Exploring possible modes of damage caused by neutron radiation in thin-film and two-dimensional Hall-effect systems

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We describe the potential use of two-dimensional carbon-based structures and semiconductor thin-film materials in the energy industry as magnetic field detectors capable of operating under extreme conditions. In magnetic-confinement fusion reactors, electronics will be exposed to high temperatures and radiation damage. Our work demonstrates the experimental study on the impact of neutron irradiation and determining its influence on the electrical parameters of semiconductor thin-film and two-dimensional systems. For this purpose, we fabricated a 2D-material in form of hydrogen-intercalated quasi-free-standing graphene on semi-insulating 4H-SiC (0001), passivated with an Al_2O_3 layer [1]. The other structure was prepared in the form of donor-doped InSb-based thin-film on a semi-insulating GaAs substrate [2]. The tested systems were exposed to fast neutron fluence of 7×10^{17} cm^{-2} using the MARIA research nuclear reactor.

For graphene-based structure after irradiation, we theorize that the main factor affecting the electrical parameters is the loss of atoms in the hydrogen layer, based on Hall effect measurements and micro-Raman characterization. We have predicted, with the use of density functional theory calculations, that damage to the intercalation lowers carrier concentration in graphene. We anticipate that temperatures above 200°C will facilitate diffusion of the hydrogen atoms from parts with higher to lower concentration. This effect can reduce the surface area where intercalation is too low to support the separation of the graphene [3].

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 environment.

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