Progress in Materials Science 96 (2018) 217–321

Contents lists available at ScienceDirect

Progress in Materials Science

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

Progress in Materials Science
An International Review Journal

Radiation damage in nanostructured materials

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ARTICLE INFO

Article history:
Received 30 December 2016
Received in revised form 4 March 2018
Accepted 13 March 2018
Available online 15 March 2018

Keywords:
Radiation damage
Nanomaterials
Modeling
In situ radiation
Defect sinks
Materials design

ABSTRACT

Materials subjected to high dose irradiation by energetic particles often experience severe damage in the form of drastic increase of defect density, and significant degradation of their mechanical and physical properties. Extensive studies on radiation effects in materials in the past few decades show that, although nearly no materials are immune to radiation damage, the approaches of deliberate introduction of certain types of defects in materials before radiation are effective in mitigating radiation damage. Nanostructured materials with abundant internal defects have been extensively investigated for various applications. The field of radiation damage in nanostructured materials is an exciting and rapidly evolving arena, enriched with challenges and opportunities. In this review article, we summarize and analyze the current understandings on the influence of various types of internal defect sinks on reduction of radiation damage in primarily nanostructured metallic materials, and partially on nanoceramic materials. We also point out open questions and future directions that may significantly improve our fundamental understandings on radiation damage in nanomaterials. The integration of extensive research effort, resources and expertise in various fields may eventually lead to the design of advanced nanomaterials with unprecedented radiation tolerance.

Abbreviations: BCC, body-centered cubic; CG, coarse-grained; CTB, coherent twin boundary; DDZ, defect denuded zone; dpa, displacements-per-atom; ECAP, equal channel angular pressing; FCC, face-centered cubic; GB, grain boundary; HCP, hexagonal close-packed; HRTEM, high-resolution transmission electron microscopy; ITB, incoherent twin boundary; IVEM, intermediate voltage electron microscopy; KS, Kurdjumov–Sachs; MD, molecular dynamics; MDI, misfit dislocation intersection; NC, nanocrystalline; NP, nanoporous; NT, nanotwinned; NV-NT, nanovoid-nanotwinned; ODS, oxide dispersion strengthened; OKMC, object kinetic Monte Carlo; PED, precession electron diffraction; PKA, primary knock-on atom; PPM, parts per million; RT, room temperature; SAD, selected area diffraction; SFE, stacking fault energy; SFT, stacking fault tetrahedron; SIA, self-interstitial atom; SITB, symmetric incoherent twin boundary; SRIM, stopping and range of ions in matter; SS, stainless steel; STEM, scanning transmission electron microscopy; TB, twin boundary; TBAZ, twin boundary affected zone; TEM, transmission electron microscopy; TJ, triple junction; UFG, ultra-fine grained; VDZ, void denuded zone; XTEM, cross-sectional transmission electron microscopy; 0/1/2/3 D, zero/one/two/three dimensional.

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https://doi.org/10.1016/j.pmatsci.2018.03.002
0079-6425/

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