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

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Introduction

- As a results of long term reprocessing strategies and recent decisions on the dismantling of nuclear weapon, separated plutonium stocks are rising
- The promising way of plutonium and minor actinides utilization in a safe and economical manner is the burn-up them in inert matrix fuel
- The matrix is necessary as a packaging and dilution material and serves as a storage medium
- Of the candidate non-fertile materials for inert matrix fuels, several ceramics with a high melting point and low neutron absorption cross section such as Spinel (MgAl2O4), Zirconia (ZrSiO4), Silicon carbide (SiC), MgO, Al_2O_3, etc have received much attention
- Radiation stability of inert matrices in large measure depends on damage created by fission products resulting from fission of actinides

Aim and objective

- To study the structural changes in ceramics and oxides under 1-5 MeV/amu heavy ion bombardment simulating the fission product impact.
- To study and understand material performance in radiation environment in a nuclear reactor and accelerators.
- To determine the level of mechanical stresses

Experimental setup

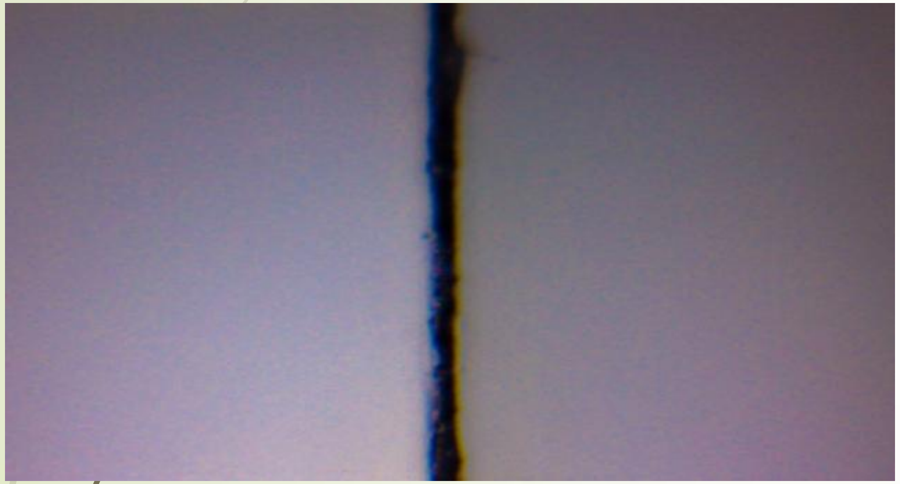
LCSM- laser beam pass through a light source aperture which is then focused by an objective lens into a small area on the surface of the sample and an image is built up pixel-by-pixel by collecting emitted photons from the fluorophores in the sample

Spatial resolution-number of pixels utilized in construction of a digital image.

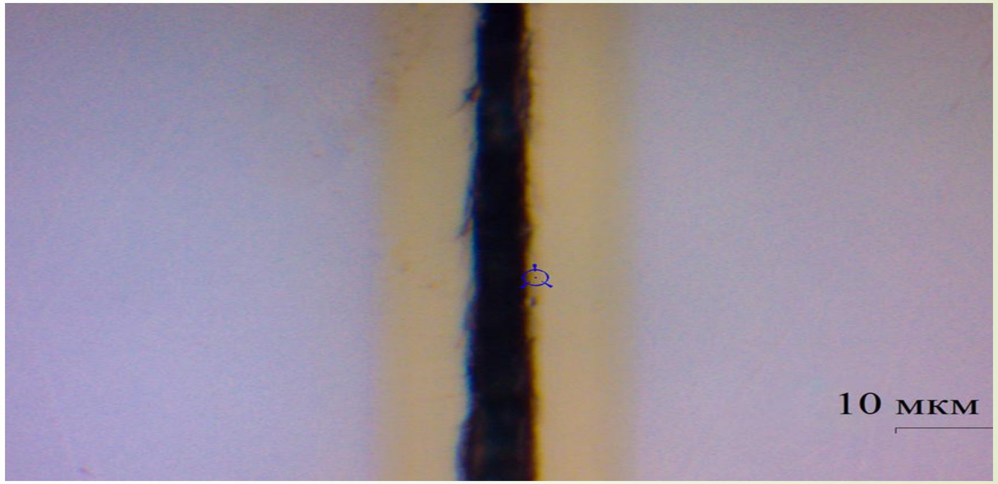
NTEGRA Spectra Laser Confocal Scanning Microscope (NT-MDT)

Preparations of samples

Un irradiated Al_2O_3: Cr



Al_2O_3: Cr radiated Xe



- Al_2O_3 :Cr irradiated with Xenon ions
- Energy of 1.2 MeV
- Ion fluence of 3.4*10^14 cm^-2

Piezo spectroscopic effect

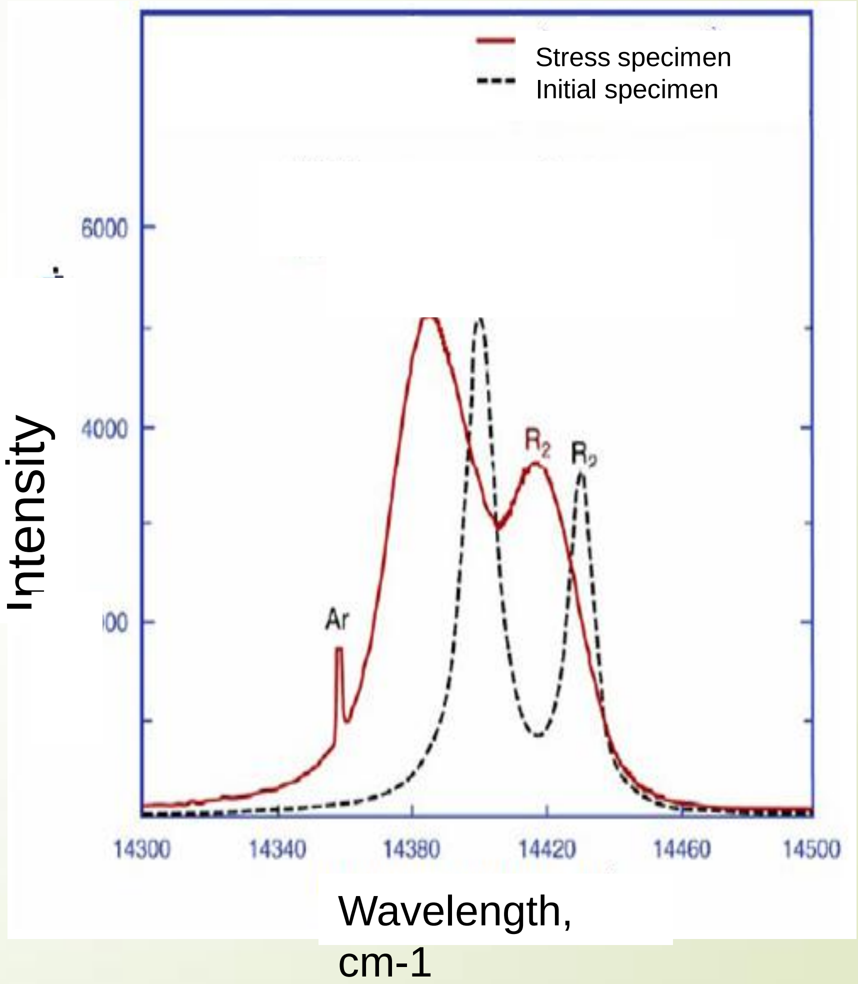
- Stress and strain play a very important role in the behavior of materials
- The information about the stress/strain of the material can be provided by the Raman, (Infrared) IF and Luminescence's techniques.
- The influence of stress on the peak frequency of a spectroscopic band is known as piezo-spectroscopic effect
- Ceramics are optically transparent because of their large bands, however, the presence of trace impurities, mostly transition metal ions and rare earth ions, can cause intense fluorescence when excited

Piezospectroscopic effect applied to Al2O3: Cr

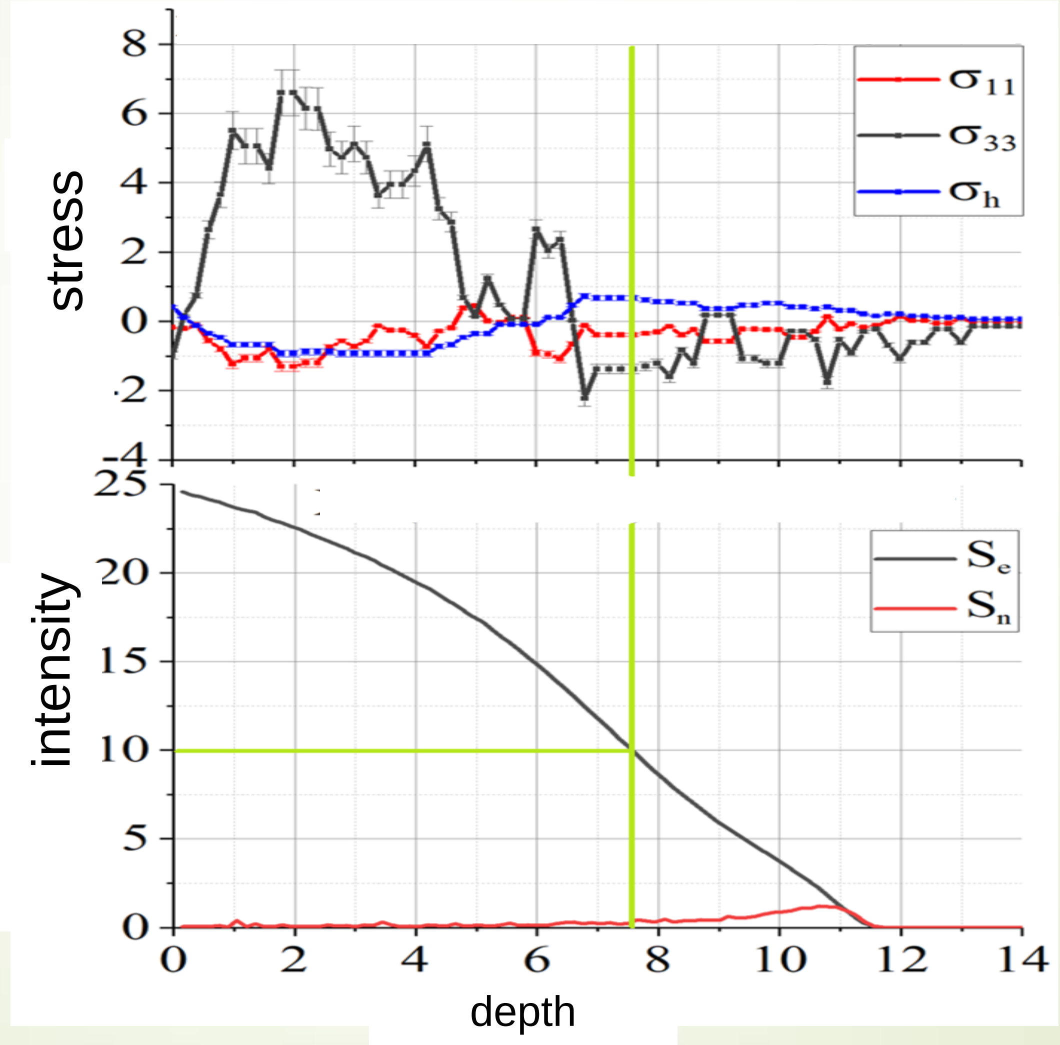
A method based on the relationship between the parameters of the optical absorption, luminescence, or Raman scattering spectra with the magnitude of mechanical stresses

$$\Delta \nu = \prod_{ij} \times \sigma_{ij}$$

Where Пij- piezo-spectroscopic coefficients

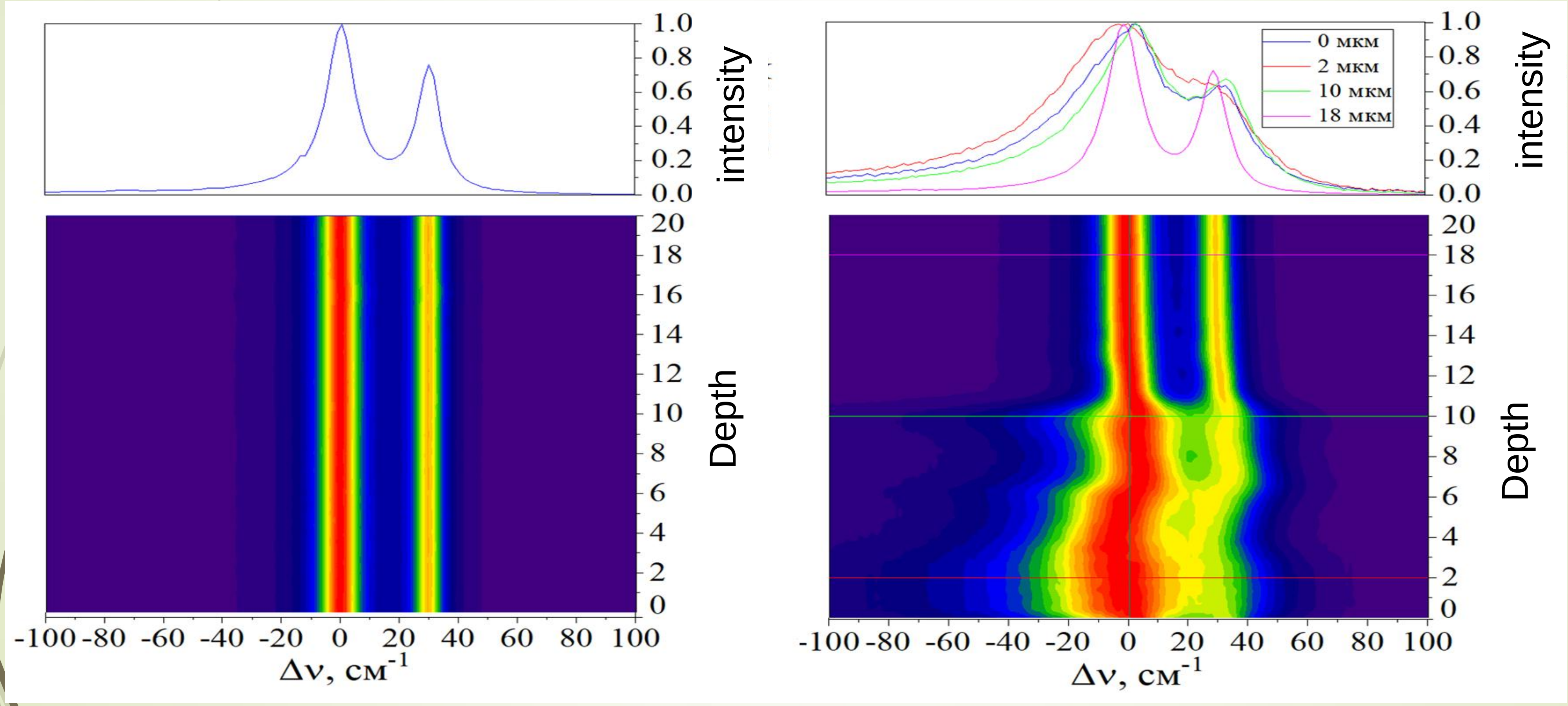


Stress profiles in Al2O3: Cr crystals irradiated with Xe ions



Results and discussion

Spectrum of un-irradiated and irradiated samples



Discussion

- The stress level profiles were determined through the shift of the R-line luminescence
- Stress profile component in ruby crystals across swift heavy ions irradiated layers have been obtained from depth-resolved photo-stimulated R-lines spectra using piezo-spectroscopic effect which provide information on the stress to which the material are subjected, through the shift of the respective spectroscopic bands.
- Radiation damage produced by the high energy heavy ions besides widening of the R-lines induce visible shift towards low wavenumber
- When the frequency shift toward lower energies means that irradiated target is under compression

Conclusion

- The stress level is found to be dependent on the ionizing energy loss
- A link is shown between the profile of mechanical stresses in Al_2O_3:Cr single crystals

THANK YOU

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