The Applicability of Synchrotron X-ray Analyses for VHTR materials

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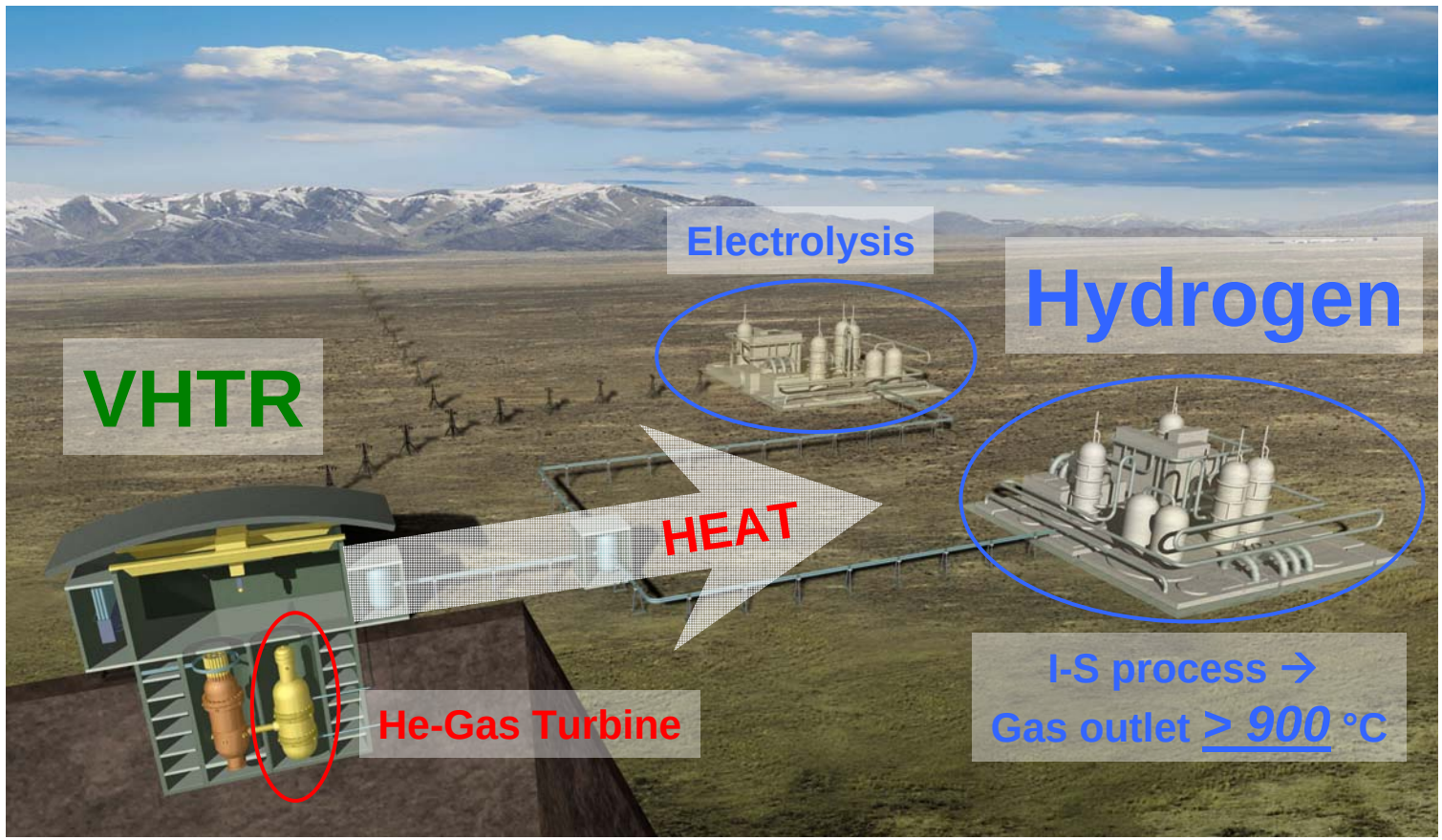
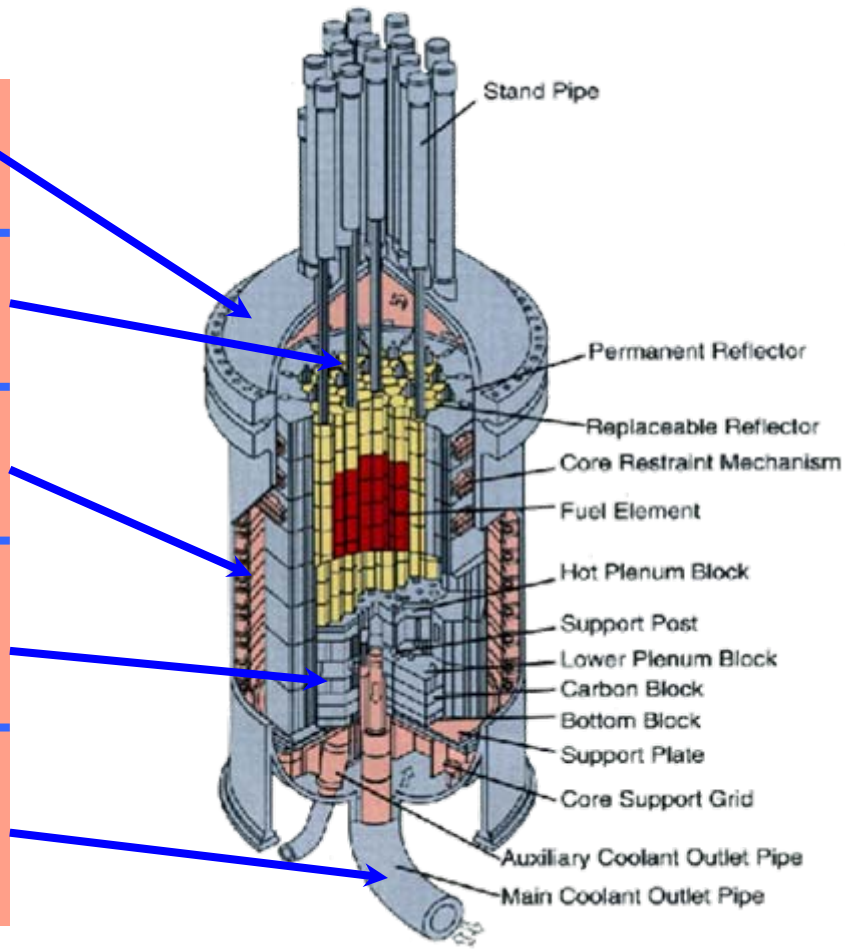
Combined cycle plant (electricity – hydrogen)

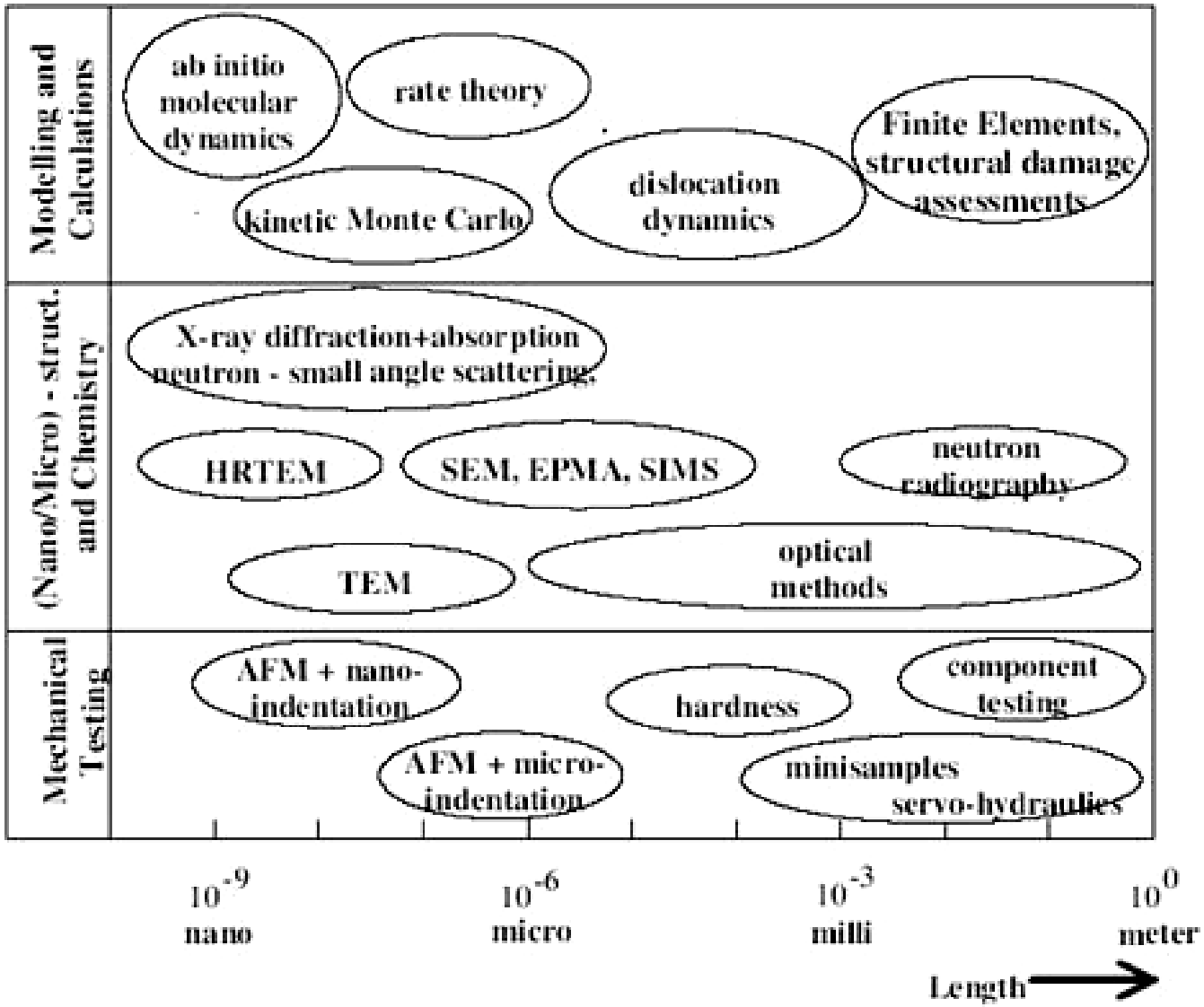


Possible Materials Selection (VHTR)

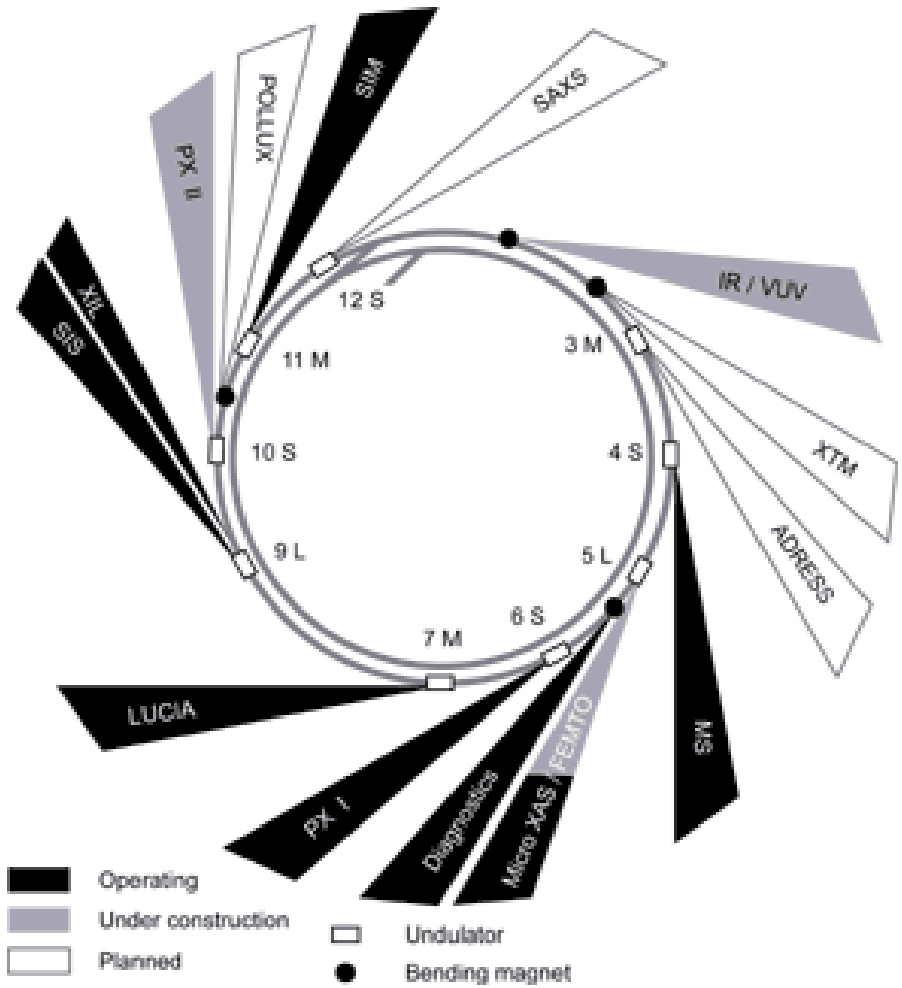
today	tomorrow
2¼ Cr-1 Mo	9-13 % Cr, superalloys
graphite	**C/C, SiC/C, SiC/SiC**
superalloys	**ODS, intermetallics**
graphite	**C/C, SiC/C, SiC/SiC**, ZrO_2 superplastic, Refractory alloys
Superalloys, austenites	**ODS**, **intermetallics**, ZrO_2 coatings



Multi-scale approach for investigation of high temperature materials



SLS (Swiss Light Source) Facility



Speciality

- **High Quality**

(high brightness, small beam size, excellent resolutions of microscopy/spectroscopy)

- **High Flexibility**

(wide wavelength spectrum)

- **High Stability**

(building, temperature, diagnostic equipment, top-up injection, high-precision power supplies)

>> microXAS BEAMLINE

- **X-ray Beam:**
  - photon flux: → ~ 10^{12} photons/s on sample; max. flux density, min. source size, and max. brilliance
    → energy range: ~ **4.5 - 20 keV**
  - monochromator: → energy resolution **dE/E of ~10^{-4}**
  - focusing optics: → **1 x 1 μm^2** spatial resolution
    → focus adjustable to problem
- **Micro-Techniques:**
  - **X-ray fluorescence**
  - **X-ray absorption**
  - **X-ray diffraction**
- **Other Features**:
  - **Active Samples**
  - **Time Resolved Studies (e.g., pump and probe techniques)**
  - **Experimental Station** → **modular** concept for different (non-standard) applications
    → **controlled sample environment** (pressure, temp., etc.)
    → **state-of-the-art detectors** (speed, resolution, range, etc.)

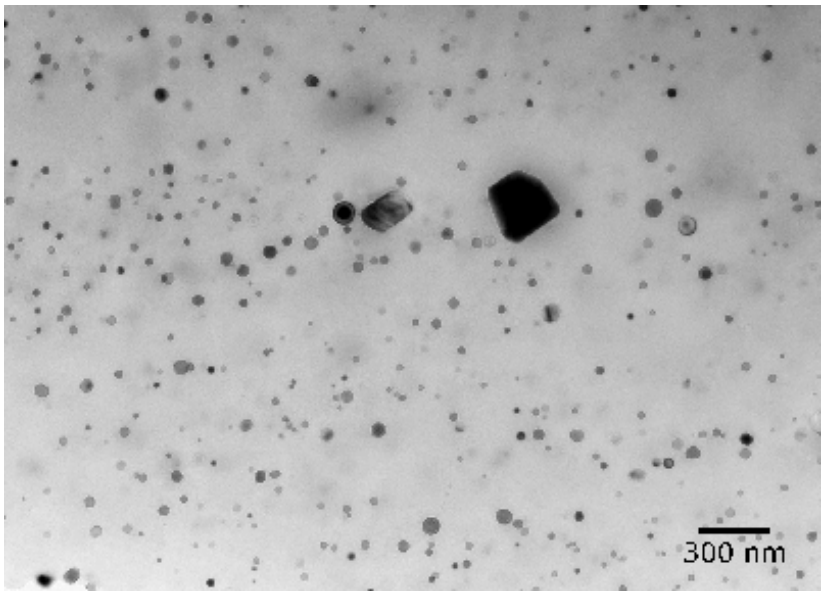
Main techniques:

- X-ray Diffraction (XRD, Micro-XRD, SAXS)
- X-ray Absorption (EXAFS, XANES)
- X-ray Tomography

Main applications:

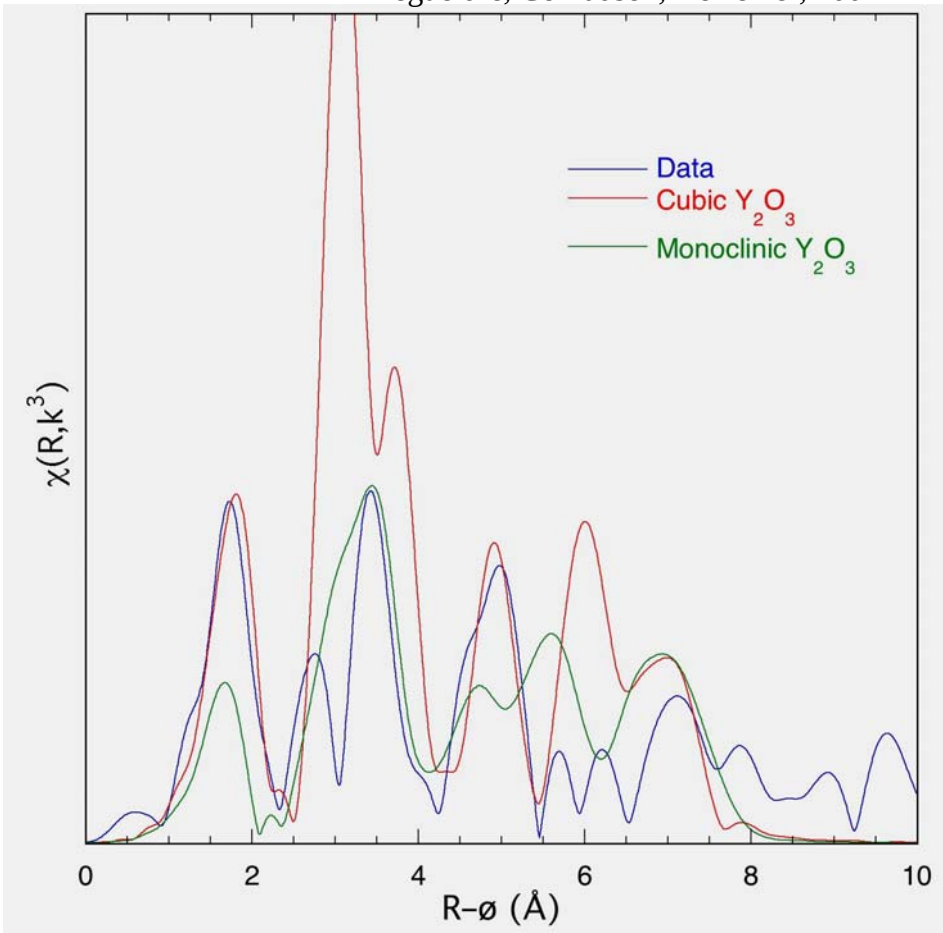
- Phase stability, layer formation, mechanical deformation,
- In-situ analyses

Oxide dispersion strengthened ferritic steel for VHTR-applications



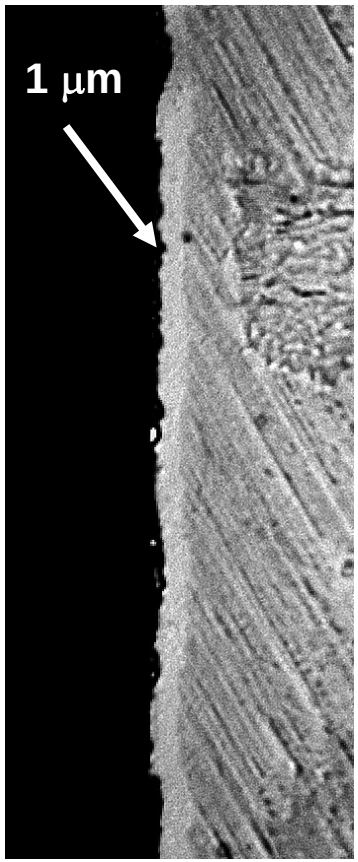
TEM-micrograph showing yttria dispersoids in ferritic matrix

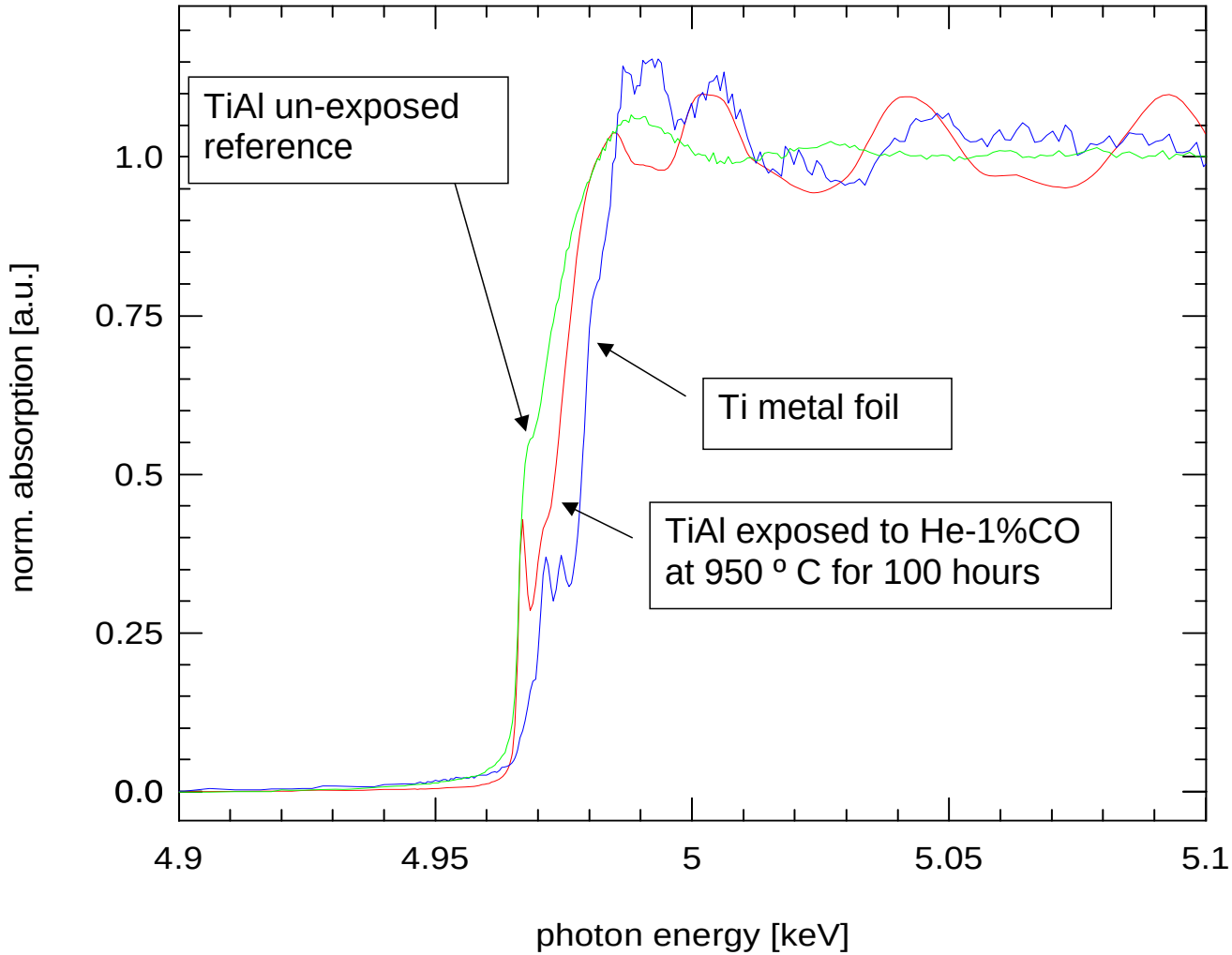
Degueldre, Conradson, Hoffelner, 2004



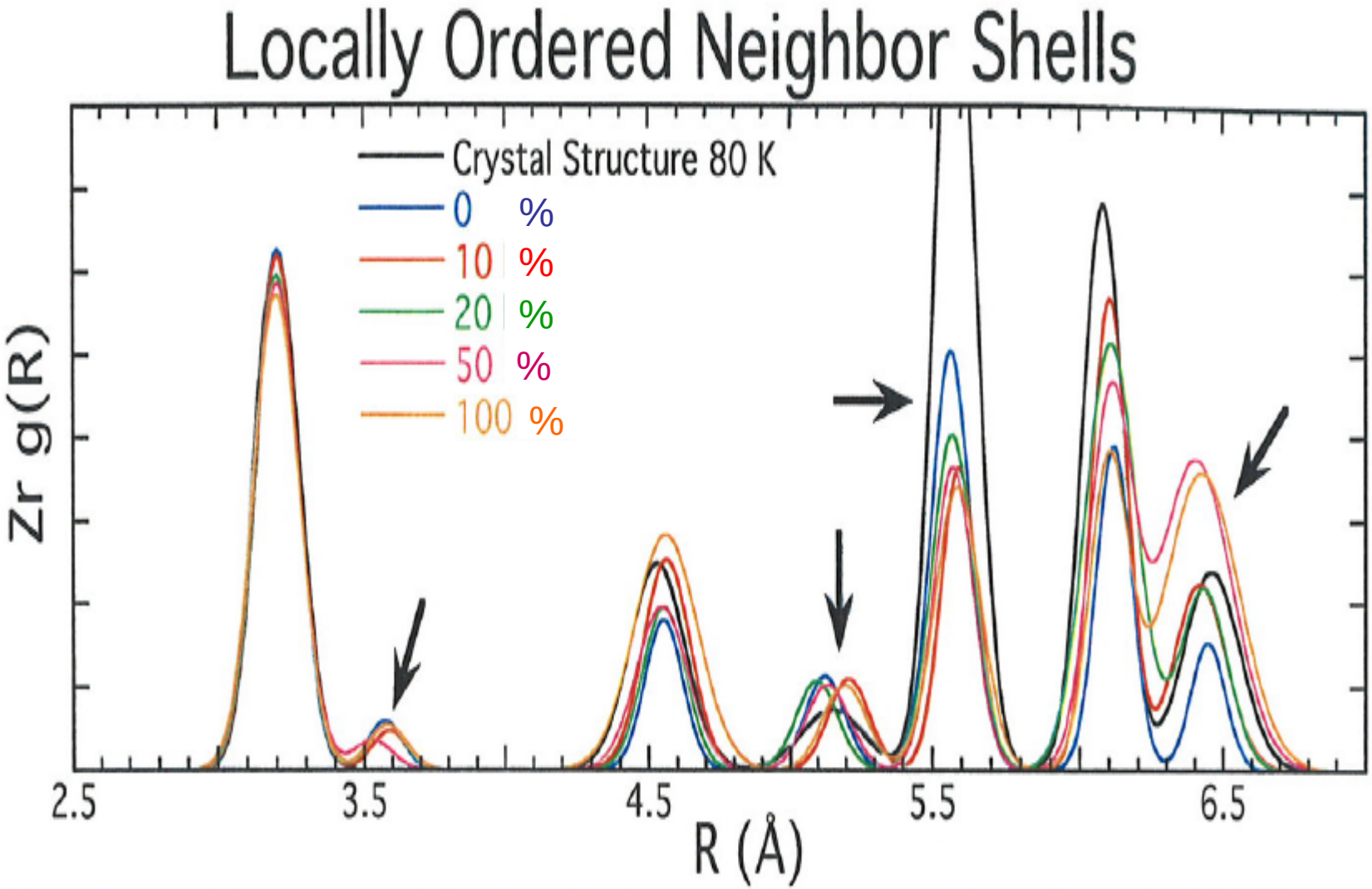
EXAFS-spectrum indicating that the yttria particles are cubic, highly stressed. Necessary input for modeling of deformation.

Corrosion investigation of an Intermetallic alloy
(Ti-47Al-2W-0.5Si)

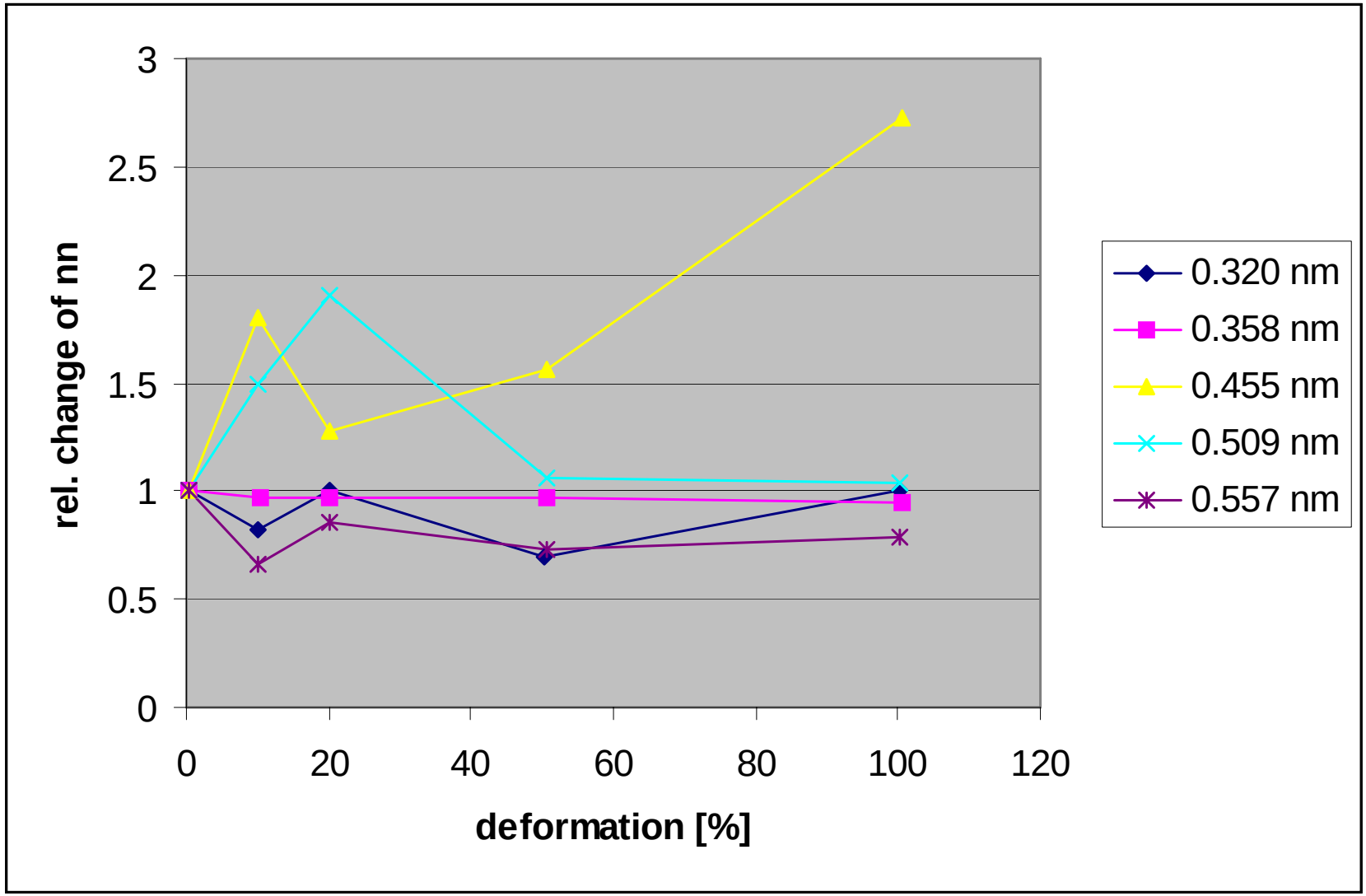




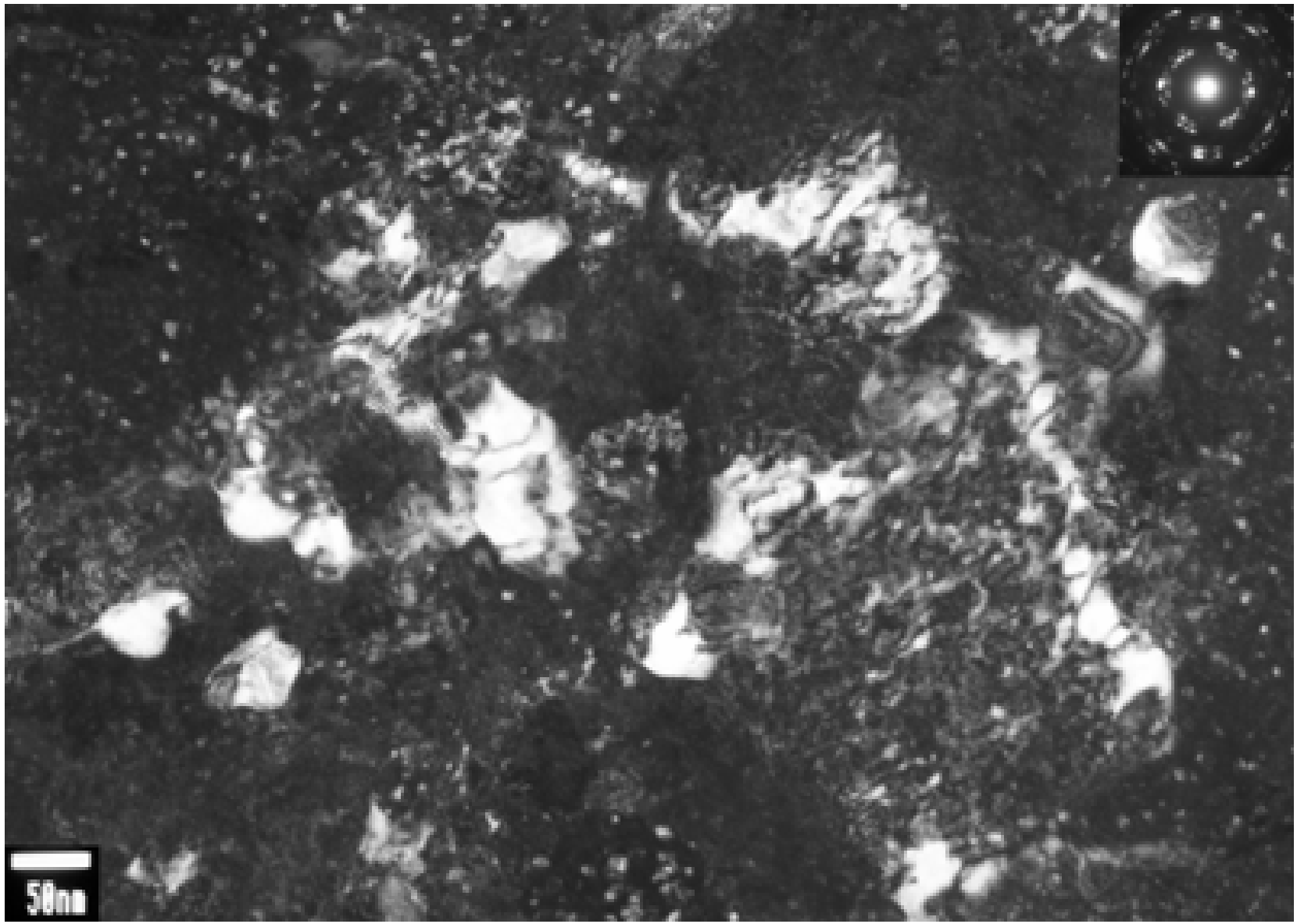
Investigation of Cold Rolled Zircaloy by EXAFS



Relative change of next neighbours as a result of cold rolling of zircaloy 2



Microstructure of Cold Rolled Zircaloy 2



Conclusions

- Synchrotron X-ray analyses provide a very powerful technique for analysis of VHTR-materials
- X-ray absorption allows the investigation of microstructural stability, phase changes and layer build-up
- First results on ODS and TiAl and Zircaloy demonstrate the applicability of EXAFS for analysis of environmental damage, stability of dispersoids and mechanical deformation.
- The current results were made on single experiments and they are still preliminary. A quantitative analysis needs additional microstructural investigations like TEM