Characterizing Point Defect Damage from Proton Irradiation in Narrow Bandgap Materials

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Narrow bandgap semiconductor heterostructures are used for a wide variety of applications, including infrared sensing in space. However, sensor performance can suffer in the space environment through the formation of point defects caused by ion irradiation. This degradation is often studied to derive an empirical damage factor characterizing the decline in performance as a function of dose for a given epitaxial detector stack. A key metric in evaluating these detector materials is the minority carrier lifetime, which directly corresponds to leakage current and detectivity. While this approach is crucial for evaluating detectors and predicting their useable service life, it does not identify the precise defect trap states that are created and decrease minority carrier lifetime. Thus, identifying the atomic scale defects and their energy levels that are present both from materials growth are critical for characterizing and improving the performance of infrared detectors.

Identifying defects in narrow bandgap materials presents a distinct challenge: all defects are shallow and are difficult to resolve from band edges. Further, these defects are active even at cryogenic temperatures. Thus, we take a multifaceted approach combining theory and experiment, focusing on InAs as a model system to build a foundation for understanding more complex alloys and heterostructures. We use electronic device measurements including deep level transient spectroscopy, and material characterization such as time-resolved microwave reflectance and time-resolved photoluminescence to measure minority carrier lifetime, and compare these results to candidate point defects predicted by *ab initio* calculations. This approach allows us to resolve the ambiguities in experimental data that can only quantify defect activation energies without knowledge of their atomic structure, while sifting out the variety of defects that might be predicted to be stable but that do not correspond to experiments.

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