

Electronic Energy Deposition and Radiation Effects in Oxides, Carbides and Metallic Alloys

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The effects of extreme ionization can effectively alter the atomic processes, modify thermodynamic properties, and affect evolution of microstructure in nuclear materials [1]. Realistic prediction of radiation effects in irradiated materials requires understanding of the coupled processes of electronic and atomic dynamics. Using experimental and computational approaches, the separate and combined effects of nuclear and electronic energy deposition in SiC, ABO₃ model oxides, and concentrated solid-solution alloys (CSAs) are investigated. We show that defect evolution closely depends on electronic/nuclear stopping powers, the electronic-to-nuclear ratio, as well as the temporal and spatial coupling of electronic and atomic subsystem for energy dissipation. Athermal recovery of pre-existing defects may occur above a threshold of electronic energy loss, and significant in-cascade recovery may be active at an even lower threshold. In SiC [2-4], the threshold energy to activate the dynamic recovery process is ~450 keV for both Si and C PKAs. In oxides [5-7], intense electronic energy deposition may result in a non-linear increase in damage production (synergistic effect), even fully amorphization. On the other hand, ionization may induce significant defect annihilation and amazingly restore lattice order (competitive effect). In metallic alloys [8-10], electronic energy loss affects damage production in collision cascades (30 to 150 keV), induces defect recovery and strain relaxation in pre-damaged materials (10 to 20 MeV), and causes structural modification (GeV energies) in CSAs. These results have significant implications on the use of energetic ions to emulate neutrons. Understanding the coupled effects will allow prediction of complex non-equilibrium defect processes and lead to improved predictive models.

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