Exploring the limits of graphene's operation in extreme conditions imposed by the future energy industry

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Our research explores the potential of using two-dimensional (2D) carbon structures as magnetic field detectors capable of operating in the extreme conditions of future thermonuclear power plants. In so-called magnetic-confinement fusion reactors, electronics will be exposed to high temperatures and radiation damage. We demonstrate the experimental study on the impact of neutron radiation and determine its influence on the electrical parameters of epitaxial graphene-based systems. We have conducted preliminary research to investigate the impact of high temperature [1] and neutron irradiation [2] separately. For this purpose, we fabricated a hydrogen-intercalated quasi-free-standing (QFS) graphene on semi-insulating 4H-SiC(0001) and 6H-SiC(0001), passivated with an Al_2O_3 layer [3,4]. The systems were exposed to high-energy neutron fluxes using the MARIA research nuclear reactor.

We theorize that the main factor affecting the QFS properties of graphene in tested systems is the depletion of atoms in the hydrogen layer, based on Hall effect measurements and micro-Raman characterization supported by high-resolution transmission electron microscopy. We have predicted, using density functional theory calculations, that damage to the intercalation lowers carrier concentration in graphene. We anticipate that temperatures above 200°C will facilitate the diffusion of the hydrogen atoms from parts with higher to lower concentrations. This effect can reduce the surface area where intercalation is too low to support the separation of the graphene and improve its QFS properties [2].

Understanding the mechanism of damaging the tested systems by neutron radiation is a key milestone in assessing its suitability for magnetic field detection in harsh environments.

References

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