

Post-irradiation observations on U-7wt% Mo atomised dispersion fuel

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Irradiation program

Irradiation in the FUTURE rig of the BR2 reactor at SCK•CEN of :

2 Full sized fuel plates :

- U-7wt% Mo atomized powder dispersed in Al matrix
and surrounded by an Al alloy cladding
- Low enrichment ($<20\%$ ^{235}U)
- High uranium loading ($> 8 \text{ g U/cm}^3$)

Objective irradiation :

- surface heat flux $\approx 340 \text{ W/cm}^2$
- cladding temperature $< 130 \text{ }^\circ\text{C}$
- Local burnup of $\approx 70\%$ ^{235}U

Irradiation program

After second cycle (40 FPD's): observation of increase of the fuel plates thickness in the axial hot plane →

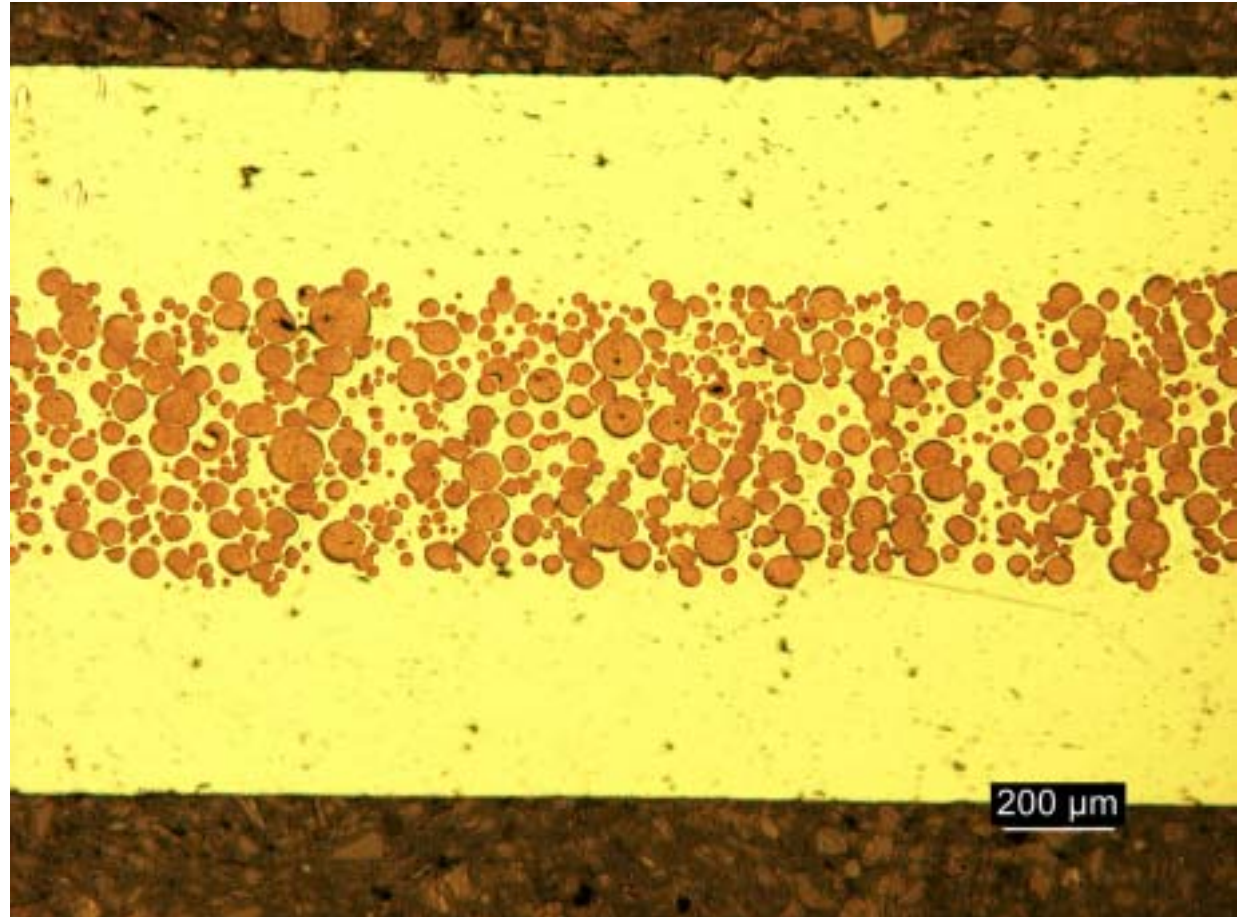
- irradiation stopped and fuel plates retrieved
- burnup of $\approx 33\%$ ^{235}U ($\approx 1.41 \cdot 10^{21}$ fissions/cm³)
- Post-irradiation campaign : samples from irradiated and unirradiated fuel plates

Unirradiated sample: Optical Microscopy

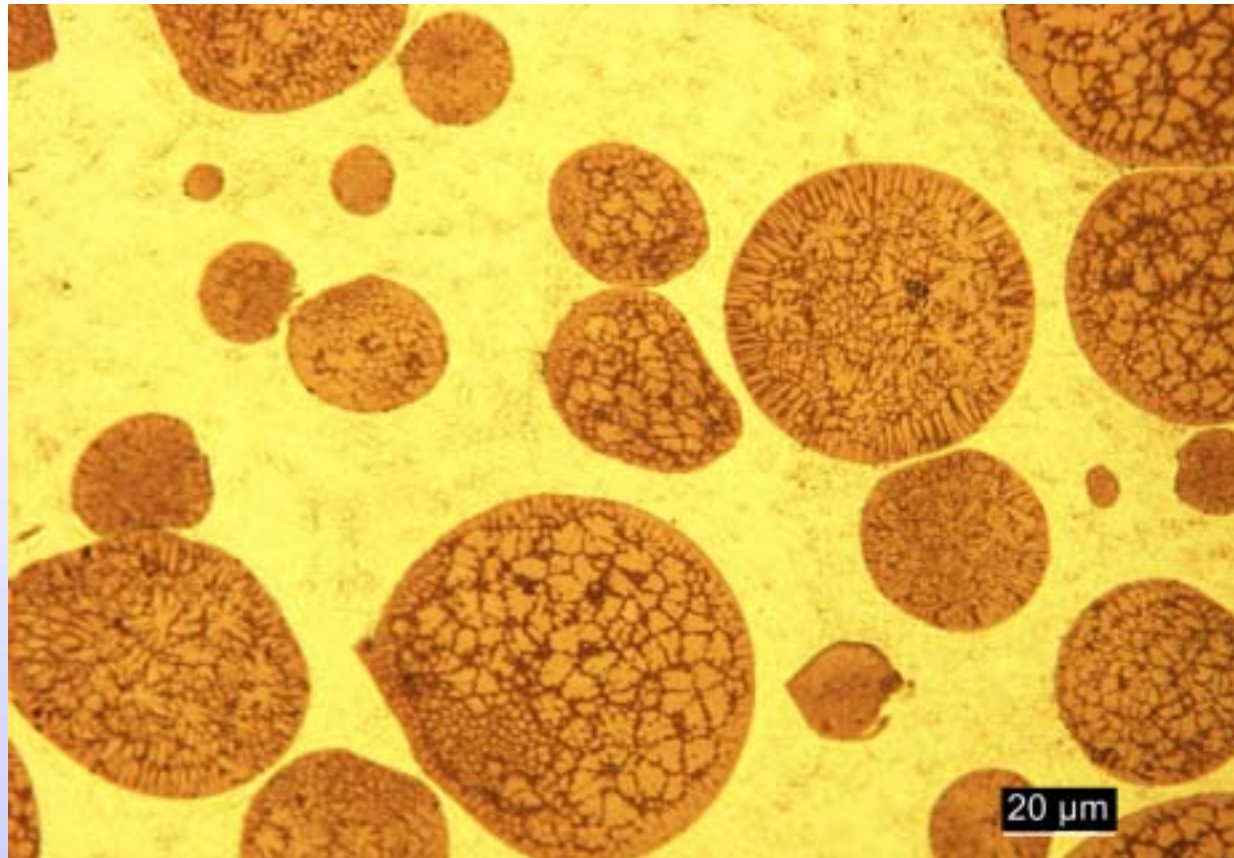
cladding →

meat →

cladding →

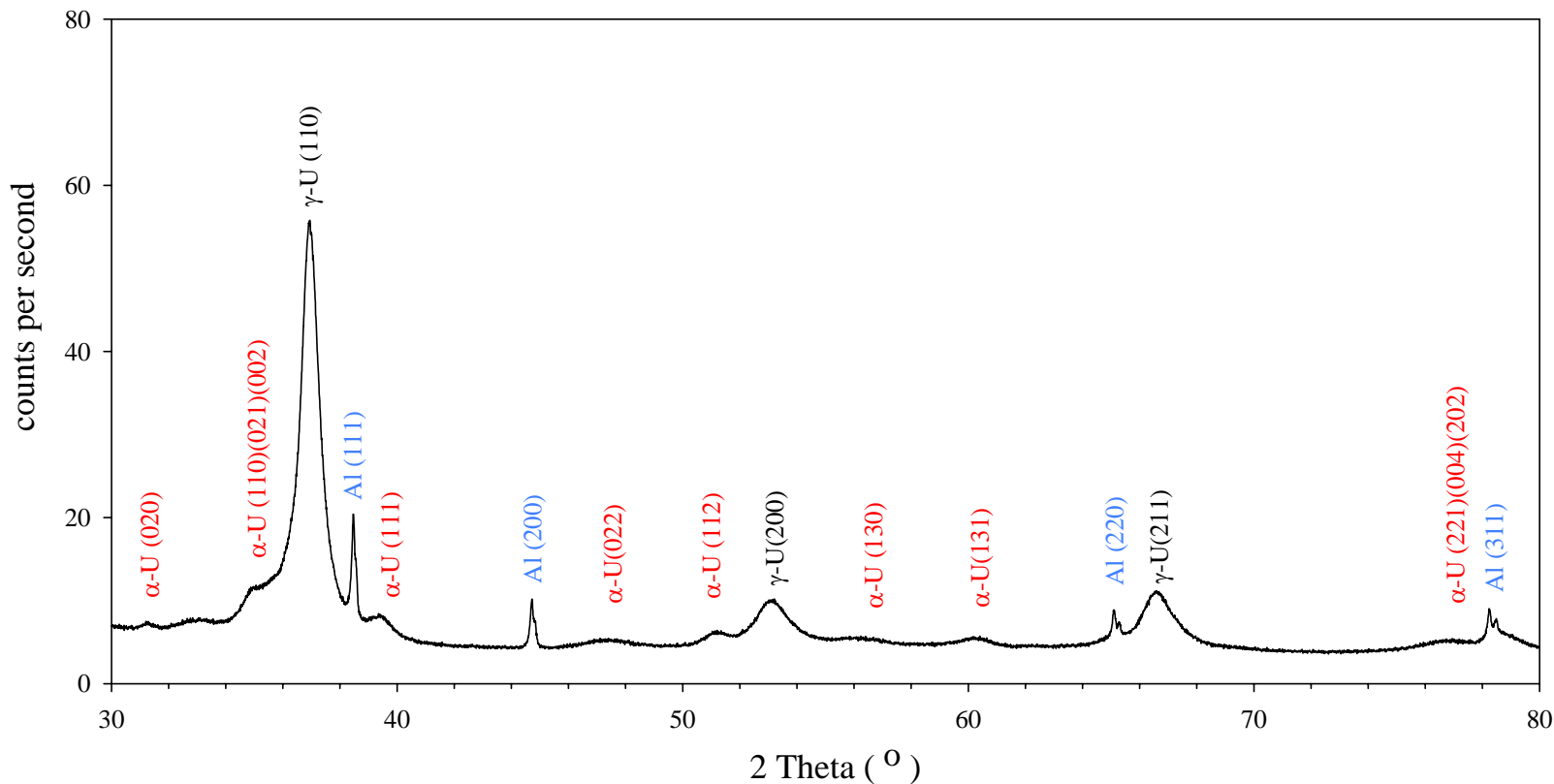


Unirradiated sample: OM in as polished condition



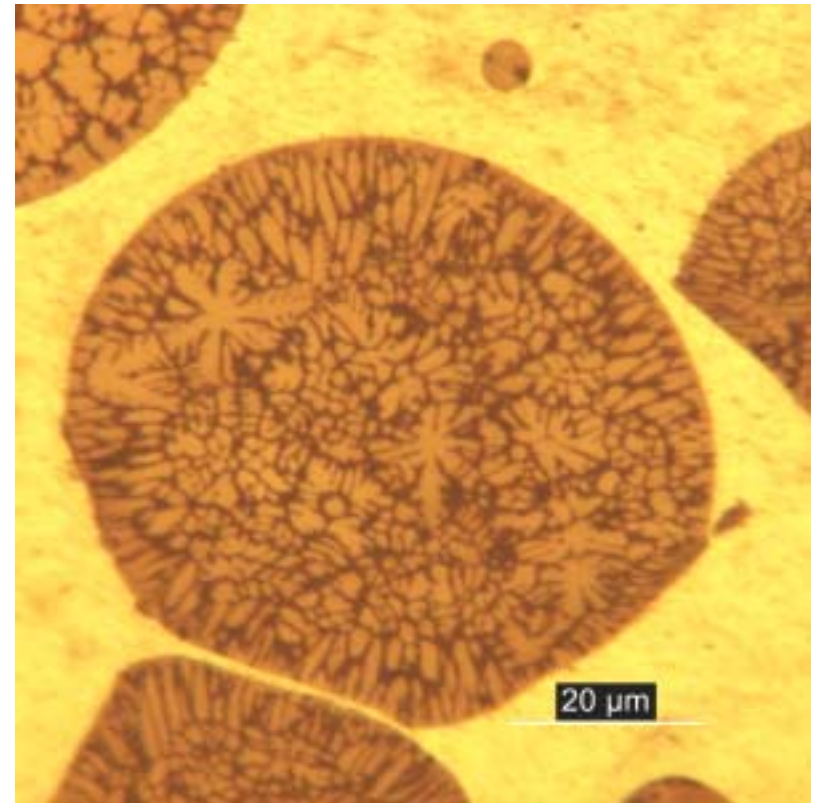
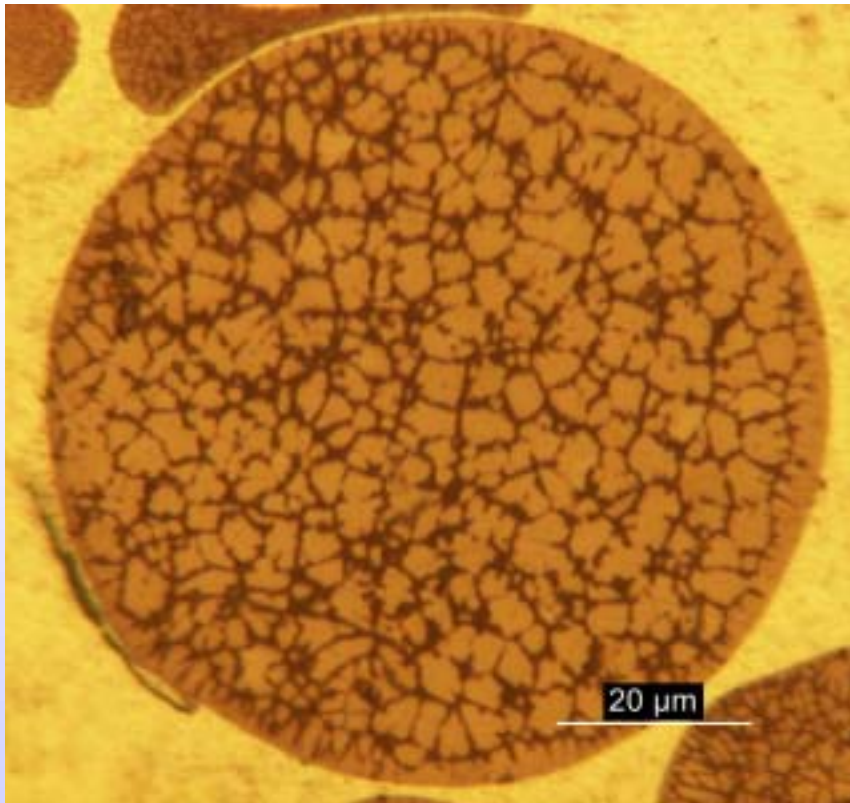
Spherical particles with a cellular structure due to rapid solidification during the atomization process.

Unirradiated sample X : X-ray diffraction



XRD pattern \rightarrow $\alpha\text{-U}$ in addition to $\gamma\text{-U}$
 \rightarrow Al of cladding/matrix

Unirradiated sample: OM in as polished condition

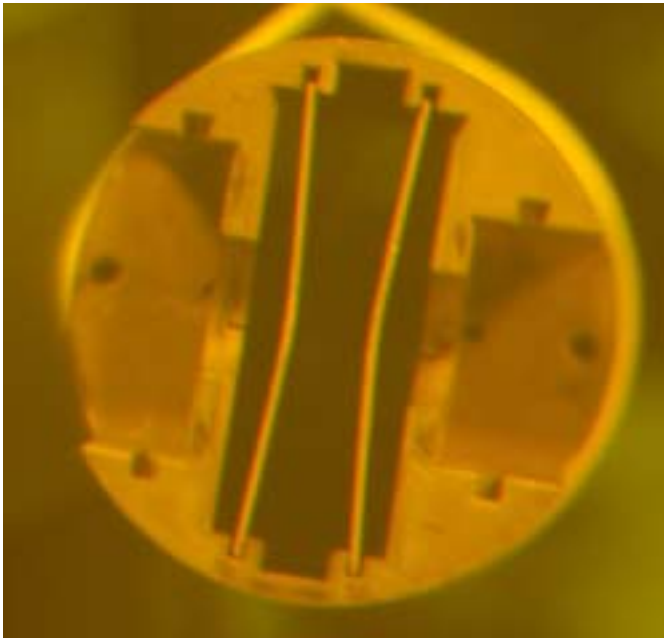


Literature : Cell boundary is depleted in Mo

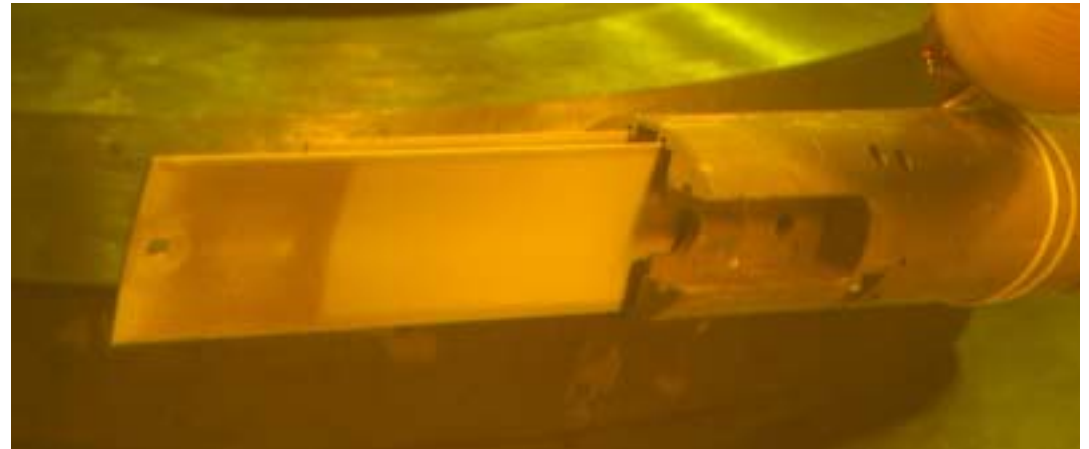
→ α -U on cell boundary

Irradiated fuel plates

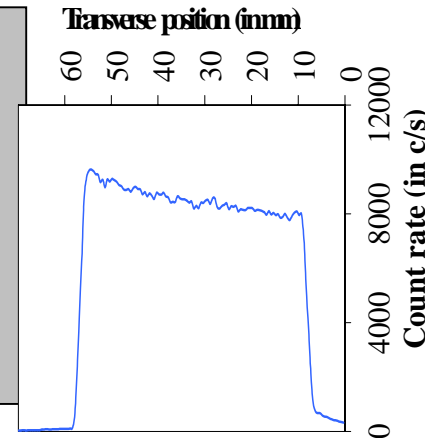
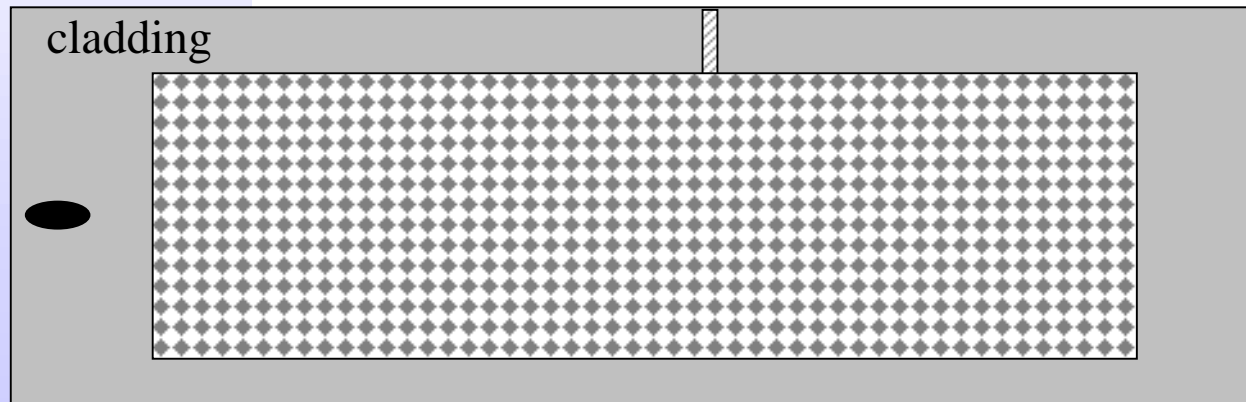
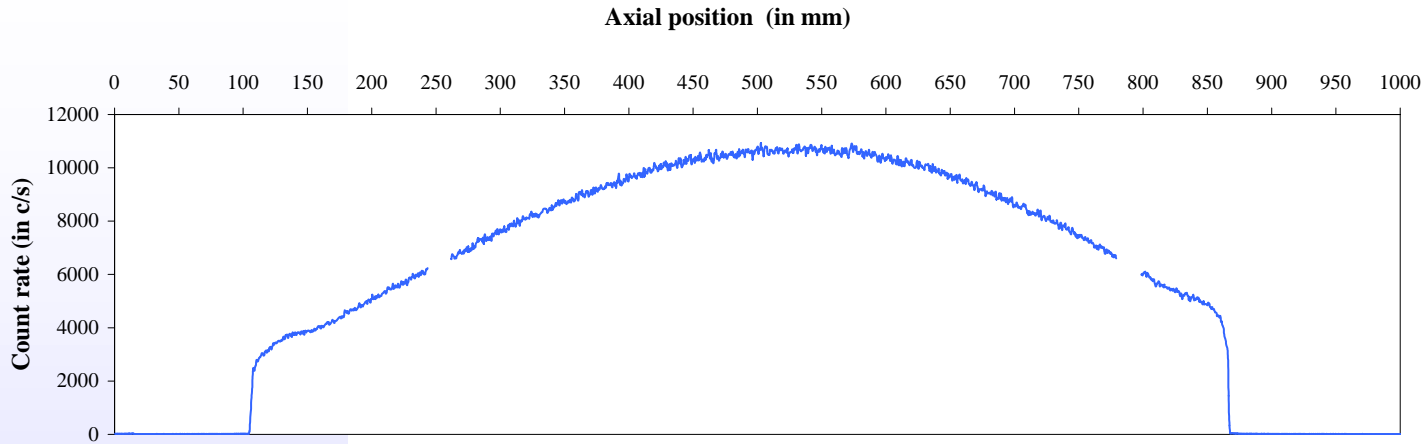
FUTURE irradiation rig

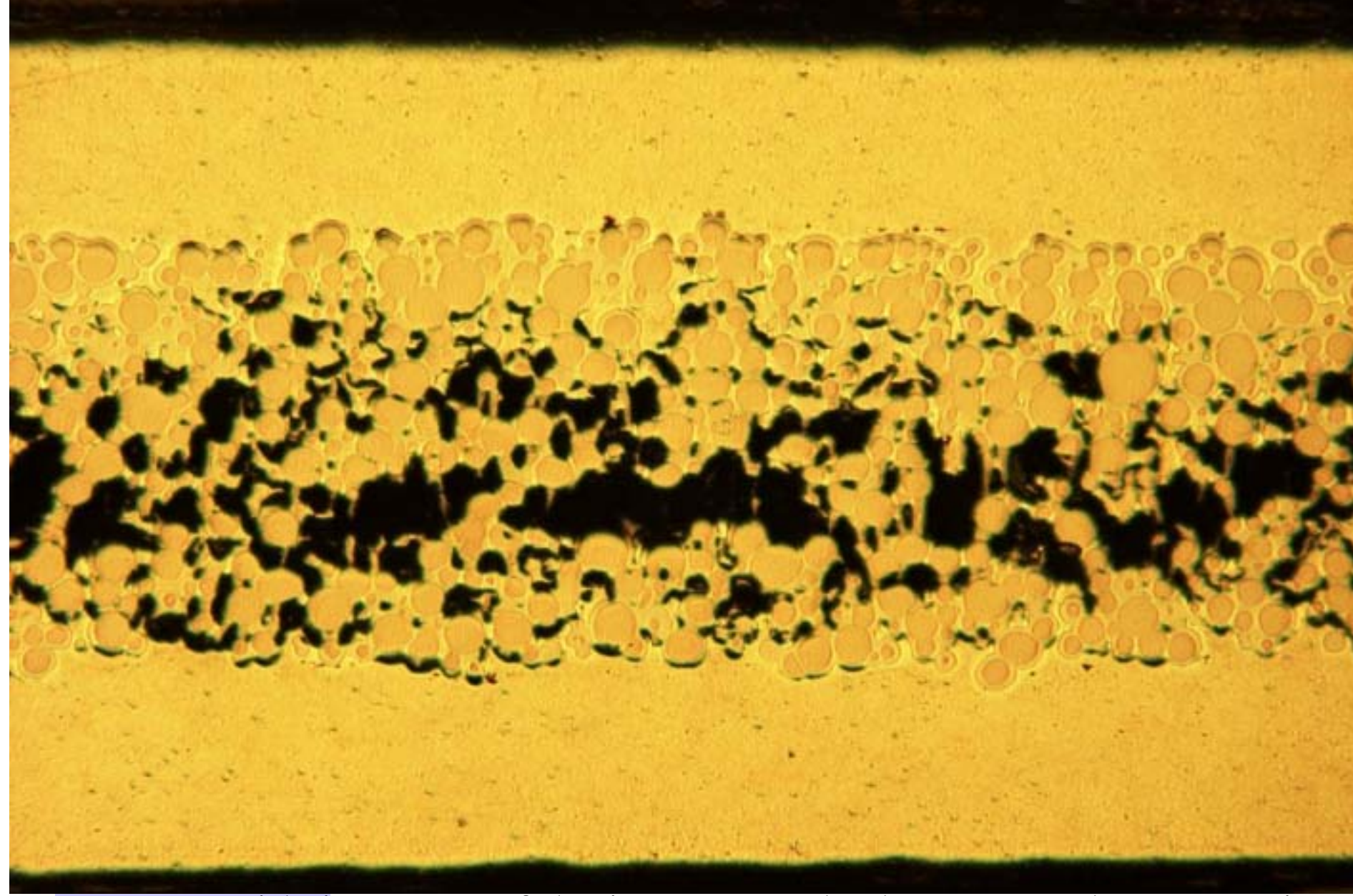


Flat plate configuration



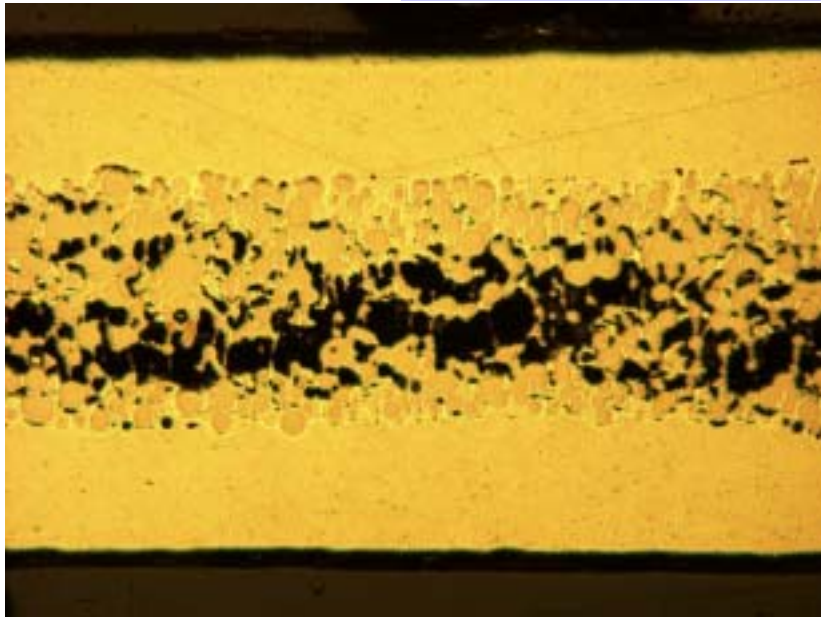
Cutting scheme



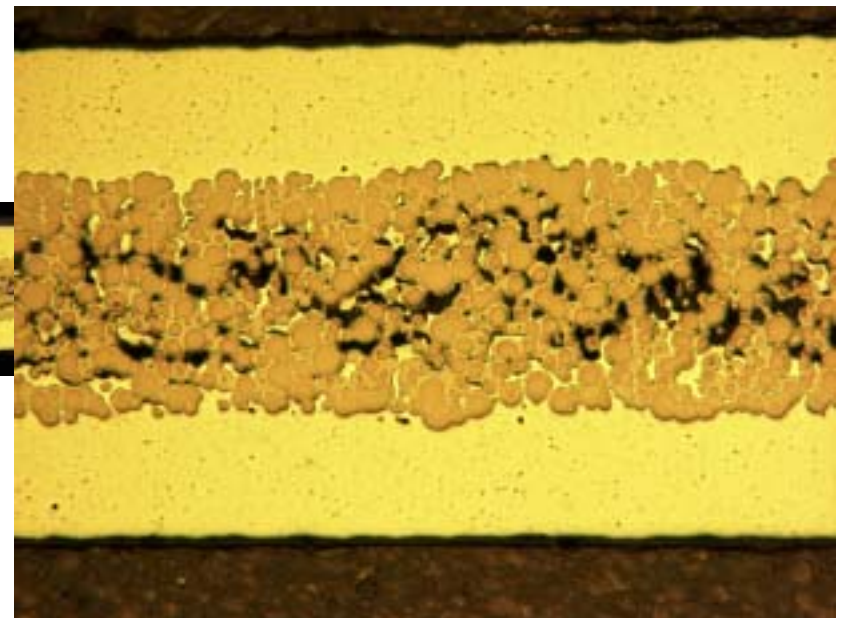
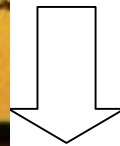


- Large voids in center of the image mostly due to sample preparation
→ weakening of meat cohesion

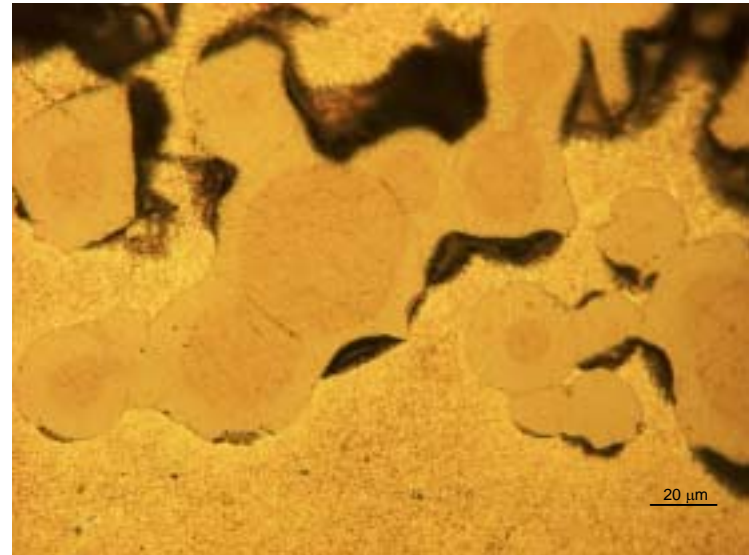
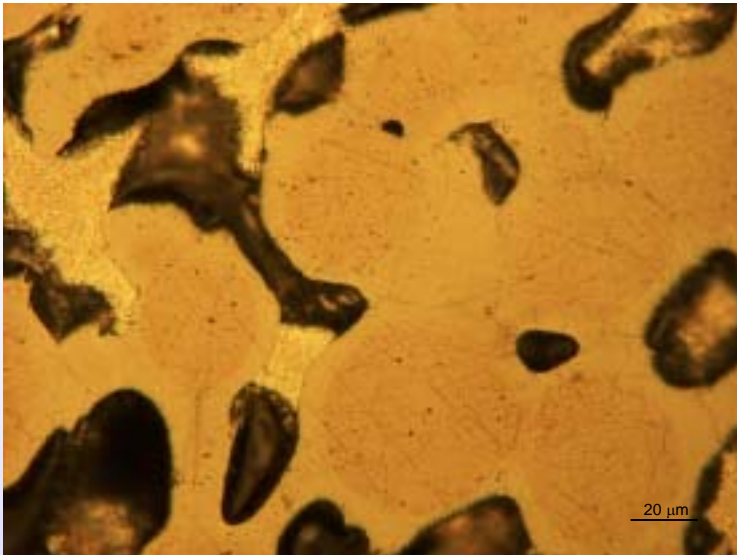
Irradiated sample : Optical Microscopy



Impregnate + polishing



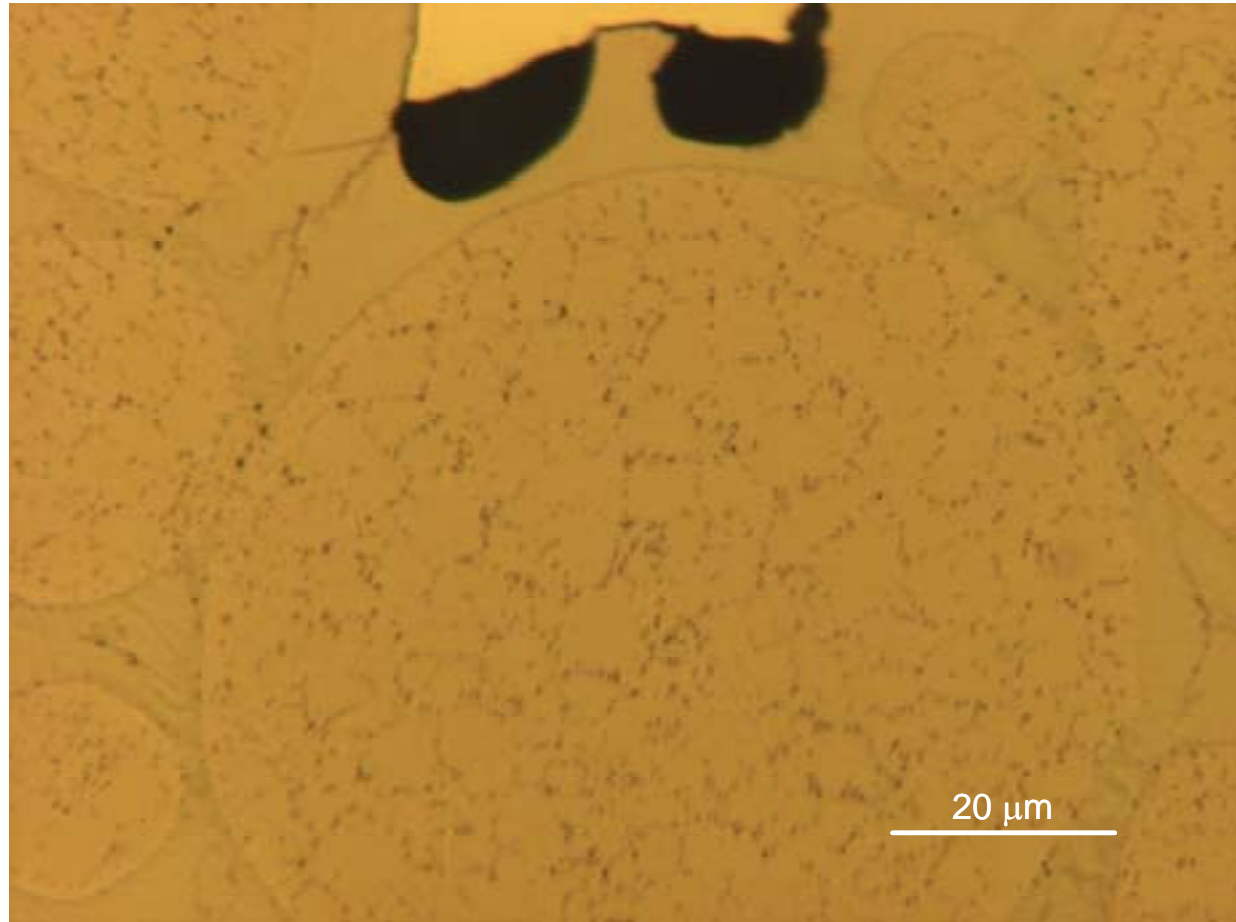
Irradiated sample : OM in as polished condition



Formation of

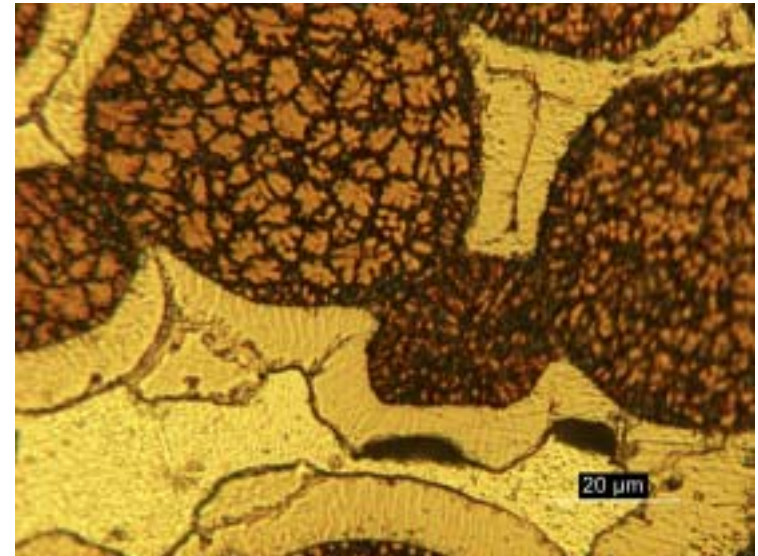
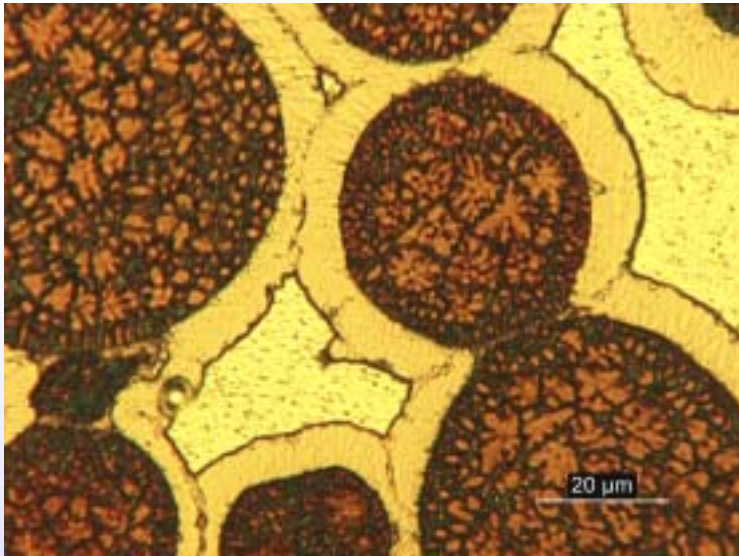
- an interaction layer
- voids at interface interaction layer/matrix
(Kirkendall effect or fission gas related?)

Irradiated sample : OM in as polished condition



Fission gas related bubbles at the cell boundaries

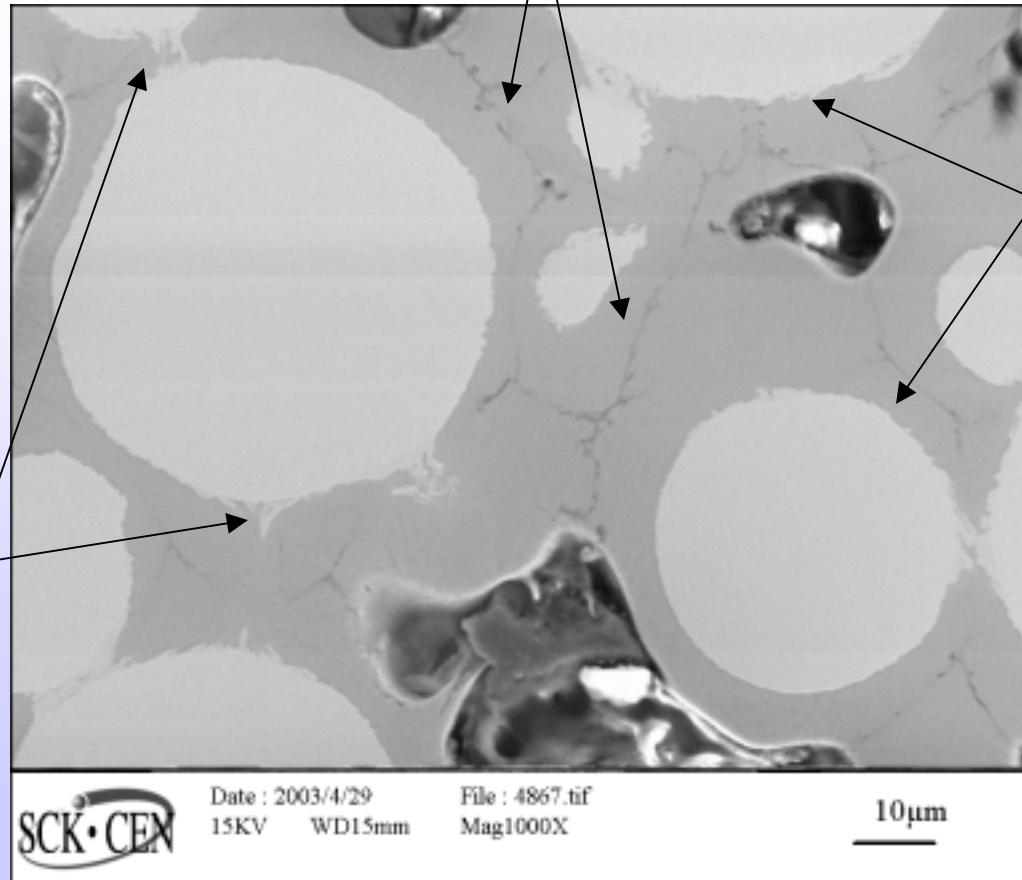
Irradiated sample : OM in etched condition



- Cellular structure of the UMo fuel particles
- Interaction layer has structure of long elongated grains
- Former interface interaction layer – matrix visible

Irradiated sample: Scanning Electron Microscopy

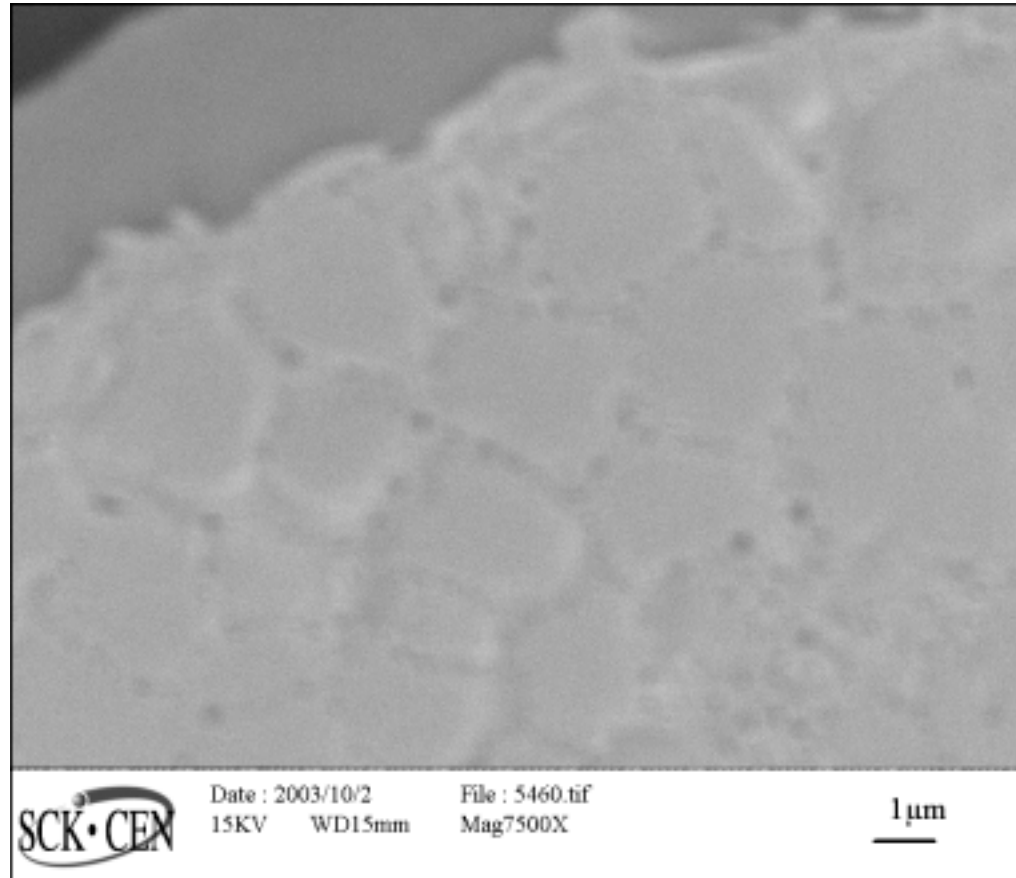
Clear contrast of interaction layer edge



Jagged edge
of the
UMo particle

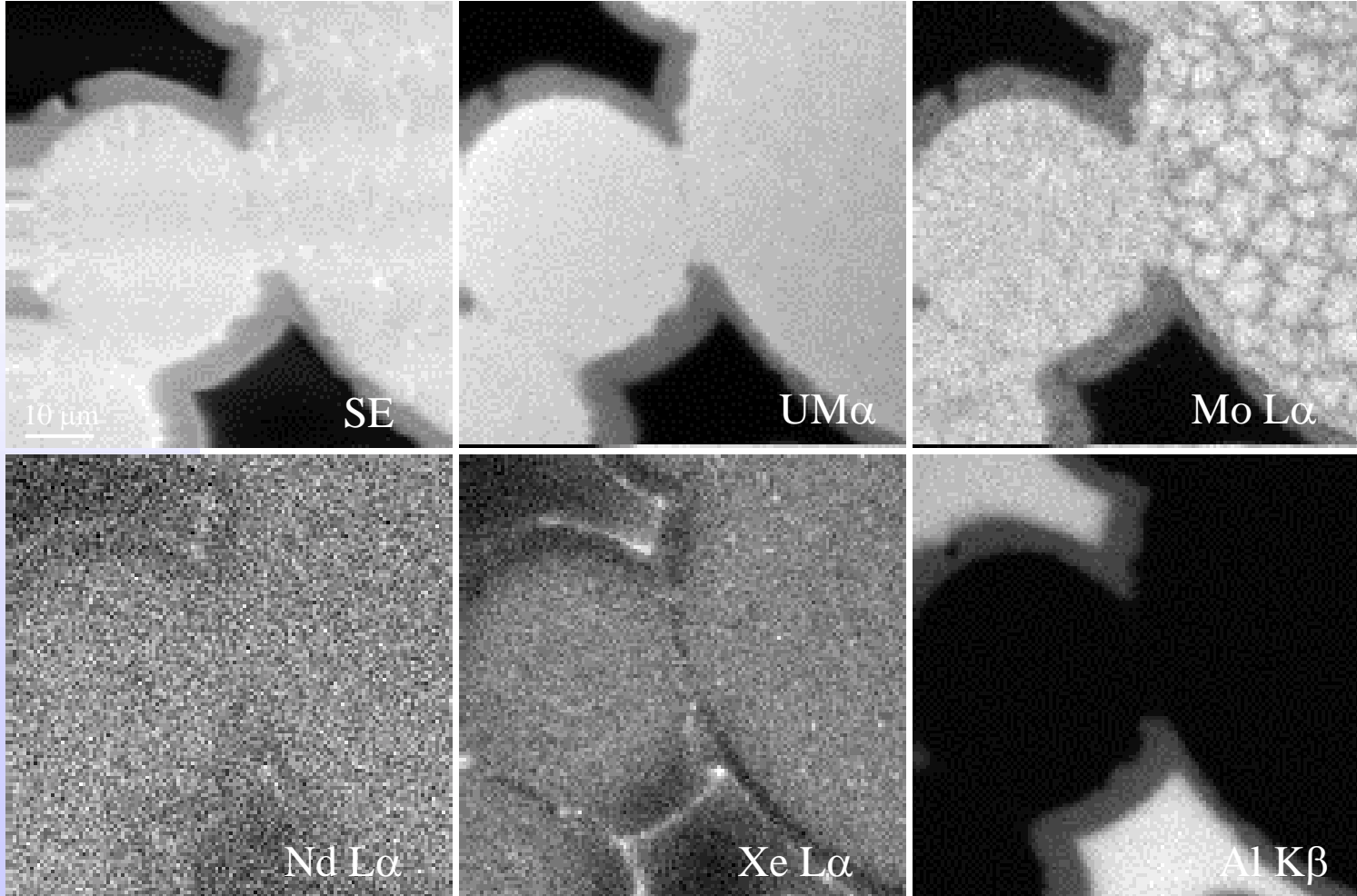
“Plastic”
deformation

Irradiated sample: Scanning Electron Microscopy

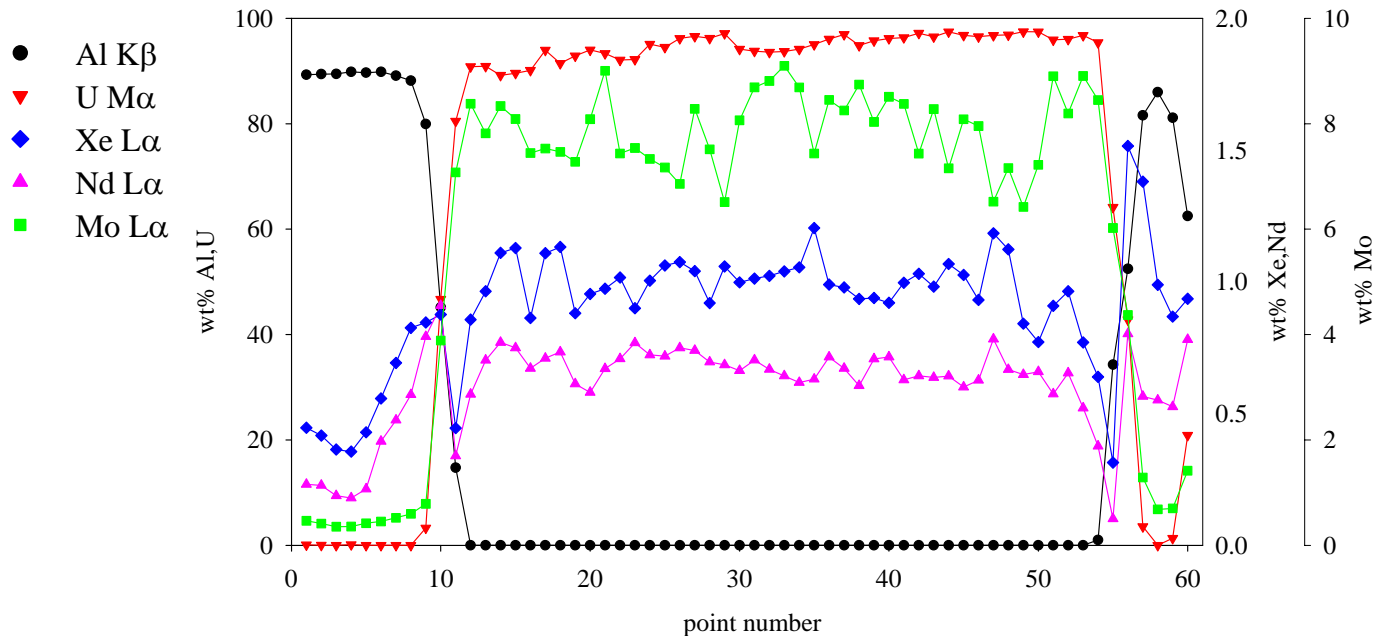
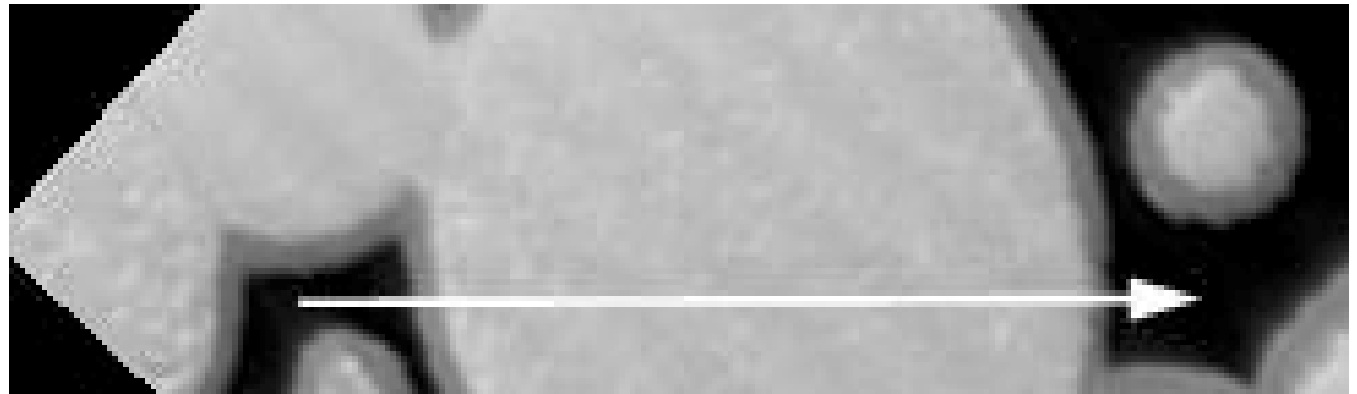


Fission gas related bubbles at the cell boundaries

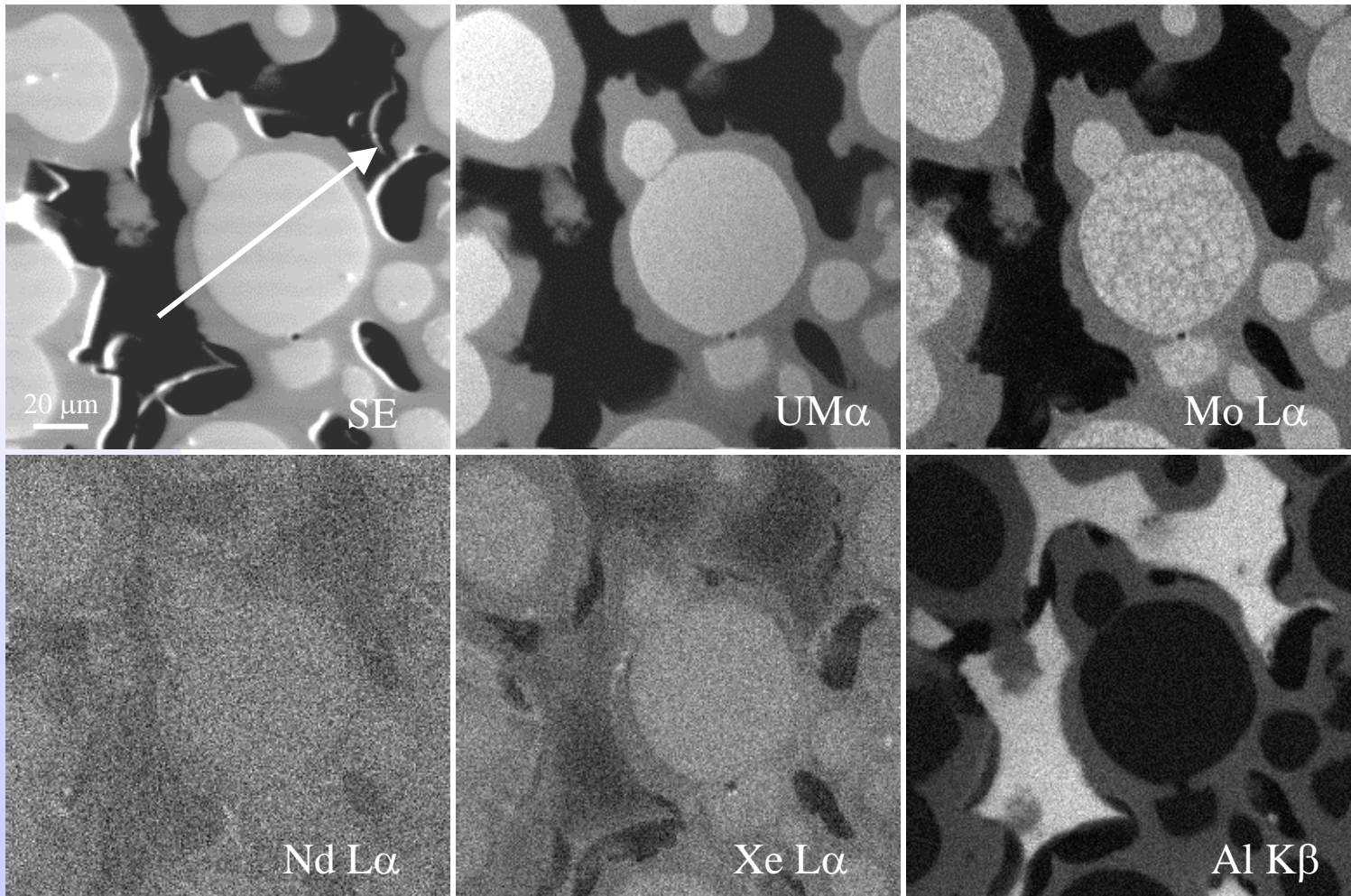
Irradiated sample: ElectronProbe MicroAnalysis



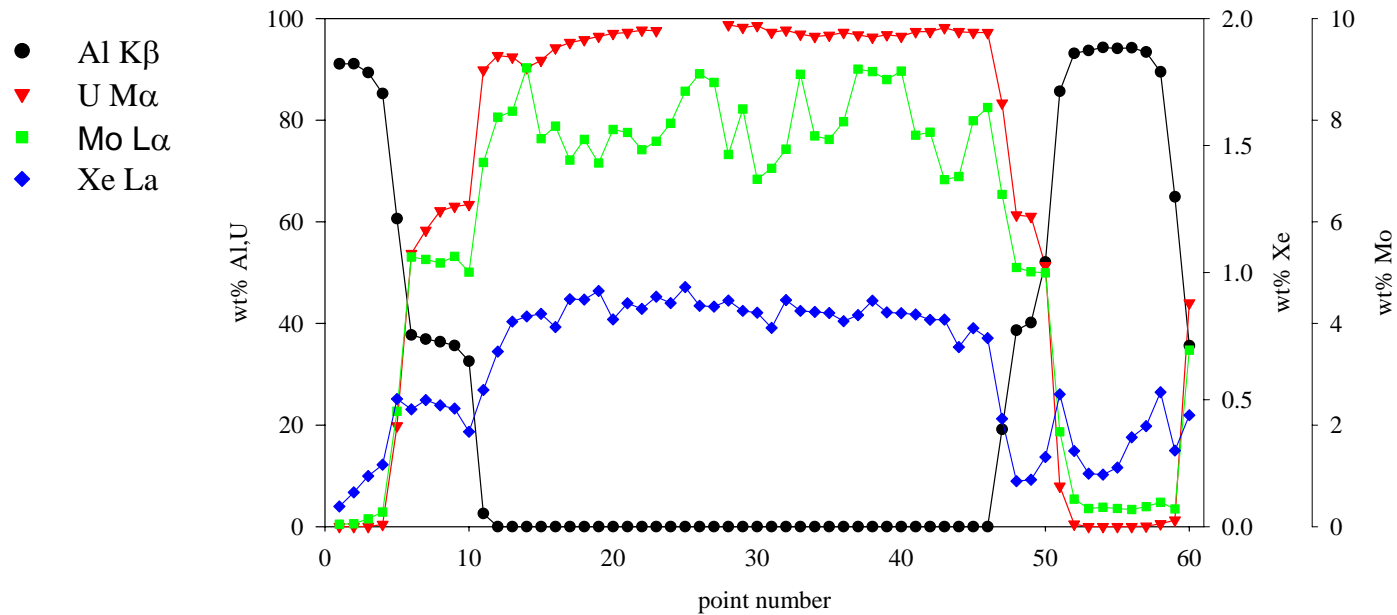
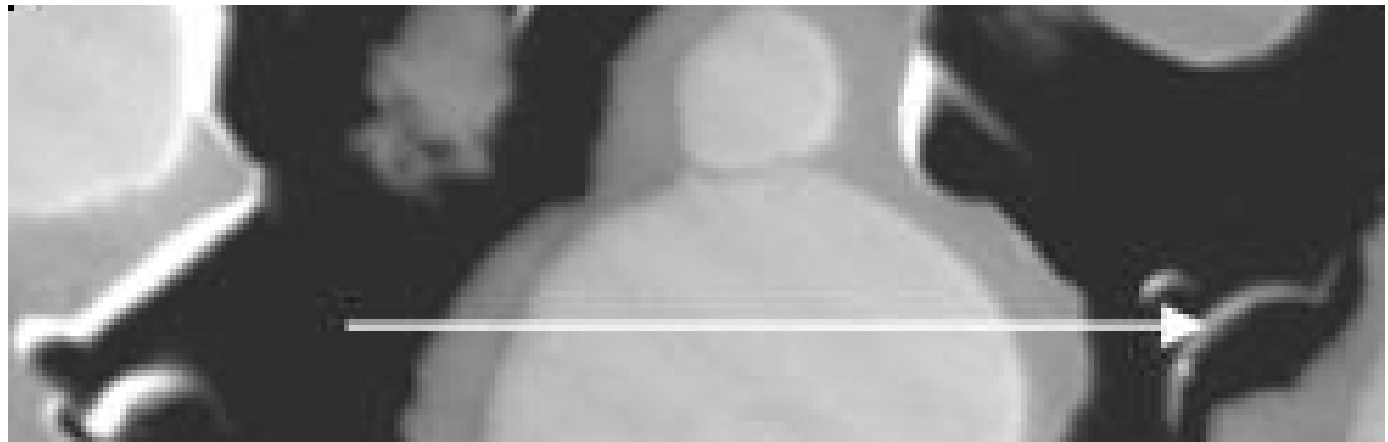
Irradiated sample: EPMA : semi-quantitative linescan



Irradiated sample: ElectronProbe MicroAnalysis



Irradiated sample: EPMA : semi-quantitative linescan



U-Mo-Al interaction layer

Future - BR2:



Iris - OSIRIS:



U-7wt%Mo

Atomized powder

Heat flux : 340 W/cm³

Cladding temperature : <130 °C

U-7wt%Mo

Ground powder

Heat flux : 136 W/cm³

Cladding temperature : <75 °C

Fuel plate behavior

Cladding : intact, formation of oxide layer

Meat : increase in fuel meat thickness

- Formation of interaction layer
- Formation of voids

Fission gas related

Kirkendall

⇒ Decohesion of the fuel meat

+
thermo-mechanical stress

(flat plate configuration)



Observed pillowing of the fuel plate