Ion-irradiation induced structure changes in the Ln_2TiO_5 system

Aughterson, R.[1], Lumpkin, G.[1], Smith, K.[1], Ridgway, M.[2] and Cairney, J.[3]

[1] Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia, [2] Australian National University, Australia, [3] University of Sydney, Australia

By using combinations of lanthanides, in this study holmium and ytterbium, it is possible to control the average lanthanide size and also the resultant crystal structure for compounds of nominal stoichiometry Ln_2TiO_5 (Ln = lanthanides). By controlling the structure it is possible to influence the material properties. Of particular interest for the Ln_2TiO_5 ceramic oxide series are potential nuclear applications [1, 2]. For these nuclear applications a tolerance to exposure from high energy particles is a desirable characteristic and in particular the resistance to transition from the crystalline to amorphous state upon exposure.

A systematic series of $Ho_{(x)}Yb_{(2-x)}TiO_5$ (x = 2, 1.6, 1.2, 1, 0.8, 0.4, 0) compounds has been fabricated and characterised using X-ray diffraction and TEM (imaging and diffraction). There are significant differences in structural detail derived from XRD and TEM diffraction. All compounds have a long-range fluorite structure but there is variation in the amount of shorter range pyrochlore domains found within the series. Several of these materials have been tested for radiation tolerance using accelerated ions to simulate the damage created via fission. Characterisation of this ion-irradiation response has been achieved via TEM techniques; both in-situ and ex-situ.

Using in-situ ion-irradiation, krypton 1 MeV, coupled with TEM characterisation we have determined the critical dose of irradiating ions required for the crystalline to amorphous transition for several of our test compounds. The critical dose of amorphisation measurements have been repeated over a range of temperatures and used to determine the critical temperature for maintaining crystallinity. A general trend of decreasing critical temperature with decreasing average lanthanide radius was found.

Bulk sample ion irradiation, Selenium 1 MeV, has also been carried out with specimens characterised using cross-sectional TEM. This has allowed critical dose of amorphisation and critical temperature for maintaining crystallinity to be determined and compared with the results from the in-situ approach. Further to this ion-irradiation induced crystal structure to crystal structure transitions have been observed. An example of the cross-sectional analysis is displayed in Figure 1.

Details of techniques plus results from the different characterisation approaches are compared and trends discussed.

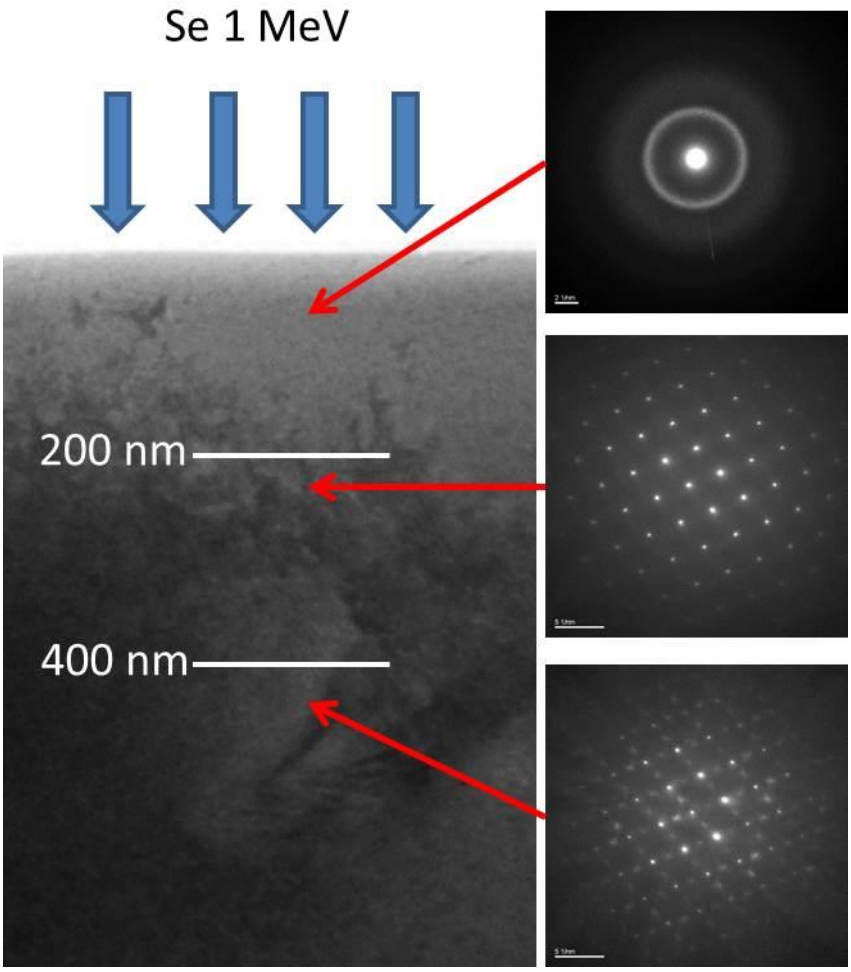

Figure 1. Cross-sectional TEM bright field image of Yb_2TiO_5 irradiated with 1 MeV selenium ions. Nano-beam electron diffraction patterns show the changing structure with depth from complete amorphisation occurring near the surface, fluorite structure detected in heavily damaged area, and pyrochlore structure detected in the bulk.

1. Sinha, A. and B.P. Sharma, *Development of dysprosium titanate based ceramics.* Journal of the American Ceramic Society, 2005. **88**(4): p. 1064-1066.

2. Risovany, V., E. Varlashova, and D. Suslov, *Dysprosium titanate as an absorber material for control rods.* Journal of Nuclear Materials, 2000. **281**(1): p. 84-89.