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# In-situ Ion Irradiation and Recrystallization in Highly Structured Materials

Jeffery A. Aguiar[1*], Anthony Monterrosa[2], Bryan Reed[3] , Daniel Masiel[3], Seongtae Kwon[1], Matthew L. Gong[4], Tolga Tasdizen[4], Benjamin Coryell[1], Katherine Jungjohann[2],Khalid Hattar [2], Erik Luther[5], and Howard T. Hartman[1]

[1.] Idaho National Laboratory, Nuclear Materials Department, Idaho Falls, Idaho USA.
[2.] Sandia National Laboratories, Center for Integrated Nanotechnologies Albuquerque, New Mexico USA.
[3] Integrated Dynamic Electron Solutions, Pleasanton, California USA.
[4.] University of Utah, Scientific Computing Imaging Institute, Department of Electrical and Computer Engineering, Salt Lake City, Utah USA.
[5.] Los Alamos National Laboratory, Los Alamos, New Mexico USA.
* Corresponding author: Jeffery.Aguiar@inl.gov

Structured materials represent a challenge to decouple their fundamental defect and annihilation mechanisms that largely influence their defect accumulation rates under extreme environments [1–3]. Open scientific questions remain on the relative defect recovery rates in these materials, including effects of local density, connected porosity, and defect content in largely highly oriented two-dimensional materials, such as graphite. Pending the atomic arrangements, incident energies, and chemistries, there are further varying outcomes on whether ion-induced defects can be annealed in the vertical, horizontal, or combination axes. Current post analysis TEM studies are not enough to support and report a conclusive understanding of the creation and annihilation of ion-induced defects and subsequent annealing mechanisms in graphite and similar anisotropic materials. Atomic level *in situ* characterization can begin to these answer questions, as well as augment our ongoing atomistic and first principles-based understanding of radiation damage.

There are significant scientific reasons to suspect differences in how structured materials recover from ion-induced radiation damage. *In situ* ion beam transmission electron microscopy has proven to be one reliable and potentially high throughput approach to begin tracking microstructural evolution with adequate resolution to address these challenges [4]. To study the interplay between structure, chemistry, and defects, high temporal resolution imaging and diffraction has allowed for the collection of adequately resolved multimodal datasets for higher-level structural classifications by which materials damage and recover under extremes [5]. Pending activities include developing our understanding of ion-induced defect production, accumulation, and remediation as shown in Figure 1 for graphite.

In this presentation, we will discuss the additional benefits and challenges associated with studying structured materials with *in situ* ion beam irradiation. In addition to extracting meaningful data, it is necessary to create complex neural networks that utilize machine learning to decouple the information for these highly compressible images to suggest and validate potential per defect recovery mechanisms for each of these material systems. In this presentation, the basic approach to studying highly structured materials and analysis strategies that incorporate structure, chemistry, diffraction, and atomistic modeling data will be presented. Results showing the use of atomic scale imaging, modeling, and *in situ* ion beam irradiation to better classify resolved mechanisms with minimal *a priori* knowledge will be presented in detail and the potential insights gained by increasing acquisition speed and/or decreasing the electron dose will also be discussed.

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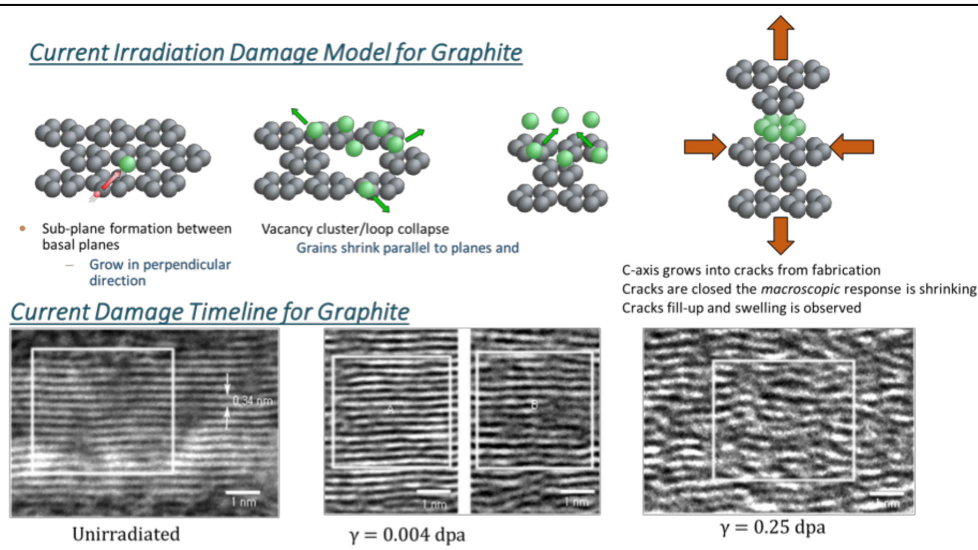


**Figure 1. Current damage accumulation and remediation model for irradiated graphite.** The model is largely unconfirmed by current electron microscopy where for low damage levels we only have post-irradiated behavior that largely does not provide temporal information on the atomic rearrangements of graphite under irradiation.

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