The irradiation testing of nuclear ceramics and oxides with heavy ions of fission fragment energy

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In order to reduce the environmental impact of radioactive waste, innovative concepts are being developed for the recycling of actinides, which make up most of the radiotoxicity of spent fuel. One of the concepts under investigation is the use of inert matrix fuels, which consist of a fissile phase embedded in an inert, i.e. transparent to neutrons, matrix phase. Materials to be employed as inert matrices for transmuting of minor actinides by means of nuclear reactions should obviously present suitable characteristics as hosts for the actinides and as targets for the irradiation in a reactor. A key parameter to be considered is the resistance to radiation damage due to neutron exposure, gamma and beta radiation, self-irradiation from alpha decay, and fission fragments. Structural modifications induced by fission products, i.e. atoms with a mass ranging from 80 to 155 and an energy of about 100 MeV, still remain uncertain because the effects cannot be investigated using classical low-energy ion implanters. In particular, dense ionization, that is a main peculiarity of fission fragment effect in comparison to convenient irradiation, may introduce phase transformations and accompanying volume changes in swift ion (fission fragment) track region. This can consequently produce unacceptable stresses in fuel pin assemblies, limiting the fuel performance. Such swift ion radiation-induced changes are poorly understood and cannot be predicted from neutron or conventional ion irradiation behavior. To date, only a few data concerning the microstructural response of nonfertile ceramics to ion irradiation of fission energy are available and external bombardment with energetic ions offers a unique opportunity to simulate fission fragment-induced damage. The overall intention of this project is to yield sufficient basic data to qualify several ceramics and single crystals ($MgAl2O_4$, MgO, Al_2O_3, ZrO_2, SiC, ZrC, AlN, Si_3N_4) as candidates for inert matrix fuel hosts with respect to the susceptibility to radiation damage due to fission-events.

Our irradiation testing experiments will be focused on study of:

– temperature dependence of swift heavy ion-induced phase transformations and dense ionization effect on pre-existing defect structure in irradiating materials;

– correlation between surface and material bulk radiation damage induced by heavy ions with energies above 1 MeV/atomic mass unit (amu).

The project fulfilment allows us to acquire new knowledge concerning evolution of defect structure in nuclear ceramics under dense electronic excitations simulating the fission fragment impact.

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