Joint Institute for Nuclear Research

Nelson Mandela Metropolitan University

for tomorrow

# RADIATION DAMAGE IN NANO-CRYSTALLINE ZrN IRRADIATED WITH SWIFT HEAVY IONS OF FISSION FRAGMENT ENERGIES

A. Janse van Vuuren[1]*, V. A. Skuratov[2], V.V. Uglov[3], J.H. Neethling[1], S.V.Zlotski[3]
[1]Centre for HRTEM, NMMU, RSA
[2]FLNR, JINR, Dubna, Russia
[3]BSU, Minsk, Belarus

Centre for High Resolution Transmission Electron Microscopy

# Collaboration

## CHRTEM & FLNR

This collaboration is based on the **electron microscopy** of the CHRTEM @ NMMU and the **accelerators** at the cyclotron complex of the FLNR @ the JINR.

***This research presents intriguing fundamental science questions & is of practical value in determining the radiation stability of inert matrix fuel hosts and coatings for structural materials.***

**Centre for High Resolution Transmission Electron Microscopy**

## Inert Matrices for Transmutation of Minor Actinides

**Materials employed as inert matrices (for transmuting minor actinides through nuclear reactions) should obviously present suitable characteristics such as:**

- Compatibility with actinides
- Structural stability under severe irradiation conditions

**Parameters of importance for an inert matrix is its resistance to:**

- Radiation damage due to neutron exposure
- Gamma and Beta radiation
- Self-irradiation from Alpha decay
- **Radiation damage due to fission fragments**

*Structural modifications induced by fission products, still remain uncertain because the effects cannot be investigated using classical low-energy ion implanters.*

# Simulation of Fission Fragment Damage

## Simulation of fission product damage with Swift Heavy Ions (SHI)

### Properties of Fission Products:

- Mass ranging from 80 to 155 amu
- Energy >100 MeV

### SHI Ions employed in Research:

- 250 MeV **Kr**
- 167 MeV **Xe**
- 695 MeV **Bi**

### Ion Tracks may be comparable to Grain Size

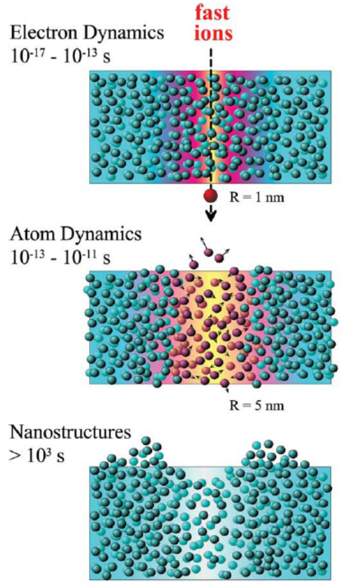



**Fig.1. Time evolution of an ion track. Initial excitation and ionization of atoms induces atomic motion, which freeze out and may lead to permanent rearrangement. In the bulk it may result in structural or chemical modification and at the surface, craters or blisters may form on an atomic scale.**

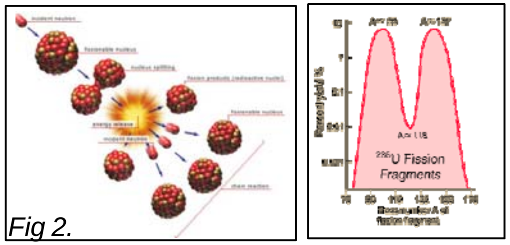
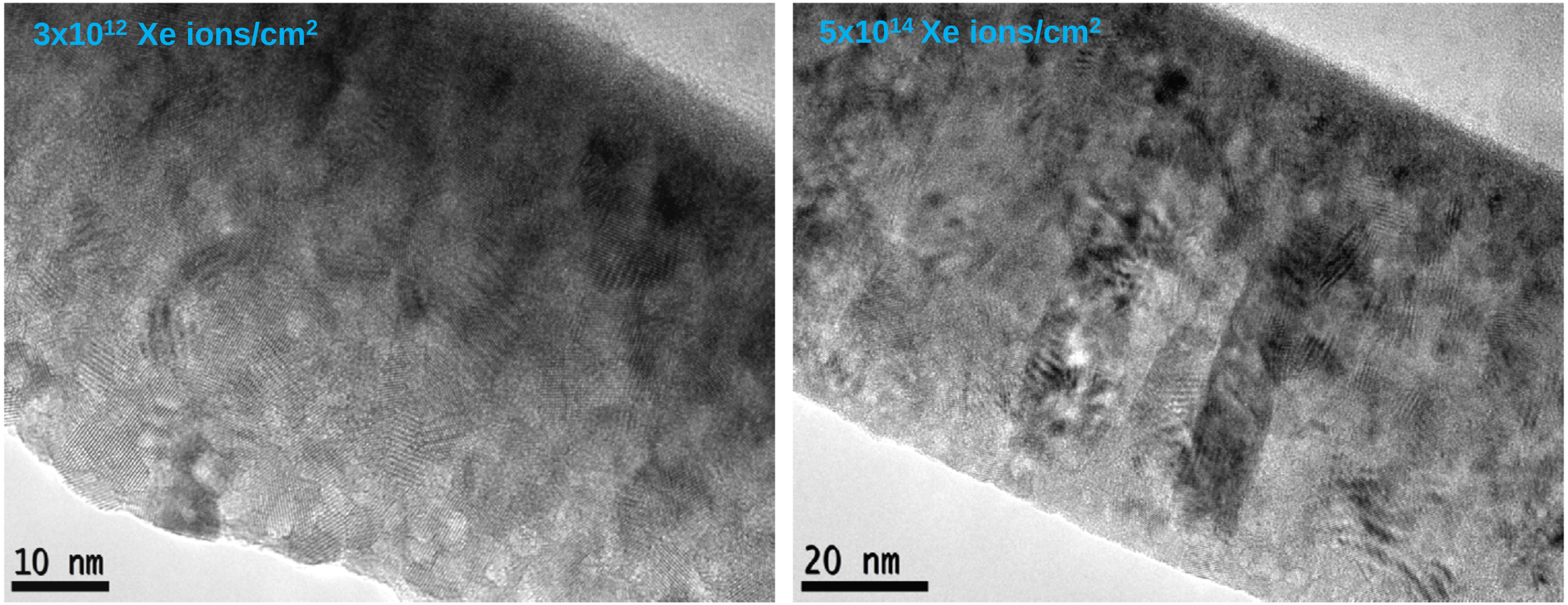
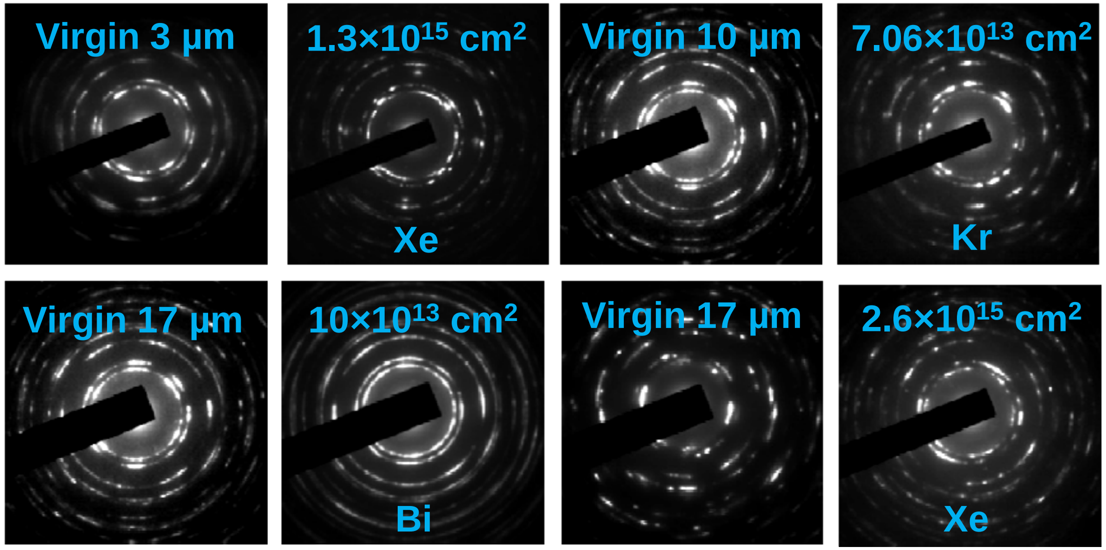



*Fig 2.*


*[Fig. 1.] G. Schiwietz et al. Nucl. Instr. and Meth. in Phys. Res B 226 (2004) 683-704*
*[Fig. 2.] visual.merriam-webster.com, [Fig 3] hyperphysics.phy-astr.gsu.edu*

# TEM of 0.1, 3, 10 & 17 μm ZrN layers



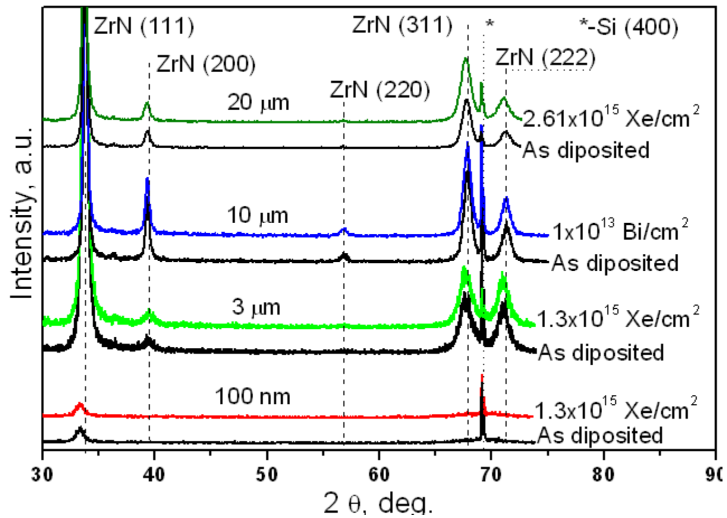



# XRD (167 MeV Xe, 695 MeV Bi)

## XRD of Nanocrystalline ZrN layers

- Typical FCC structure of the NaCl-type
- (111) preferred orientation
- No apparent changes in phase composition after irradiation
- Even for Bi which has the highest ionization energy loss (49 keV/nm) for monatomic particles in ZrN.

*ZrN nanocrystalline layers exhibit high micro-structural stability under dense ionization effects*




*X-ray diffraction spectra of **As Deposited** & **Irradiated** (**167 MeV Xe** & **695 MeV Bi**) Nanocrystalline ZrN layers grown on a Si substrate.*

# Thank You