

TWO-CHANNEL DAMAGE MODEL IN 2D/3D HETEROSTRUCTURES UNDER HIGH ENERGY NEUTRONS

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Materials with reduced dimensionality suppress collision cascades from neutron radiation that is responsible for defect accumulation in bulk materials [1]. Therefore, understanding radiation damage in 2-dimensional systems is critical for the next-generation of radiation-tolerant electronics operating in extreme environments [2] like future fusion reactors or space technologies. The question remains, does reduced dimensionality retains its advantage while a part of a 3D structure? In this study, we examine *a*-Al₂O₃/graphene/H-intercalated SiC heterostructures [3, 4] subjected to 1–2 MeV neutron radiation up to 6.5×10^{18} n/cm², focusing on how reduced dimensionality responds to defect formation within a realistic 2D/3D architecture. Despite the surrounding bulk environment, graphene shows 69—273 times lower damage than SiC and reaches an early soft saturation. Hall-effect measurements reveal a radiation-driven transition from p- to n-type conductivity, indicating progressive hydrogen depletion [5]. These observations are supported by Density Functional Theory (DFT) calculations, which link interfacial chemical evolution to the emergence of disorder without requiring significant lattice displacement [5, 6].

We interpret these results through a two-channel damage model: (i) interfacial evolution dominating defect formation in 2D layer, and (ii) direct lattice damage that is prominent in the bulk. This framework highlights the decisive role of interface chemistry and provides a pathway for engineering radiation-resistant 2D/3D heterostructures.

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