Electron Paramagnetic Resonance of Beta-Gallium Oxide Modified by High-Energy Electron Irradiation

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Several electron paramagnetic resonance (EPR) signals have been identified in $\beta{-}Ga_2O_3$, among which there is an intrinsic acceptor – gallium vacancy, both doubly ionized V^{2-}_{Ga} with spin ½ and singly ionized V^{-}_{Ga} with spin 1 [1, 2] and an intrinsic donor – oxygen vacancy O^{2-} trapping single electrons and exhibiting strong motional narrowing [3]. These EPR signals can be used to monitor defect formation and evolution of electronic properties of $\beta{-}Ga_2O_3$ modified by high-energy electron irradiation.

$\beta{-}Ga_2O_3$ single crystals doped with Sn were irradiated by a 2.5 MeV electron beam at 20 K at the Sirius facility, Ecole Polytechnique, Palaiseau. The electron irradiation produces a spread of Frenkel pairs, vacancy-interstitial. Interstitials are typically highly mobile at room temperature and annihilate at the surface, thus the expected effect of irradiation comes usually from vacancy-type induced defects. Indeed, in the EPR experiment after the irradiation, a signal characteristic to doubly ionized gallium vacancy, V^{2-}_{Ga}, is observed (Figure1), indicating a lowering of the Fermi level to the band gap. In contrast, pristine samples show the presence of shallow donor signal specific for conducting samples. The characteristic parameters of the resonance line, its linewidth, g-factor, and amplitude, evolve with temperature indicating a transition from states localized at donors to the delocalized states in the conduction band. The evolution of signals after subsequent annealing, thus removing the irradiation defects, is also discussed.

The presented study aims to shed light on the possibility of tuning the Fermi level towards the $\beta{-}Ga_2O_3$ valence band. This still unsolved issue is crucial for the practical implementation of this ultra-wide band gap material in electronics and opto-electronics.

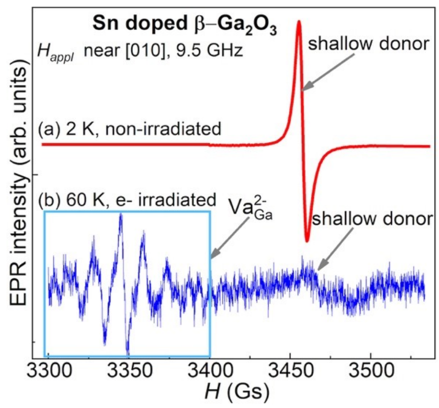

Figure 1. EPR spectra of pristine $\beta{-}Ga_2O_3$ doped with Sn (a) and irradiated with 2.5 MeV electrons (b).

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