Nuclear research and data processing

Ondřej Srba

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Research Centre Řež

- R&D organization focusing on development of technologies and technical support for power generation industry
- Since 2002/1955
- 370 employes

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CVŘ Company activities

The vision of the company

to be a leading research and development organization in energy research, playing an important role in international research community and ensuring continuity in nuclear technologies knowledge in the Czech Republic

- Services for safe and long-term operation of energy technologies
- Support for the operation of current nuclear units
- Research and development in the field of GEN IV and small modular reactors
- Processing and storage of hazardous waste
- Microstructural and microchemical analyzes
- Advanced chemical and analytical methods
- Development of new NDT methods and robotic manipulators
- Basic and advanced materials research
- Design and system diagnostics
- Evaluation of condition and qualification of components
- Reactor irradiation services
- Design, construction, manufacture
- Hydrogen and fusion technologies
- Modern technologies for energy storage
- Publishing activities in the field of nuclear energy
- Training and education

R&D background

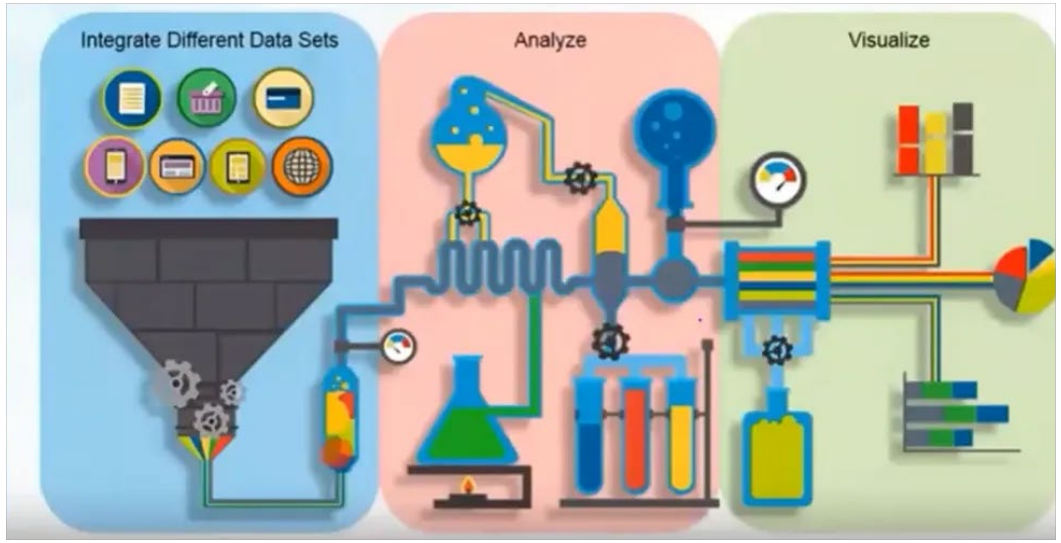
Two research reactors, set of experimental loops, microstructural and microchemical laboratories, NDE laboratory, neutron-physical and thermo-technical computation codes capabilities, design department, workshops and machinery park makes us able to participate in sophisticated research projects supporting current generation of power plants and participate in the development of new technologies for GEN IV, SMRs and the fusion.




The company has developed broad-ranging relations with Czech, foreign and international organisations and participates in many projects togehther with companies, organizations and institutes from EU, USA, Japan etc.

Why using data processing in nuclear research

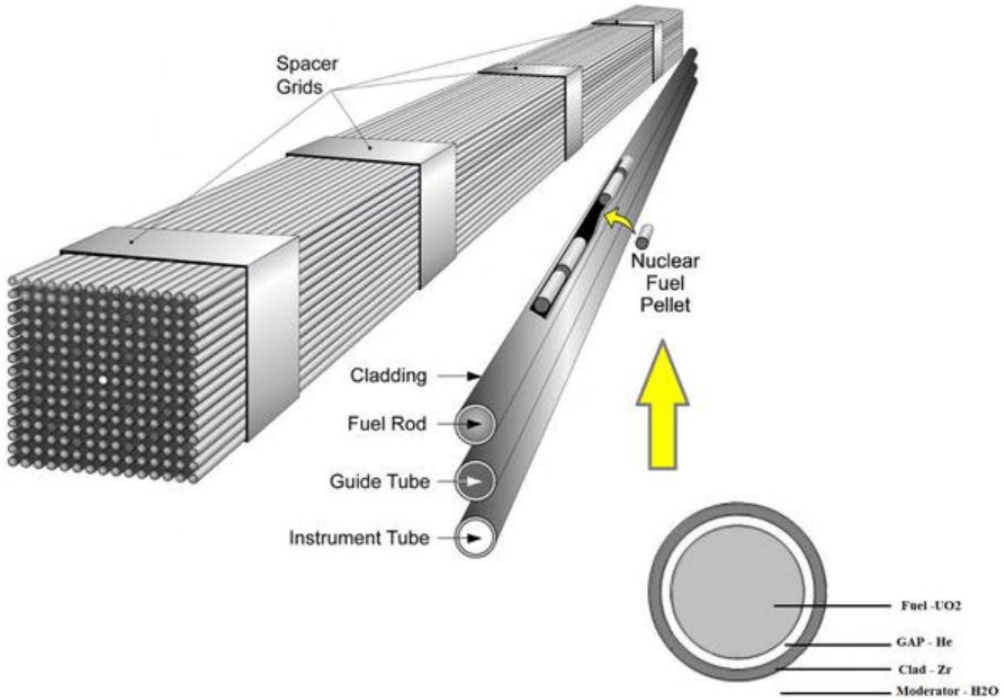
- Fast – time and money saving
- Allowed to process huge amount of data
- If debugged less errors then researcher
- Help you to get visualisation for easier and better understanding



What is data processing?.

Testing of cladding of nuclear fuel

- Fuel cladding is a part of nuclear fuel for nuclear power plant
- Why we are testing it?:
  - Performance under irradiation
  - Accident condition behaviour
  - Wet and dry storage of spent fuels
  - Missing data for simulation for safety analysis



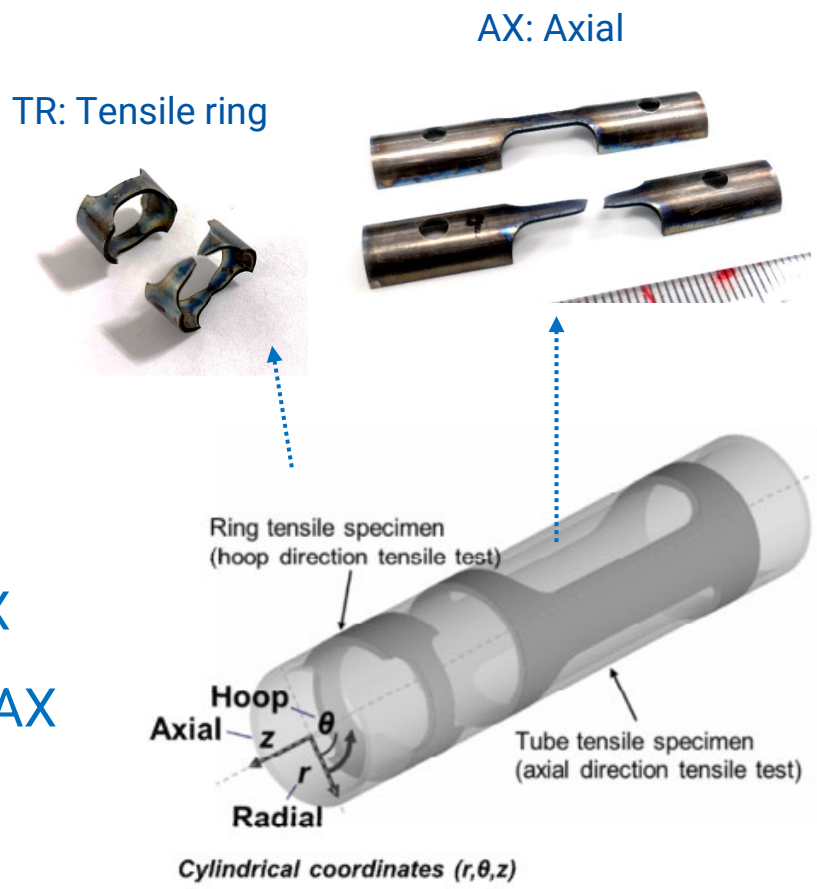
Methodologies for testing of fuel claddings

Non-deformed samples

- TEM analysis – microstructure, radiation-induced damage
- SEM-EBSD analysis – grain size, texture, misorientation

Deformed samples (tensile " rings")

- TR and AX samples till 10% F_{max}, 350 °C, de/dt = 0,002 s^{-1}
- Sample preparation in hot-cell and glove boxes
- TEM analysis – microstructure, deformation behavior - TR a AX
- SEM-EBSD analysis – grain size, texture, misorientation - TR a AX



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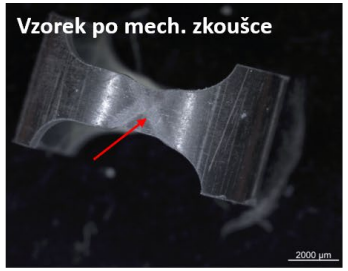
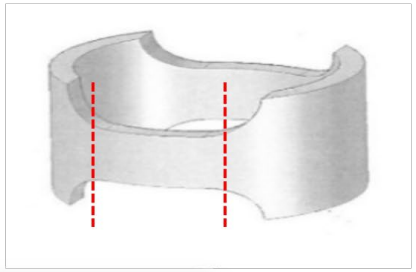
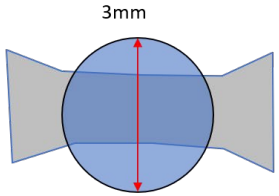
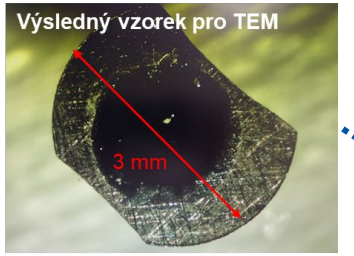
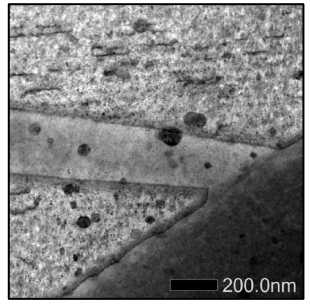
TEM sample preparation

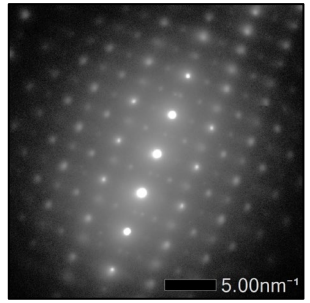


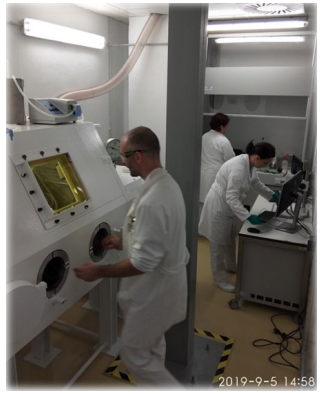


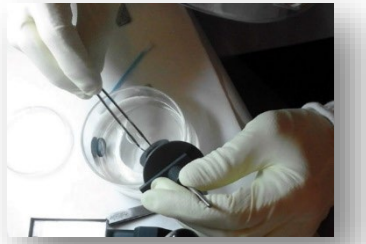












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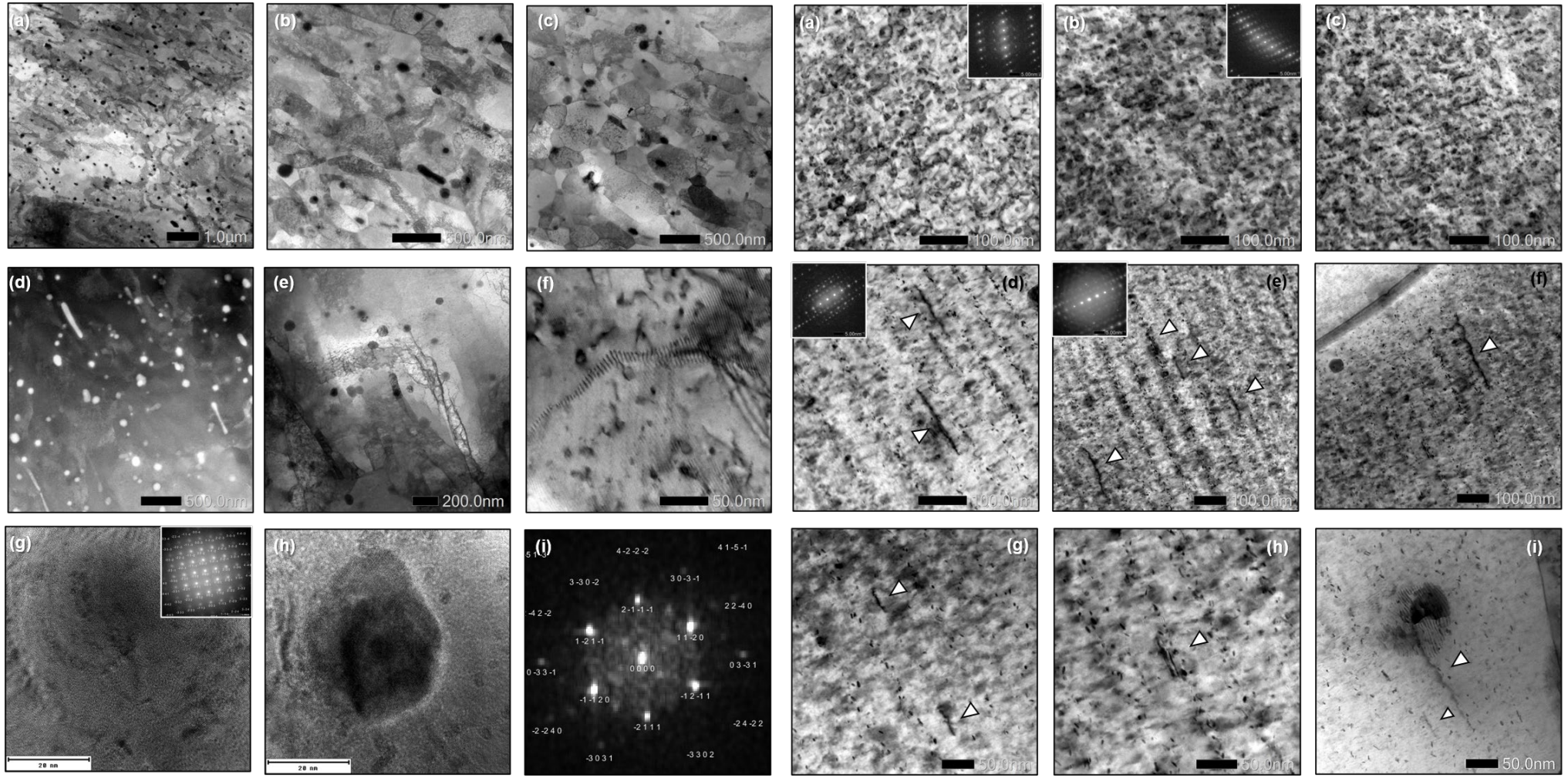
Microstructure of non-irradiated/irradiated samples:



Zr1Nb reference material

Zr1Nb after neutron irradiation to 1 cycle in VVER 1000 reactor

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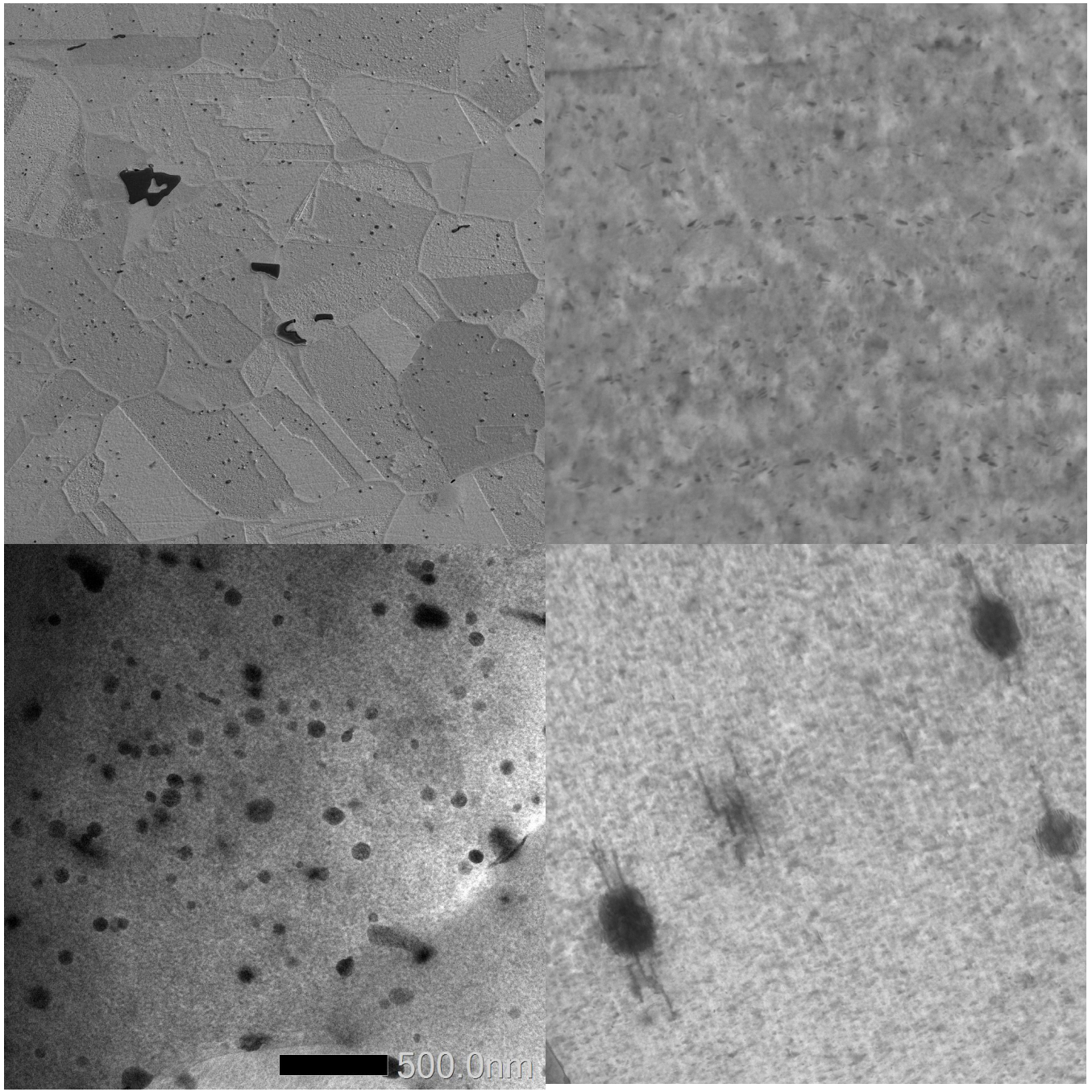
Datasets

Name	Dataset	Test Size
Delisa	33 (2 types)	6
ZrTem RIP	35	5
ZrTem SPP	40	10
C-Loops	23	6



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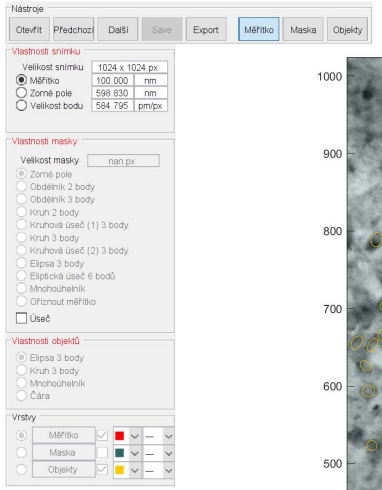
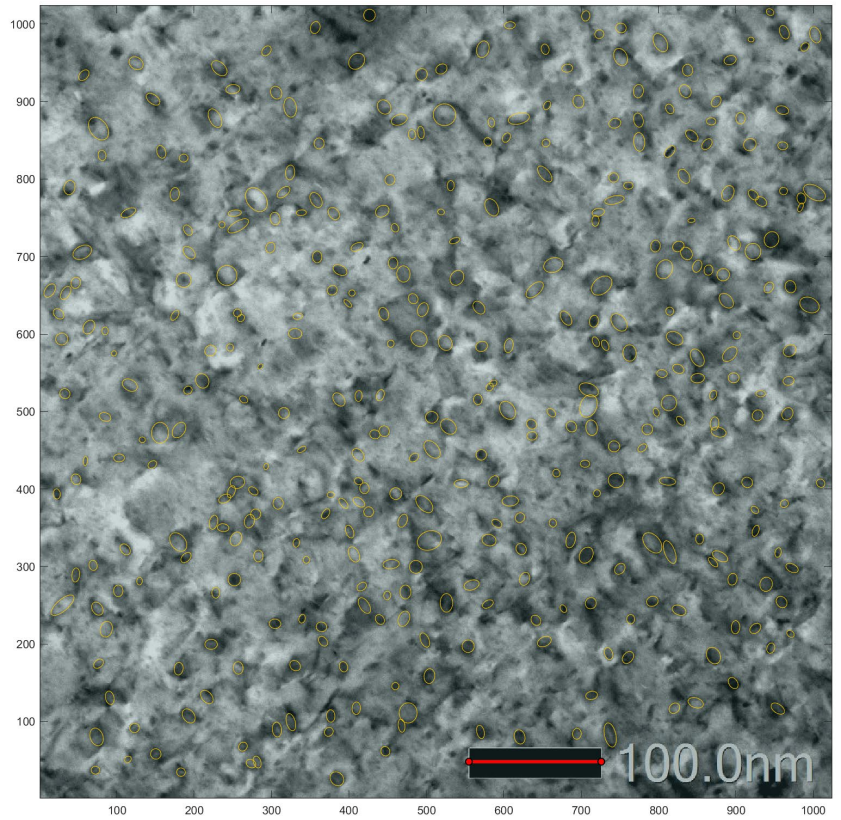
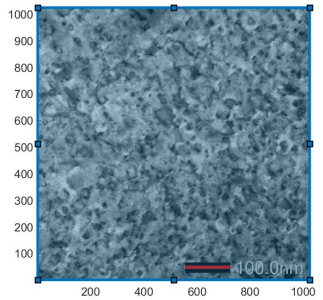
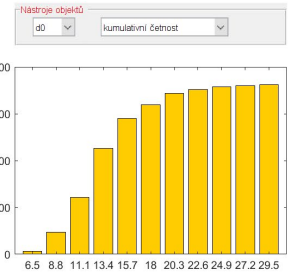
Precipitation localization









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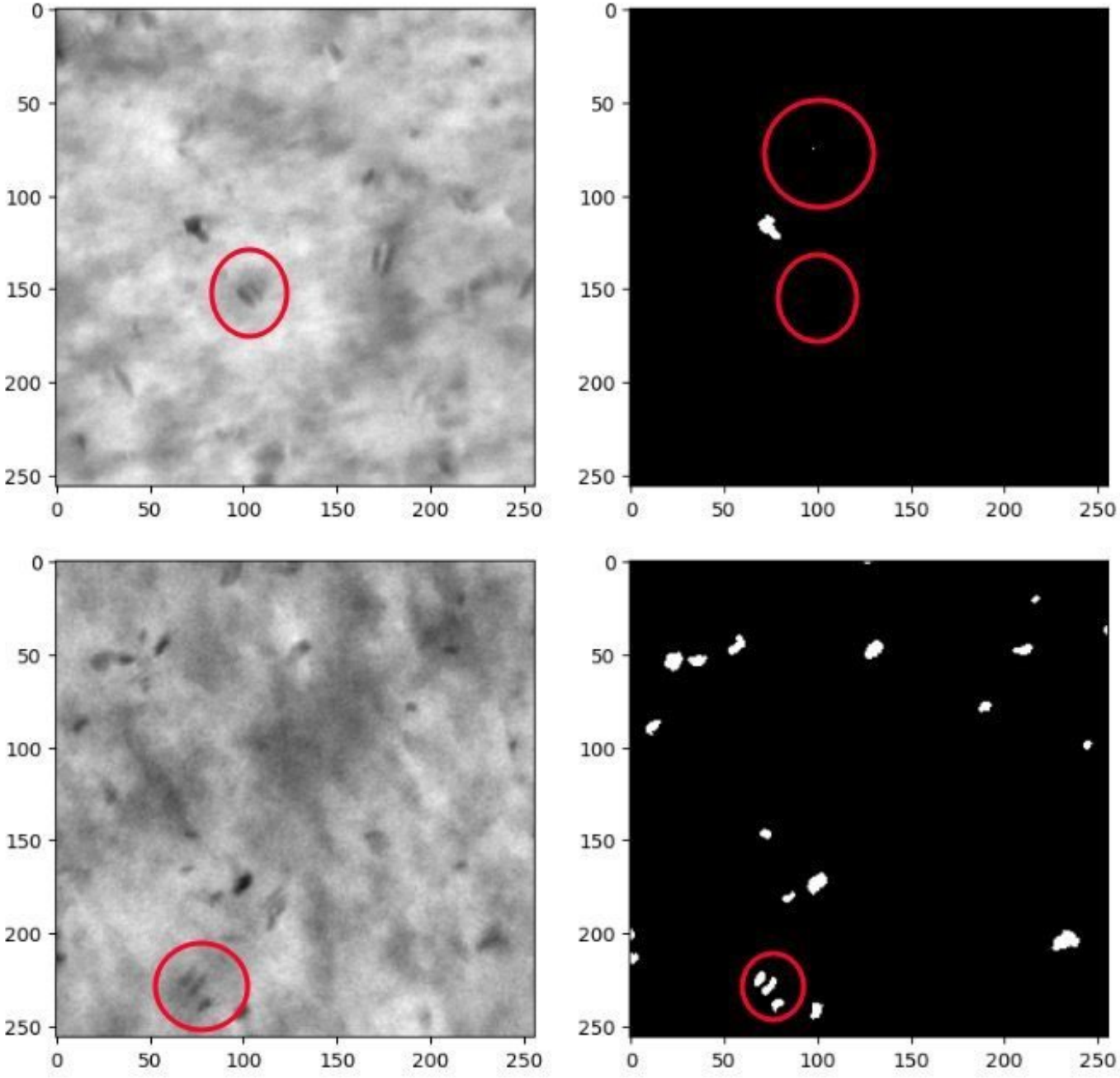
Zr TEM

Radiation induced precipitation



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Testing of Concrete and Aggregates

- Around the pressure vessel of a nuclear reactor are concrete retaining walls, which also hold the vessel. During the lifetime of NPP it is severely damaged by neutrons.

Why we are testing it?:

- It is one of the limitation of NPP lifetime.
- Could cause a problem for stability of pressure vessel
- Degradation is not visible until is too late
- During severe accident it is main bariare

Temelín NPP RPV placement

Radiation-induced damage in concrete/aggreggates

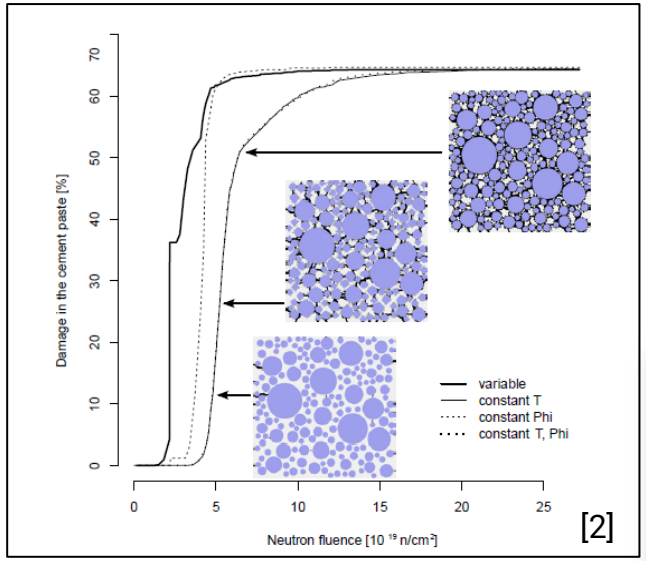
Gama irradiation

- Similar effects to heating/drying
- Radiolysis of water → shrinkage, formation of cracks
- Loss of strength and elasticity

Neutron irradiation

- Mainly affects aggregates
- **Radiation-induced volumetric expansion (RIVE)**, microstrains, lattice disorders and amorphization at high doses
- Due to the expansion of the aggregate – **crack initiation and growth**, **loss of strength**
- Activation of concrete by neutron radiation – problem at decommissioning

The compressive strength decreases because of fast neutrons (>0.1 MeV) above neutron fluence 1×10^{19} n/cm^2 and above dose 5×10^5 kGy/m^2 [1].



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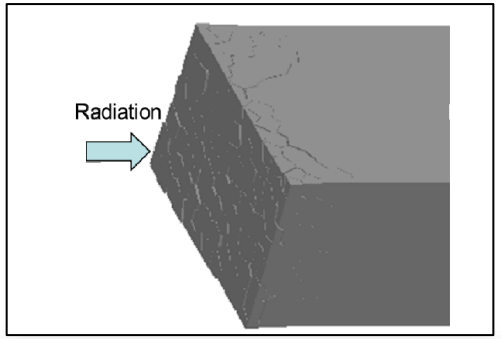
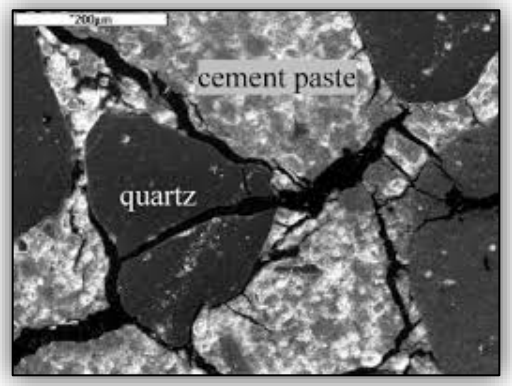




[13] Maruyama et al., 2016. Journal of Advanced Concrete Technology, vol. 14, 144-162.
[14] Le Pape et al., 2016. Journal of Advanced Concrete Technology, vol. 14, 70-86.

PIE in hot-cells

Irradiated concrete

Mechanical testing

- Ultrasonic measurements for determination of Young's modulus – homogeneity, macro and micro-cracks
- Compression test
- Pull-out test to determine concrete/steel cohesion

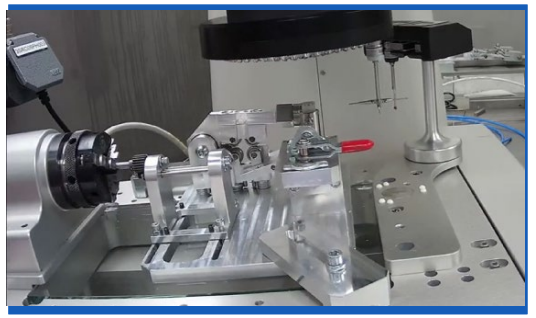
Irradiated aggreggates

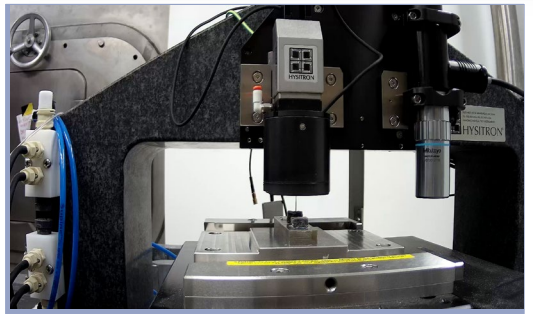
RIVE (Radiation Induced Volume Expansion)

- Precise documentation
- Density measurements by water/He-pycnometry
- Dimensional mesurements
- LOM/SEM analysis of thin samples
- Powder specimen preparation for XRD

Irradiated aggregates – methods Infrastructure CICRR Hot Cells

CICRR
Czech International Centre of Research Reactors

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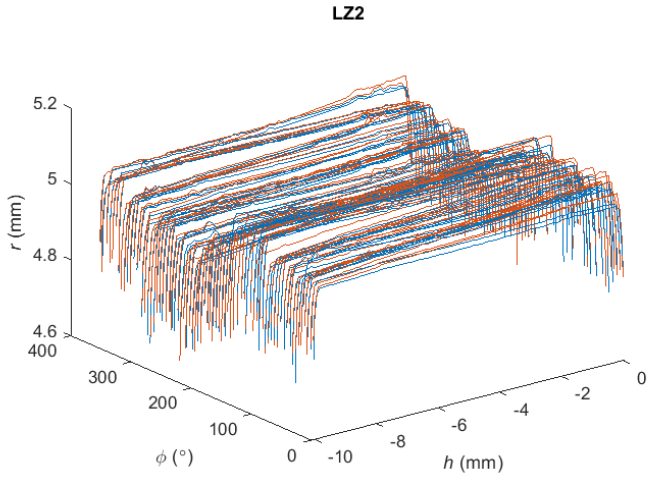
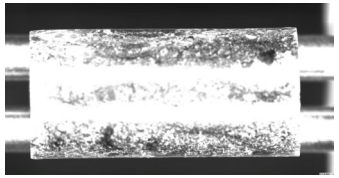
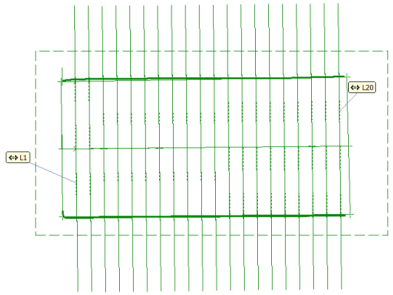
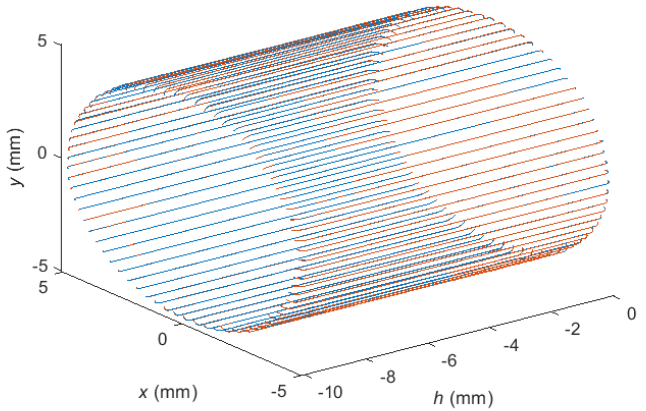
Experimental activity









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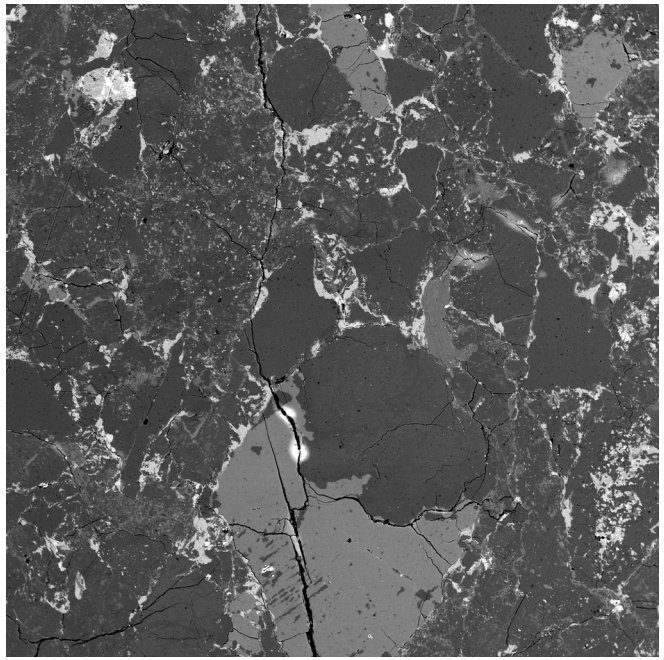
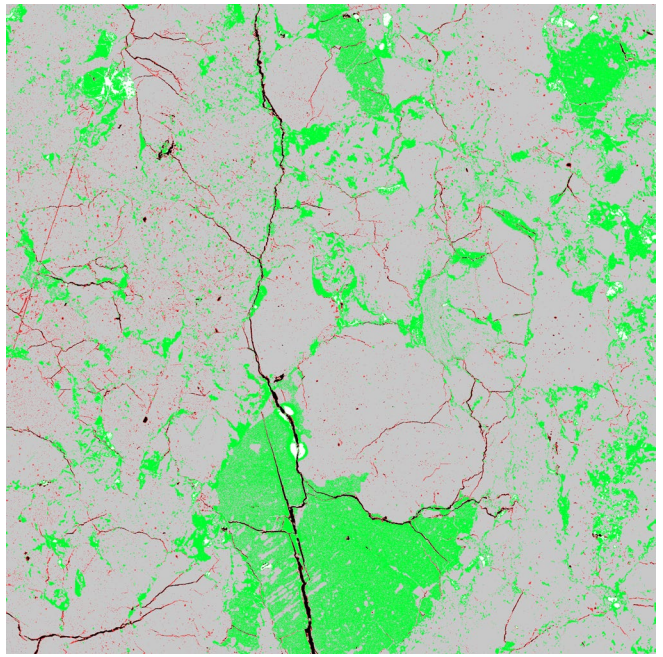
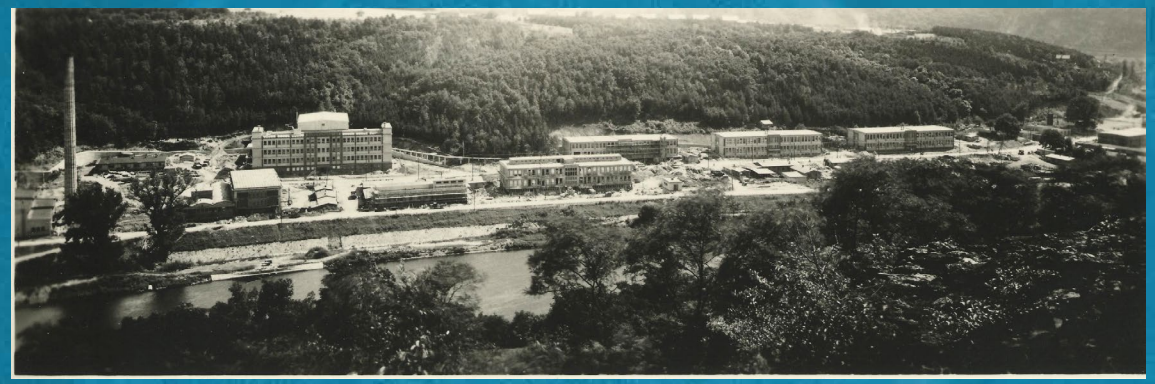
JCAMP concrete irradiation studies

Crack detection (Jan Blažek)

- Cracks are dark but not everything dark is a crack
- One-step filter results either in false positives or underestimated cracks
- Two-step filter is appropriately selective and sensitive
  - Medium-level threshold detects cracks-to-be-verified (red)
  - Low-level threshold detects pixels in crack for sure (black)







Thank you for your attention

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