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Influence of high-energy electron radiation on the electrical properties of back-gated graphene field effect transistors (GFETs) with different passivation materials

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Abstract

Back-gated graphene field-effect transistors (GFETs) have attracted significant interest owing to graphene's exceptional carrier mobility and high sensitivity, making them strong candidates for radiation sensing and detection applications. However, prolonged exposure to a high-energy radiation can degrade the graphene structure and impact device performance. This study presents a simulation-based investigation of back-gated GFETs incorporating different passivation materials (Si_3N_4 , SiO_2 , and Al_2O_3) under high-energy electron beam irradiation. The device modeling and radiation response was simulated using Victory Device tool by Silvaco TCAD. A 3 MeV electron beam at doses of 50, 100, and 200 kGy was irradiated to both passivated and non-passivated GFET models. All devices retained ambipolar characteristics with drain current increasing at 50 kGy and saturating

at higher doses of 100–200 kGy. The non-passivated GFET exhibited the highest conductivity, attributed to radiation-induced electron–hole pair generation dominating over defect-related scattering, in agreement with previously reported experimental observations. In contrast, the passivated GFETs showed a slight reduction in conductivity, which is attributed to hole trapping at the graphene-passivation interface, inducing parasitic fields that hinder electron mobility. The charge trapping mechanisms responsible for this behavior are systematically introduced and discussed in this study. Overall, despite exhibiting higher conductivity, the non-passivated GFET lacks structural protection against radiation-induced damage. These findings identify SiO₂ as a promising radiation-hardened passivation material for GFETs and demonstrate the applicability of TCAD tools in modeling radiation effects on 2D material-based devices. © 2026 IOP Publishing Ltd. All rights, including for text and data mining, AI training, and similar technologies, are reserved. This article is available under the terms of the IOP-Standard License.

Author keywords

electron radiation; GFET; graphene; silvaco TCAD; simulation; victory device

Indexed keywords

Engineering controlled terms

Electric field effects; Electron beams; Electronic design automation; Electrons; Graphene transistors; High electron mobility transistors; Hole mobility; Interfaces (materials); Passivation; Radiation effects; Radiation hardening

Engineering uncontrolled terms

Electron radiation; Graphene field-effect transistors; Graphenes; High conductivity; Passivation materials; Silvaco; Silvaco TCAD; Simulation; SiO₂; Victory device

Engineering main heading

Graphene

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