PIE TECHNIQUES FOR THE STUDY OF IRRADIATION ASSISTED STRESS CORROSION CRACKING

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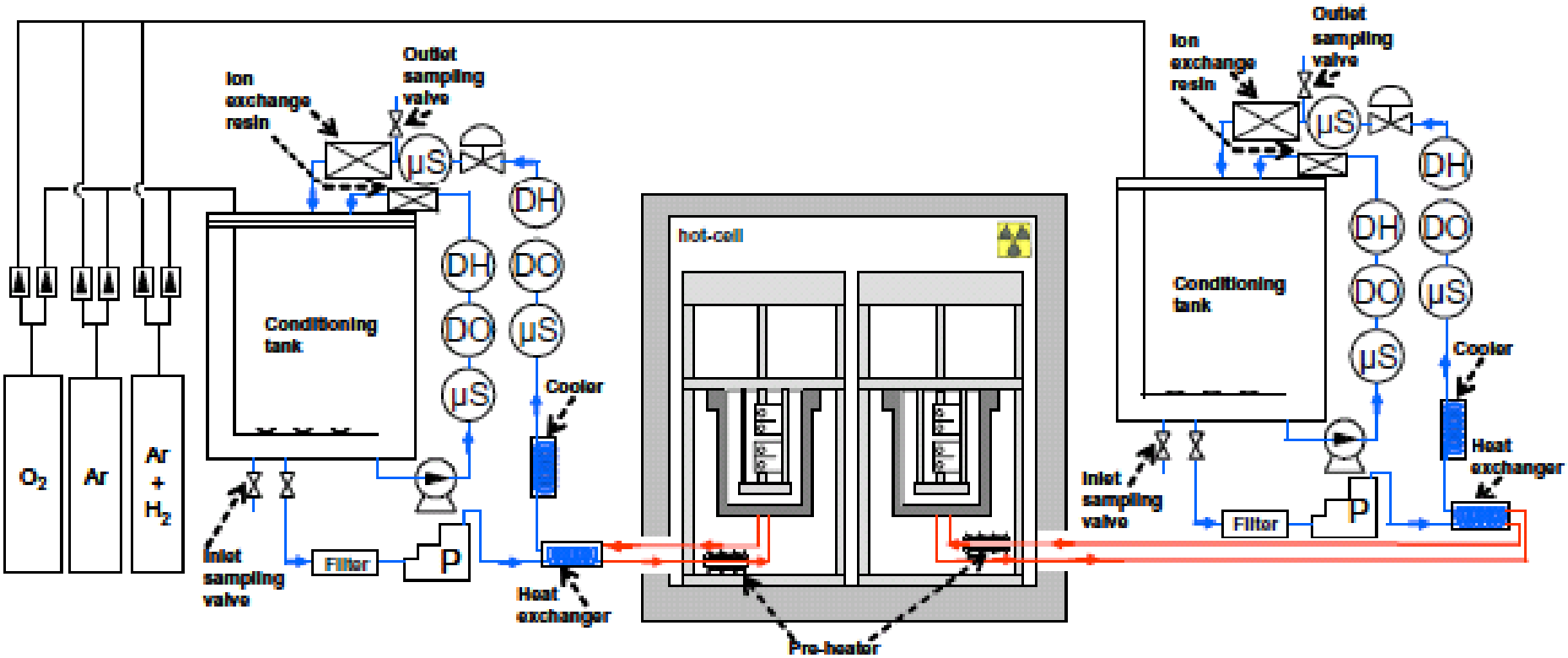
The study of IASCC

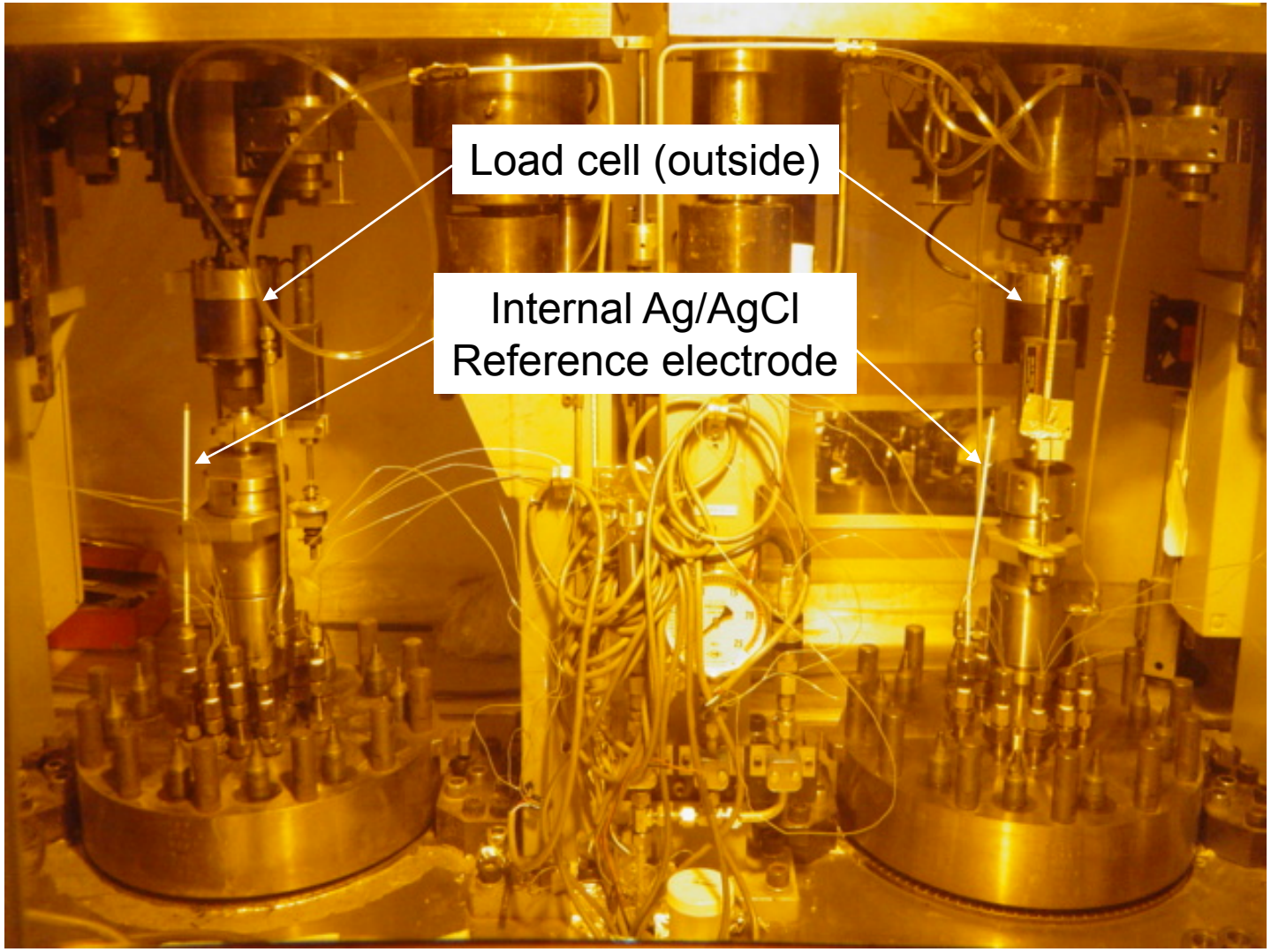
- IASCC is one of the critical concerns in materials for nuclear in-reactor components of Light Water Reactor.
- In order to investigate the mechanism of IASCC, PIEs at NFD hot laboratory were carried out on the materials obtained from commercial LWRs.
- The PIE techniques were developed for our IASCC study.

Facility for crack growth rate test

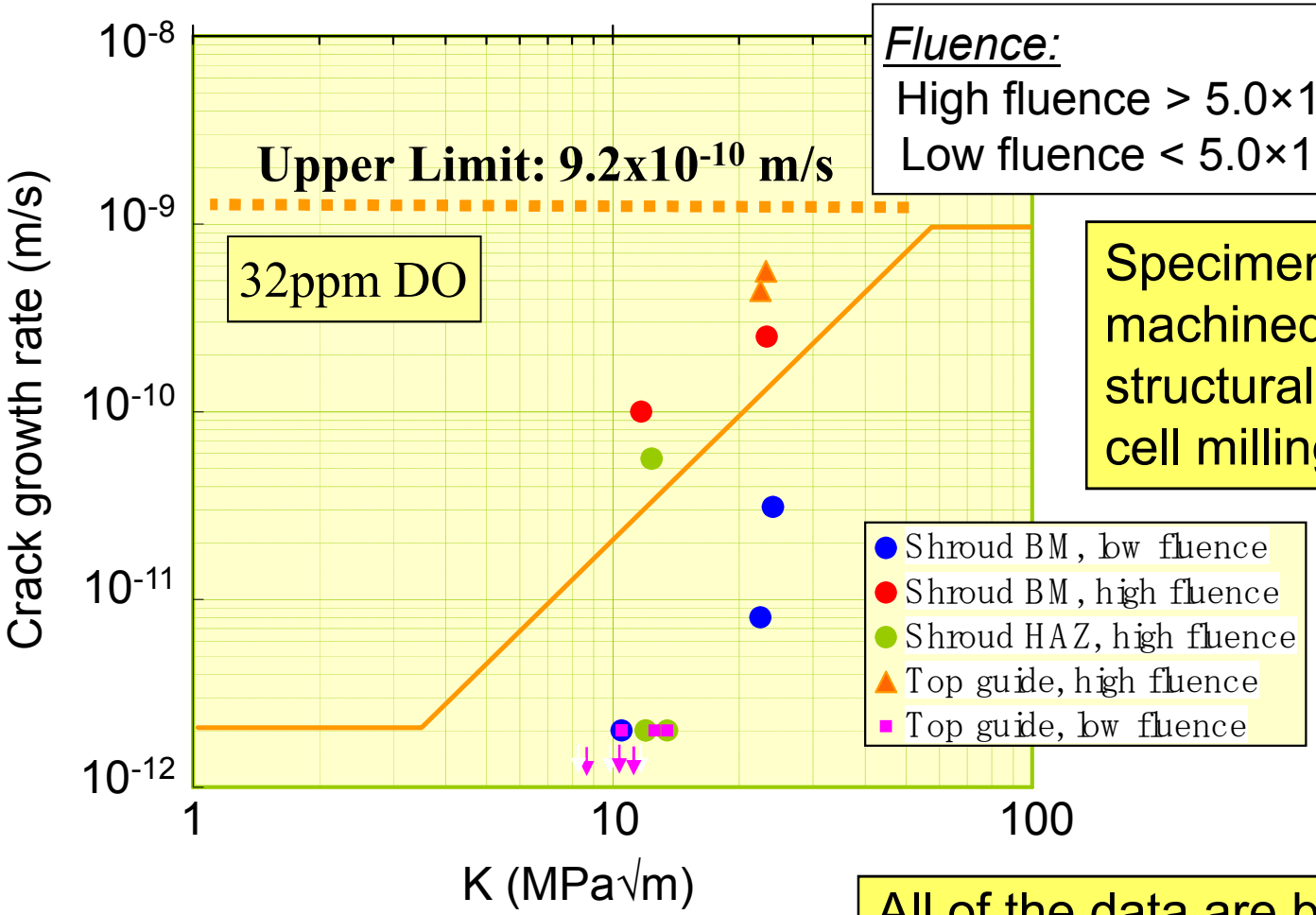


Shielding capacity: 740GBq (Co-60)
Load capacity (inside and outside load cell): 50kN
Specimen: two 0.5T-CTs or one 1T-CT each autoclave

Facility for crack growth rate test



Crack growth rate test results (1)



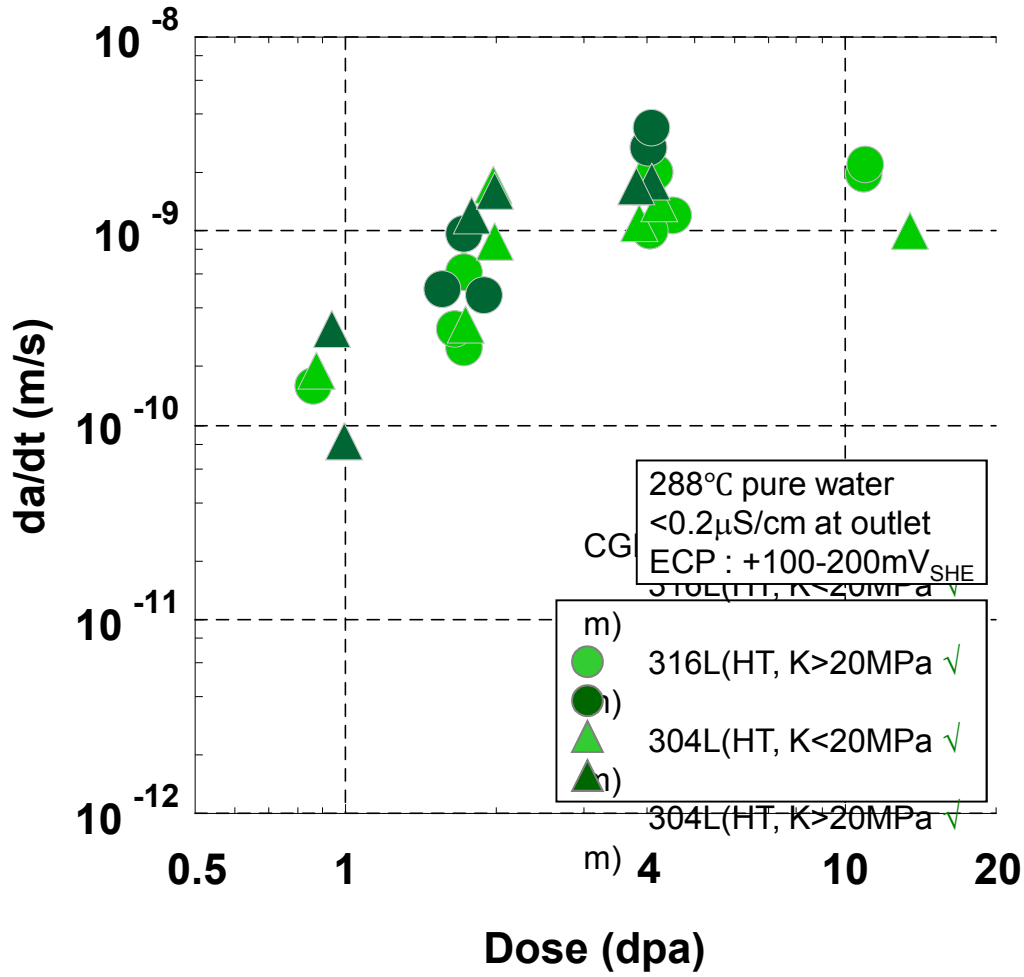
Fluence:
High fluence > 5.0×10^{24} n/m^2
Low fluence < 5.0×10^{24} n/m^2

Specimens (0.5-1.0TCT) were machined from in-core structural materials using in-cell milling machine.

All of the data are below the upper limit and low fluence data are below the disposition curves of JSME code.

S. Ooki et al., Proceeding of 12 th International Conference on Environmental Degradation of Materials in Nuclear Power System, 2005

Crack growth rate test results (2)

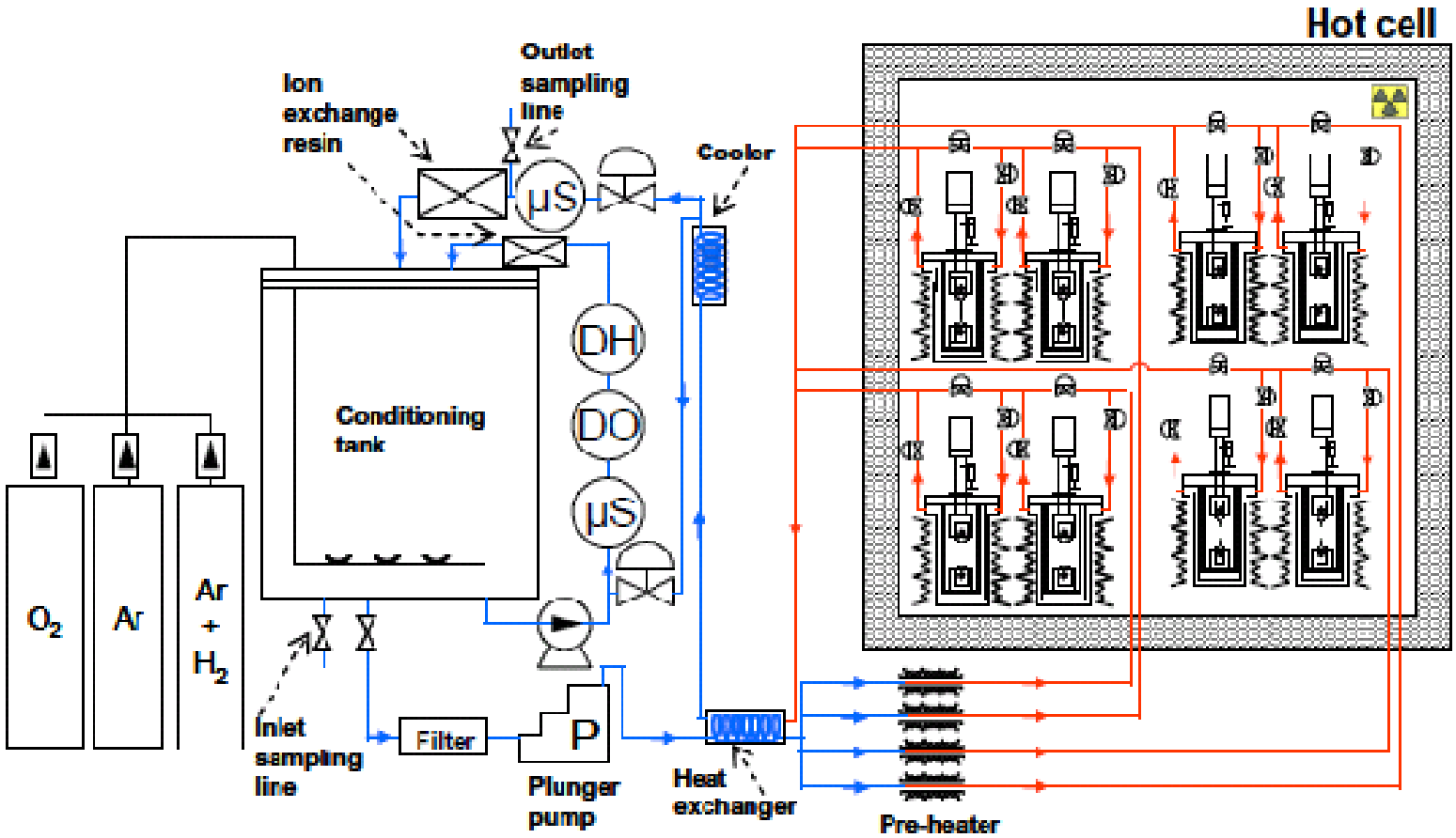


Specimens (0.5TCT) were irradiated with neutrons in high temperature water of JMTR.

The CGRs in +100 to +200mV$_{SHE}$ level (32ppmDO) were increased with increasing dose in the range about 0.9-4dpa, and there were a slight difference among the CGRs in the range about 4-13.5 dpa.

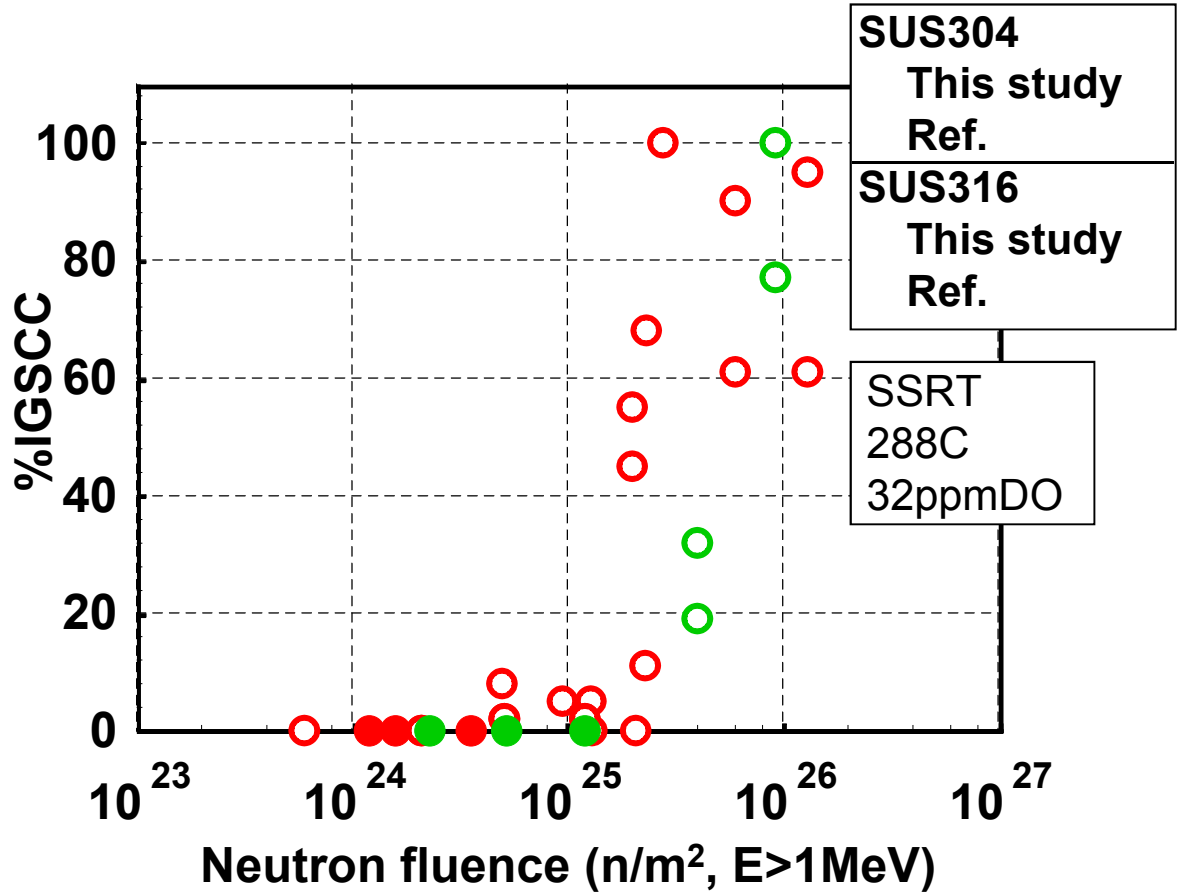
K. Chatani et al., Proceeding of 14 th International Conference on Environmental Degradation of Materials in Nuclear Power System, 2009

Facility for slow strain rate tensile and uniaxial constant load test



Shielding capacity: 3.7TBq (Co-60)
Load capacity : 10kN
Specimen: one or two tensile type specimen each autoclave

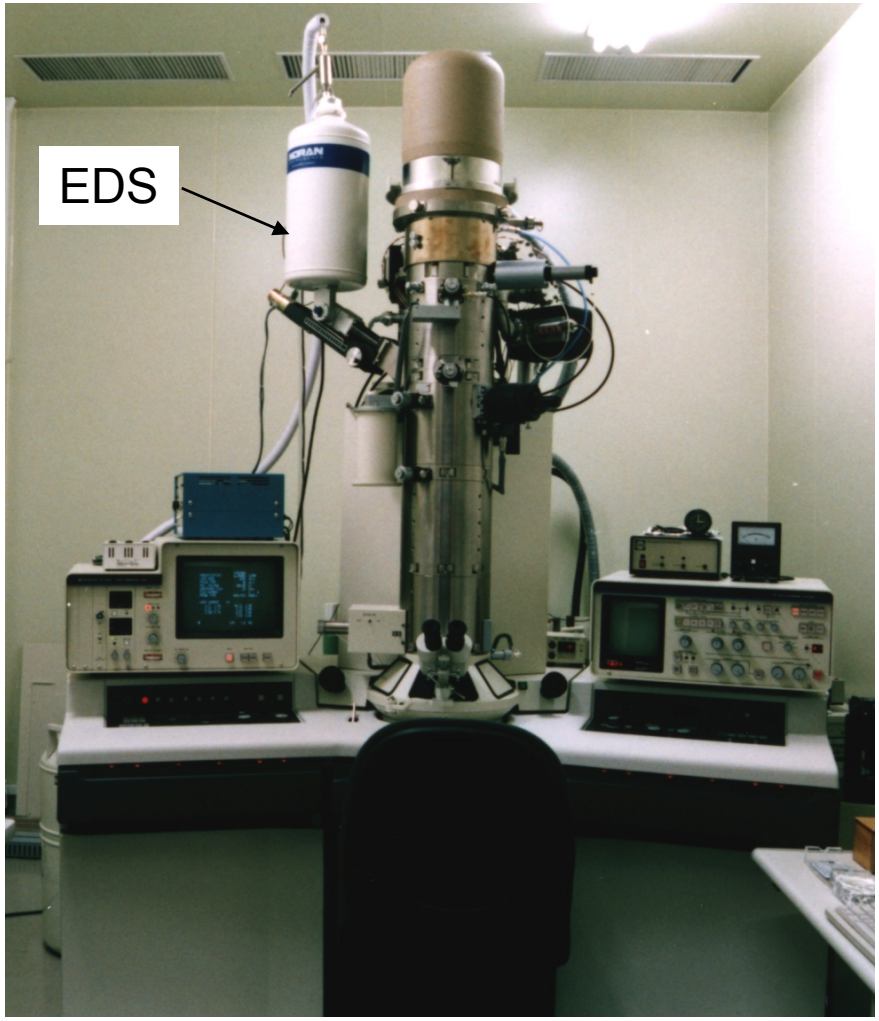
Slow strain rate tensile test results



IASCC susceptibility increased markedly for fluences exceeding 10^{25}n/m^2

K. Chatani et al., Proceeding of 12 th International Conference on Environmental Degradation of Materials in Nuclear Power System, 2005

High resolution grain boundary analytical techniques

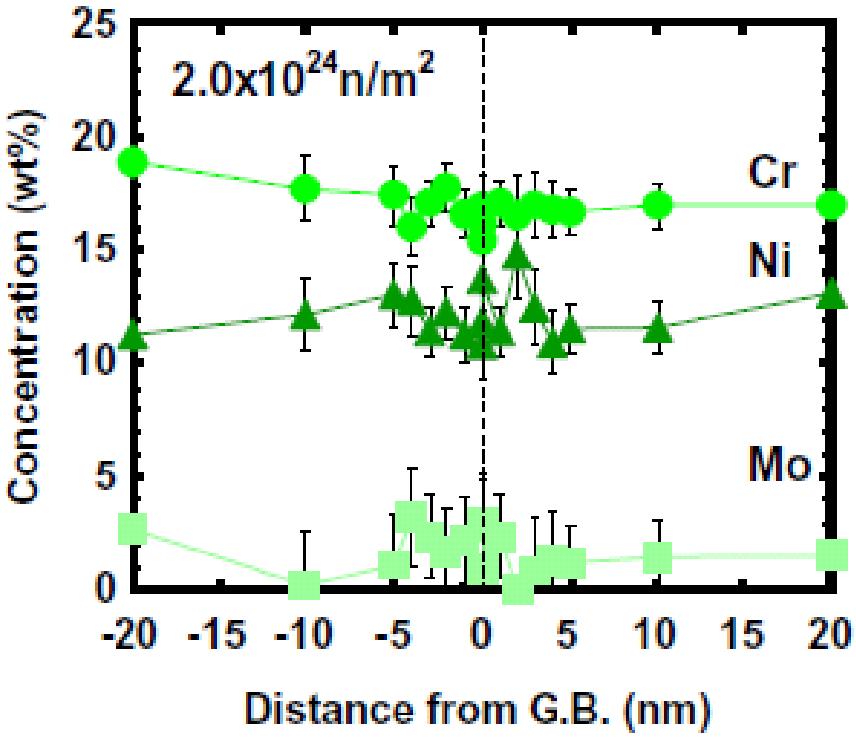


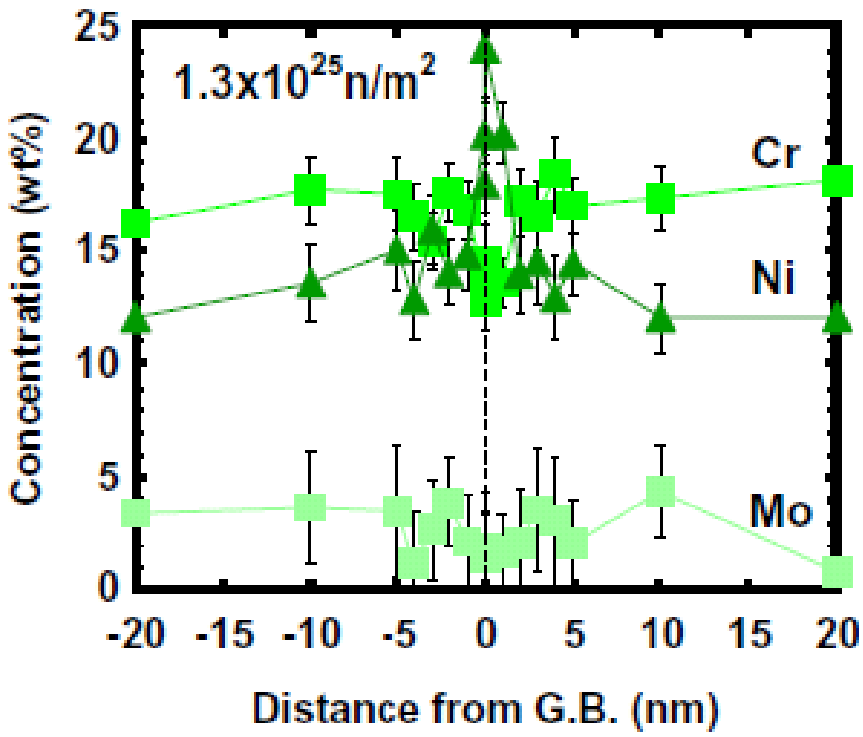
FE-TEM

Acceleration Voltage: 200kV
Probe diameter: <2nm
Specimen size: 1 mm diameter disks

Reduction in volume to minimize radiation flooding of the X-ray detector.

FE-TEM results of irradiated Type 316SS

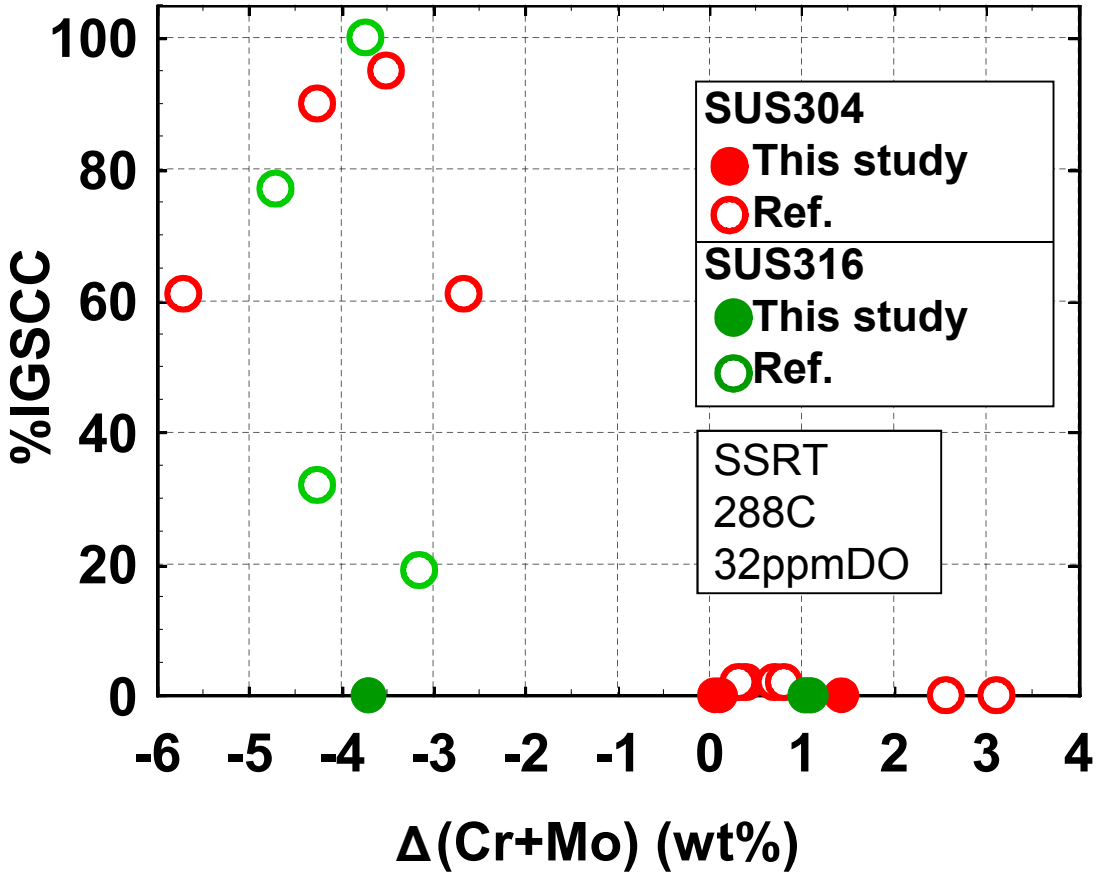




The enrichment of nickel and depletion of chromium increased with increasing neutron fluence.

K. Chatani et al., Proceeding of 12 th International Conference on Environmental Degradation of Materials in Nuclear Power System, 2005

Dependence of (Cr+Mo) segregation at G.B. on IASCC susceptibility

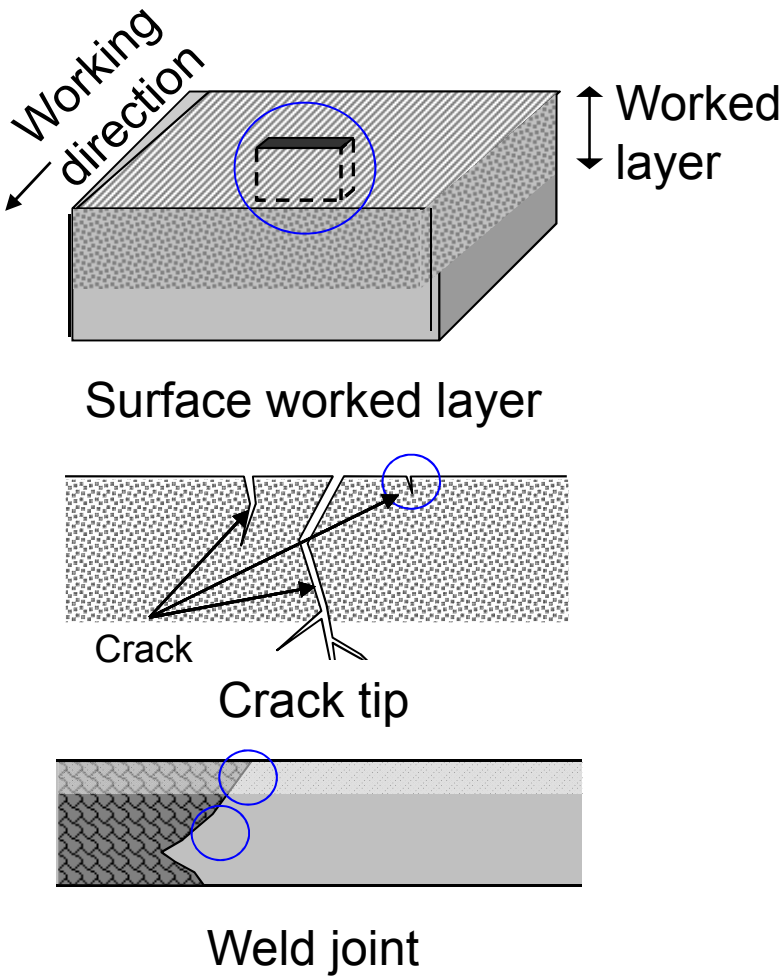


The IASCC susceptibility increases when the (Cr + Mo) grain boundary depletion increases.

K. Chatani et al., Proceeding of 12 th International Conference on Environmental Degradation of Materials in Nuclear Power System, 2005

The application of FIB for a microstructure observation technique

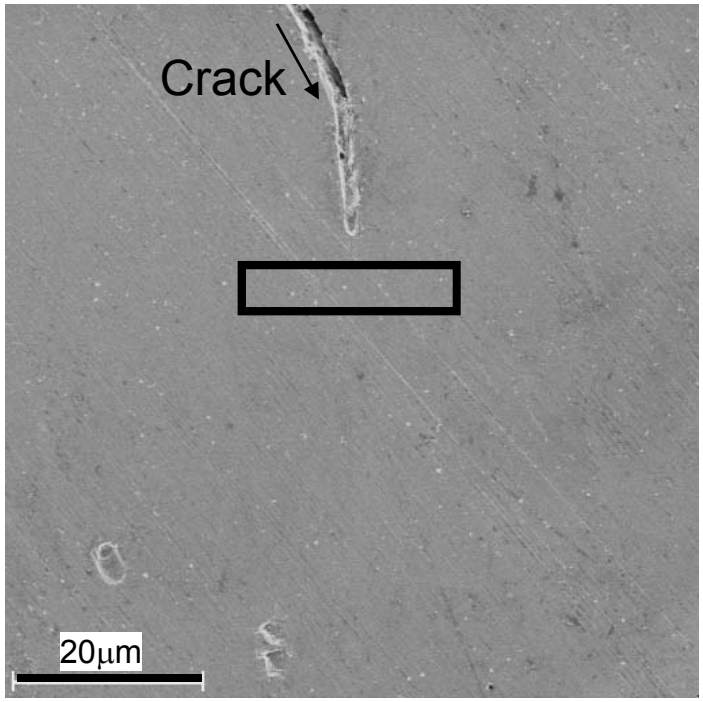
FIB (Focused Ion Beam) systems

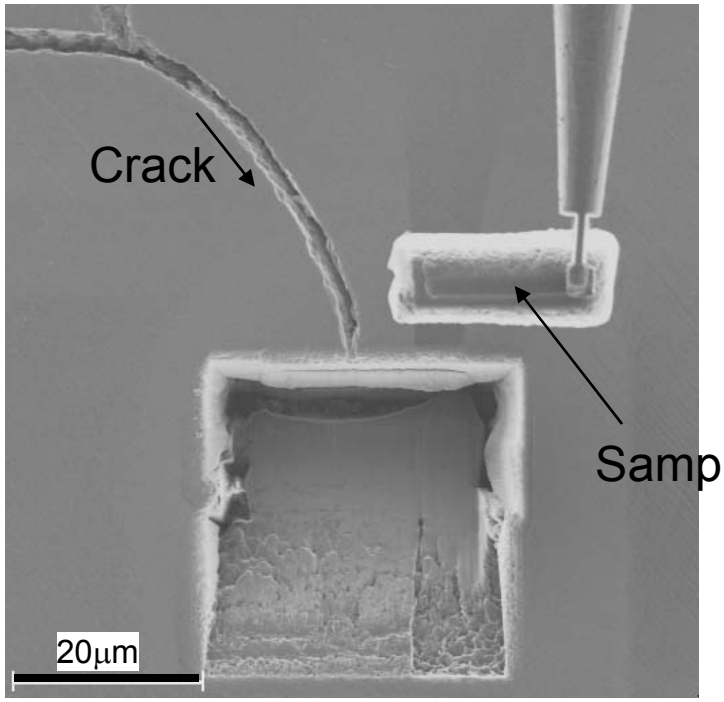


Sampling from various parts

Example of FIB sampling procedure

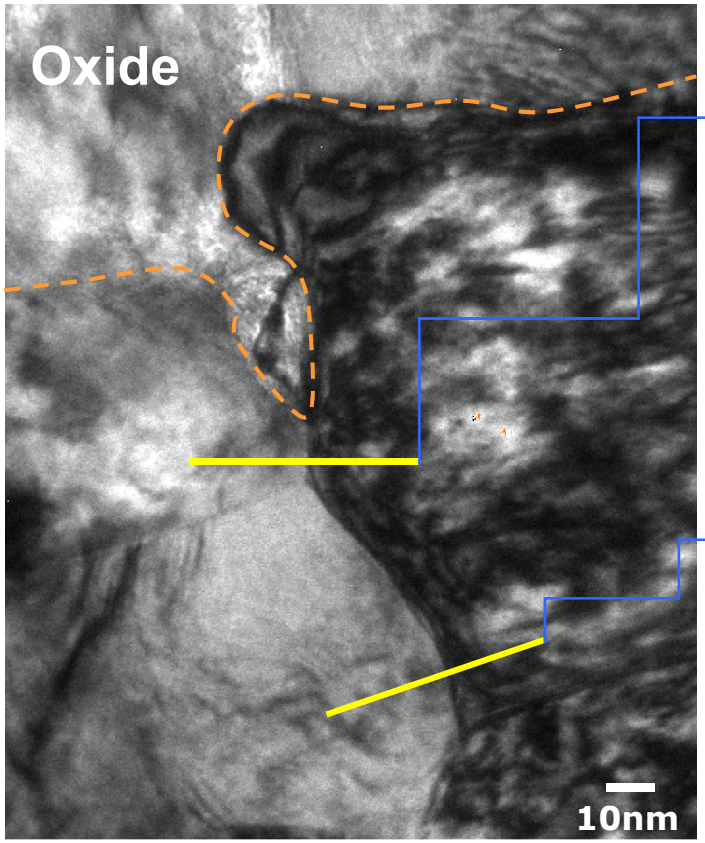
SIM Image

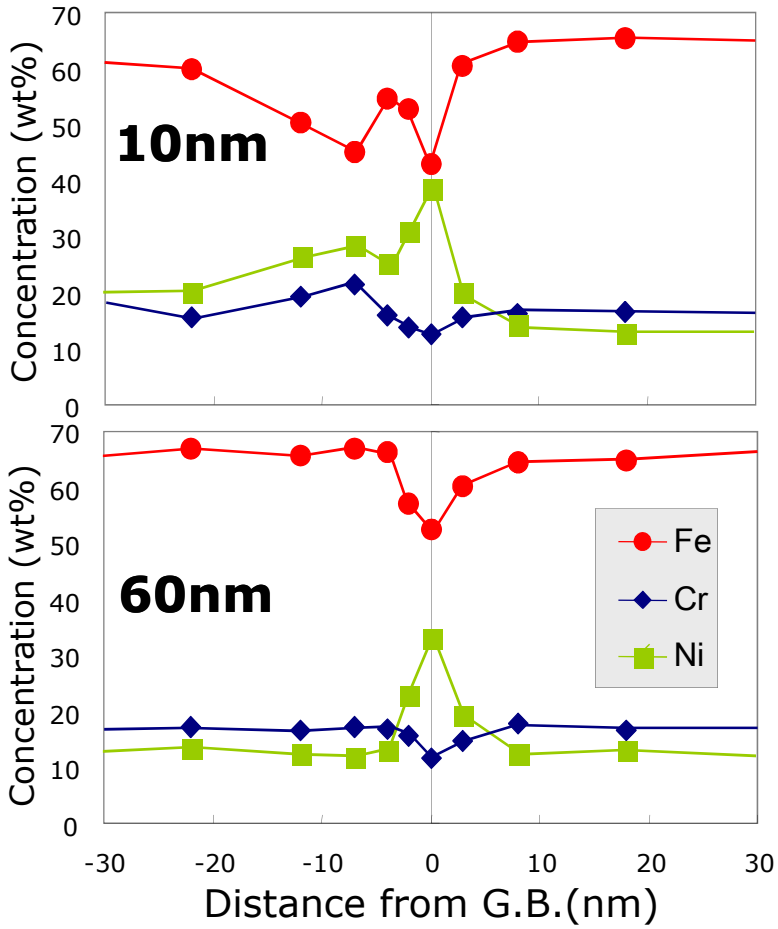




Thin film processing after sampling (Thickness: about 50nm)

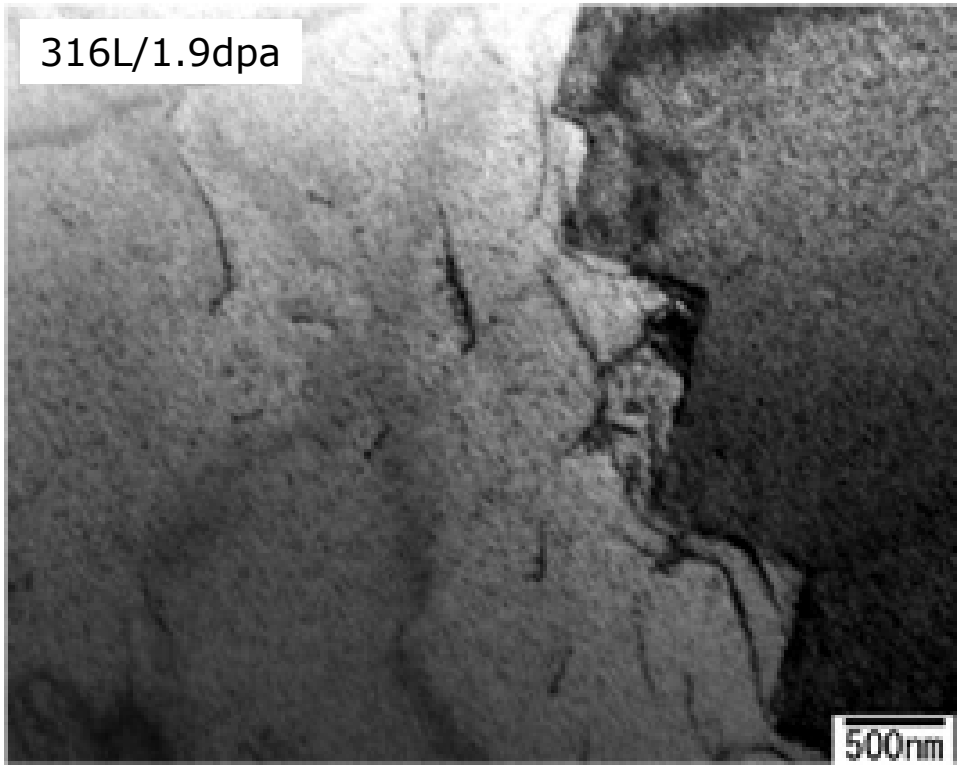
Crack tip chemical composition analysis across the grain boundary





Composition changes on the nano level at the crack tip were detected.

Deformation structure at the crack tip

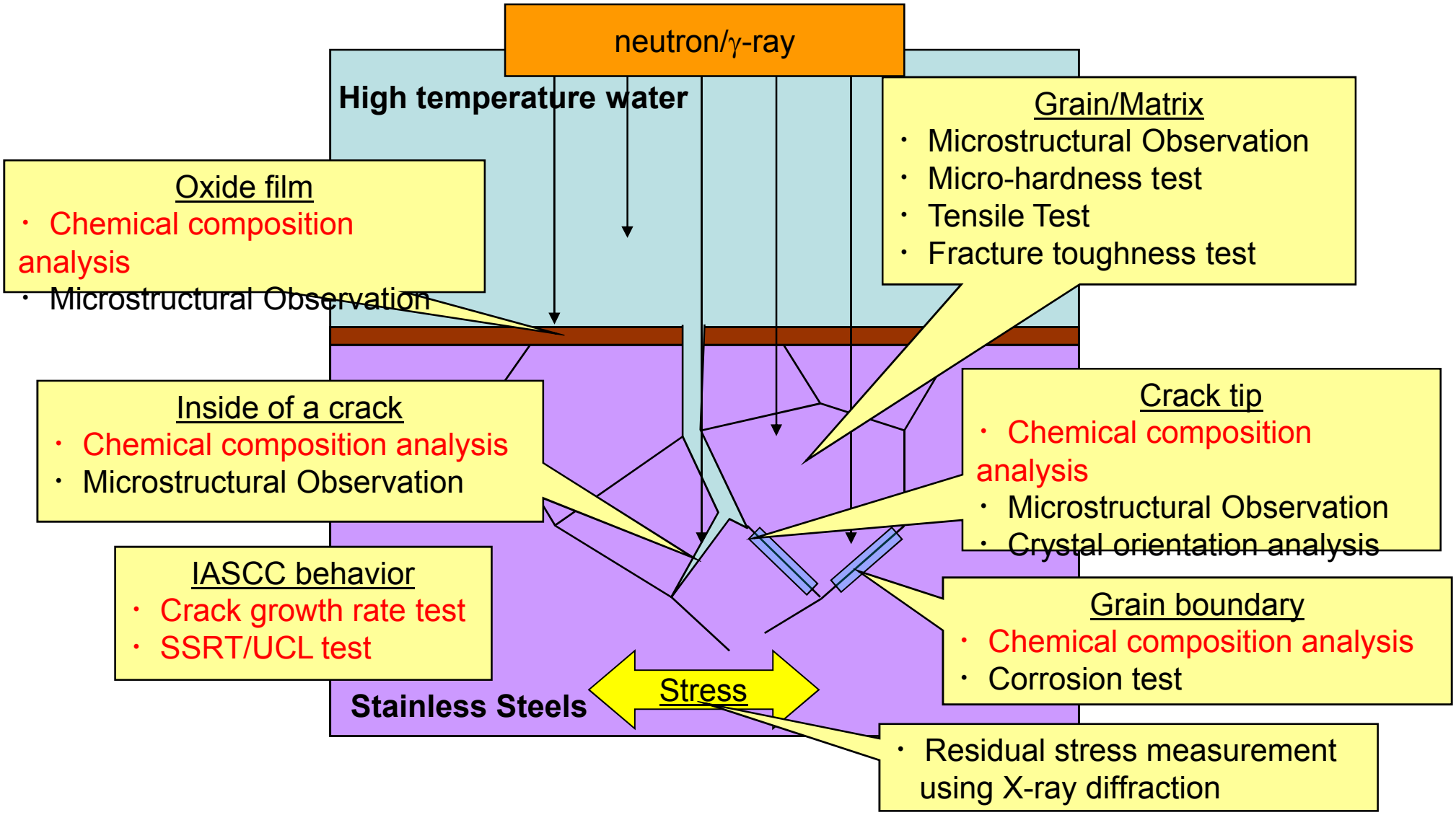


The sample was obtained from the part distorted 0.2% strain of CT specimen irradiated to 1.9dpa using FIB.

Dislocation channeling and grain boundary steps were observed.

Sumiya et al., Proceeding of 13 th International Conference on Environmental Degradation of Materials in Nuclear Power System, 2007

PIE techniques for the study of IASCC in NFD



Summary

- Various material evaluation techniques were developed in order to study IASCC and the data required for an IASCC mechanism elucidation is obtained.

- For mechanistic understanding against IASCC of in-core structural materials, we have to make the further improvement or upgrade of present PIE techniques.