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Insight into Disorder, Stress and Strain of Radiation Damaged Pyrochlores

SARAH C FINKELDEI[1], SHIRLEY CHANG[1], FELIX BRANDT[2], DIRK BOSBACH[3], MIHAIL IONESCU[4], MAX AVDEEV[5], DAVID SIMEONE[6] AND GORDON J THOROGOOD[5]

[1]University of California, Irvine
[2]Forschungszentrum Jülich, Germany
[3]Forschungszentrum Jülich GmbH
[4]Australian Nuclear Science and Technology Organization
[5]ANSTO
[6]Structures, Properties and Modeling of Solids Laboratory
Presenting Author: sfinkeld@uci.edu

$A_2B_2O_7$ pyrochlores are considered as potential nuclear waste forms for e.g. plutonium immobilization. Once radionuclides are immobilized within these waste forms, self-irradiation can cause order/disorder transitions of these nuclear waste form candidates. The aim of this study was to detect the early onset of phase transformation in relation to stress and strain of different pyrochlores: titanate based pyrochlores which are prone to amorphization, and zirconate based pyrochlores that are known to undergo a transformation to defect fluorite. Helium ion irradiation experiments of the two pyrochlore types were conducted at 2-6 MeV with a fluence of 1 x 10^{16} ions/cm^2 resulting in approximately 1 dpa to study the onset of disorder in thin samples, to mimic bulk damage. A combined approach of synchrotron X-ray diffraction (XRD), neutron diffraction, and transmission electron microscopy (TEM) as well as electron backscattered diffraction (EBSD) techniques was utilized to understand the structural and microstructural response towards radiation. Irradiation of the $Er_2Ti_2O_7$ ceramics resulted in a partially fractured sample most likely caused by strain relief. Neutron diffraction data revealed the formation of amorphized regions whereas some crystallinity remained without signs of stress or strain after irradiation. For $Nd_2Zr_2O_7$, ion irradiation caused the formation of two pyrochlore phases instead of the expected pyrochlore to defect fluorite structural transition. One of the phases appeared to be very similar to the undamaged material while neutron scattering revealed residual stress in the second pyrochlore phase with a significantly reduced lattice parameter compared to the unirradiated $Nd_2Zr_2O_7$ sample. While we did not observe indications of strain in either of the phases evidence of an increase in disorder of both the cations and anions was observed.