface [3] wherein OH- and H+ species can act as acceptor or donor defects [4].

In our study we delve deeper into understanding radiation induced defects by evaluating the material and electrical response of hBN encapsulated exfoliated GFETs and non-encapsulated CVD grown GFETs under un-irradiation and irradiation by Co_{60} (Gamma rays) conditions. The Raman spectra (at 532nm) of non-encapsulated CVD grown graphene and hBN encapsulated exfoliated graphene before and after gamma irradiation (total dose of 5kGy) shows an upshift of both G and 2D peaks by about $5cm^{-1}$ in non-encapsulated CVD grown graphene. This is in contrast to hBN encapsulated exfoliated graphene which showed no change at the D peak under 5kGy gamma irradiation but a small upshift in 2D peak by 1cm^{-1} as shown in Fig.1 and this slight upshift can be attributed to an increase in doping. The transport characteristics measured at 300K of hBN encapsulated exfoliated GFETs show shift in the Dirac voltage from -2.72V pre-irradiation to +4V post irradiation as shown in Fig.2 along with degradation of mobilities from 36x10^{3}cm^2/V.s pre-irradiation to 21x10^{3}cm^2/V.s post-irradiation. We infer that the energy deposited by radiation creates electrically charged defects in the substrate and substrate/oxide interfaces negatively affecting device performance. Furthermore we will present the electrical and material study of the effects of increasing total dosage of gamma ray radiation on hBN encapsulated exfoliated GFETs in contrast to the non-encapsulated CVD grown graphene providing further insight into creating radiation hardened graphene sensors.

References

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Figures

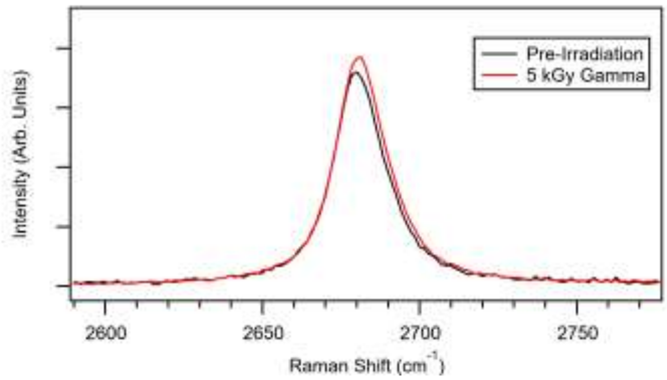

Figure 1: 2D peak of the Raman Spectrum for hBN encapsulated GFETs for pre-irradiation and post-irradiation of 5kGy Gamma rays.

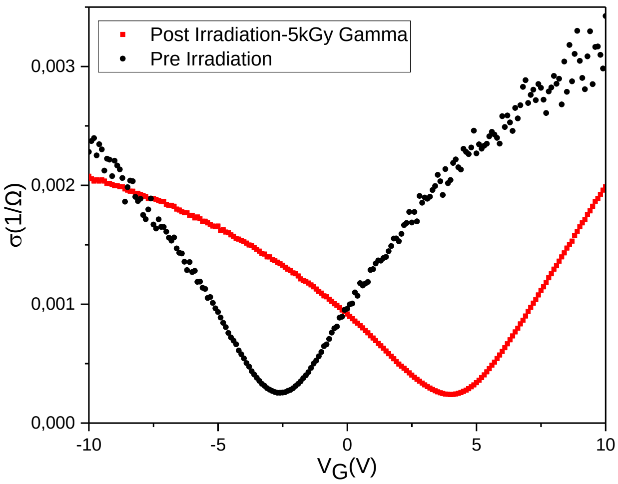

Figure 2: Conductivity versus Gate Voltage plot of hBN encapsulated GFETs comparing pre-irradiation and post-irradiation of 5kGy Gamma rays.