Journal of Nuclear Materials 605 (2025) 155545

Contents lists available at ScienceDirect

Journal of Nuclear Materials

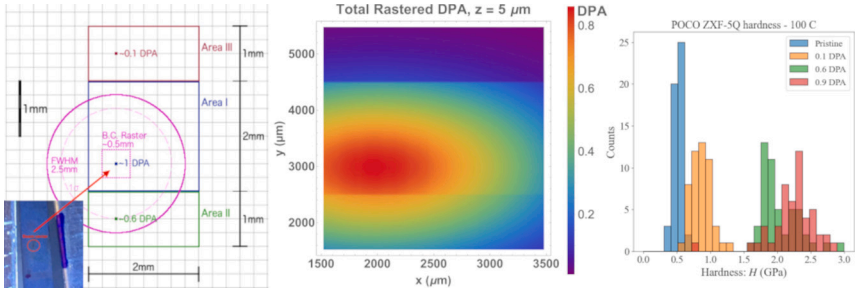
journal homepage: www.elsevier.com/locate/jnucmat

Radiation damage study of POCO ZXF-5Q graphite for neutrino production targets using 4.5 MeV helium ions

Abraham Burleigh [a,*,1], Kavin Ammigan [b], Sujit Bidhar [b], Frederique Pellemoine [b], Ovidiu Toader [c], Thomas Kubley [c,2], Kai Sun [d], Jeff Terry [a,e,f]

[a] Department of Physics, Illinois Institute of Technology, Chicago IL 60616, United States of America
[b] Accelerator Directorate, Fermi National Accelerator Laboratory, Batavia IL 60510, United States of America
[c] Michigan Ion Beam Laboratory, University of Michigan, Ann Arbor MI 48109, United States of America
[d] Department of Materials Science and Engineering, University of Michigan, Ann Arbor MI 48109, United States of America
[e] Department of Mechanical, Materials, and Aerospace Engineering, Illinois Institute of Technology, Chicago IL 60616, United States of America
[f] Center for Synchrotron Radiation Research and Instrumentation (CSRRI), Illinois Institute of Technology, Chicago IL 60616, United States of America

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Radiation damage
High-power targetry
Ion irradiation
POCO graphite
Microstructural characterization

ABSTRACT

To address the challenges of increased beam power and target survivability associated with next-generation particle production beam lines, high dose, high-energy proton beam conditions are simulated using irradiation from low-energy ion beams. A low-energy ion irradiation study of POCO ZXF-5Q graphite under conditions similar to those of the NuMI NT-02 neutrino production target at the Fermi National Accelerator Laboratory is reported. Helium ion irradiation was performed at 100° C to a maximum damage level of 0.9 displacements per atom (DPA). Irradiation induced hardening, swelling of the irradiated region, inter-plane lattice expansion, and intraplane lattice contraction with increasing ion fluence was observed using micromechanical (nanoindentation, atomic force microscopy) and electron microscopy (high-resolution imaging, selected area diffraction) characterization. Similar changes were also observed in post irradiation examination of the NT-02 target indicating that ion irradiation can be a valuable tool for estimating radiation damage in proton beam targets. Caution must be exercised though, because the hardening, lattice alteration, and swelling occur to different magnitudes for a given damage level. The observed hardening and embrittlement were greater for ion irradiated graphite. For He ion irradiated samples the lattice spacing changes were smaller at low damage levels (78% less expansion and 71% less contraction at 0.1 DPA) and larger at high damage levels (38% more expansion and 5% more contraction

* Corresponding author.
E-mail address: burleigh@fnal.gov (A. Burleigh).
[1] Now at Accelerator Directorate, Fermi National Accelerator Laboratory, Batavia IL 60510.
[2] Now at Collider Accelerator Department, Brookhaven National Laboratory, Upton NY 11973.

https://doi.org/10.1016/j.jnucmat.2024.155545
Received 28 February 2024; Received in revised form 19 November 2024; Accepted 28 November 2024

Available online 4 December 2024