Anomalous diffusion-controlled kinetics in irradiated oxide crystals

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MgO, Al_2O_3 and MgF_2 are three wide gap insulating materials with different crystalline structures. All three materials are radiation resistant and have many important applications, e.g. in reactor optical windows. It is very important to predict their long-time defect structure evolution controlled by defect migration and reactions. One could estimate the diffusion coefficients of radiation defects in solids from measurements of the main defect concentration changes (oxygen vacancies called the F-type color centers, by optical absorption) under different conditions, e.g., sample heating (annealing) after irradiation.

As is well-known, the F center mobility is much smaller than that of the complementary radiation Frenkel defects -- interstitial ions. Thus, at moderate radiation fluencies and temperatures, the kinetics of the F-type center annealing is governed by their *diffusion-controlled recombination* with mobile interstitials. The basic theory (how to extract from experimental data the *migration energy* E_a of interstitials and its *pre-exponential factor*) was developed and applied to irradiated insulators in our recent study [1,2]. It is demonstrated (Fig.1), for the first time, that in three types of strongly irradiated ionic solids the pre-exponential factor of diffusion is strongly correlated with the migration energy. It was showed [2] that the correlation of these two parameters satisfies the so-called *Meyer–Neldel rule* (MNR) [3] observed more than once earlier in glasses, liquids, and disordered materials, but not yet in the irradiated materials.

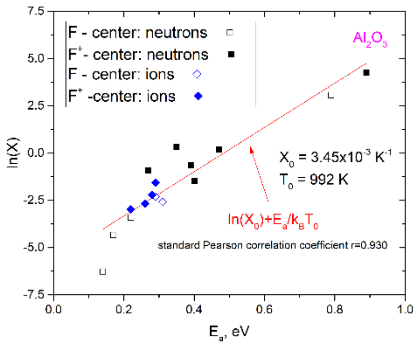

Figure 1: Correlation of the effective diffusion energies and its pre-exponents for neutron and ion-irradiated Al_2O_3.

We have shown for all three materials that with the increase of radiation fluence (dose) both the migration energy and its pre-exponent are *decreasin*g, irrespective of the type of irradiation. We discuss the origin of this phenomenon. Thus, in this study, we demonstrated that the dependence of defect migration parameters on the radiation fluence plays an important role in the quantitative analysis of the radiation damage kinetics and long time damage development of real materials and cannot be neglected.

References

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