

Micro-compression testing on irradiated model and structural alloys

Peter Hosemann, Manuel Pouchon, Erich Stergar, Yong Dai, Stuart A. Maloy

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University of California Berkeley

Los Alamos National Laboratory

Montanuniversitaet Leoben, Austria

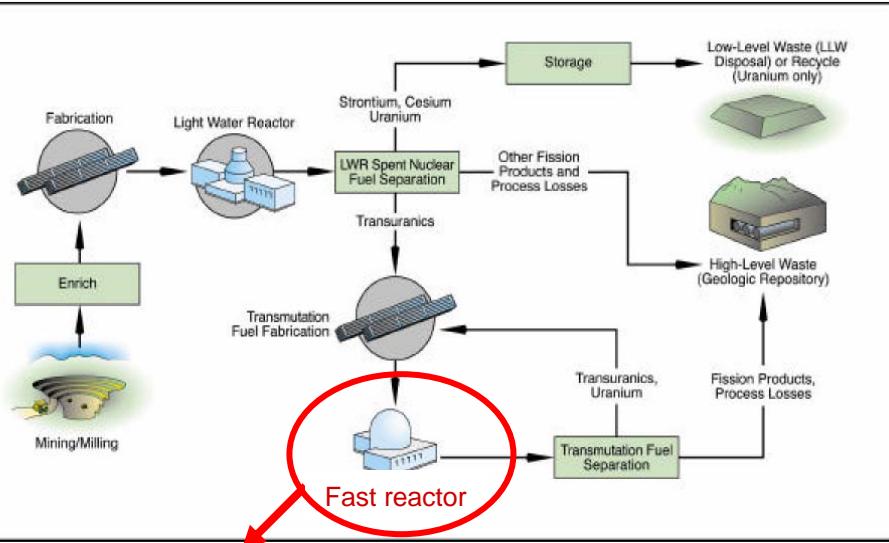
Paul Scherrer Institute, Switzerland

Outline

- Introduction/Background
- Materials irradiation/ Post irradiation examination setup
- Results on HT-9
- Results on F82H and F82H ODS
- Future work on small scale testing of materials
- Conclusion

Motivation: Fuel cycle options

Fuel Cycle options:



Fast reactors are needed:

- A fast neutron spectrum and high fuel burn up lead to extremely high radiation dose and high temperature
- The environment is rather harsh because of the liquid metal cooling.

Challenges in materials studies:

• Environment

Lead-Bismuth Eutectic, Lead, Sodium, Gas, etc.

• Elevated temperature for long period of time.

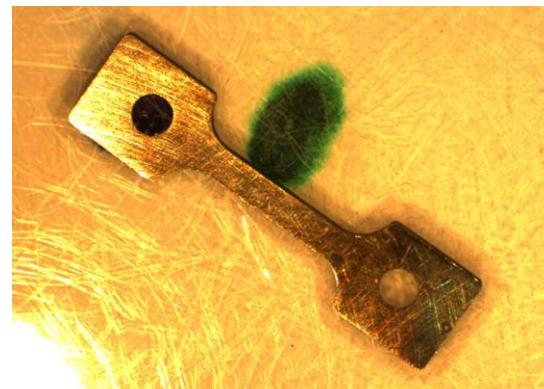
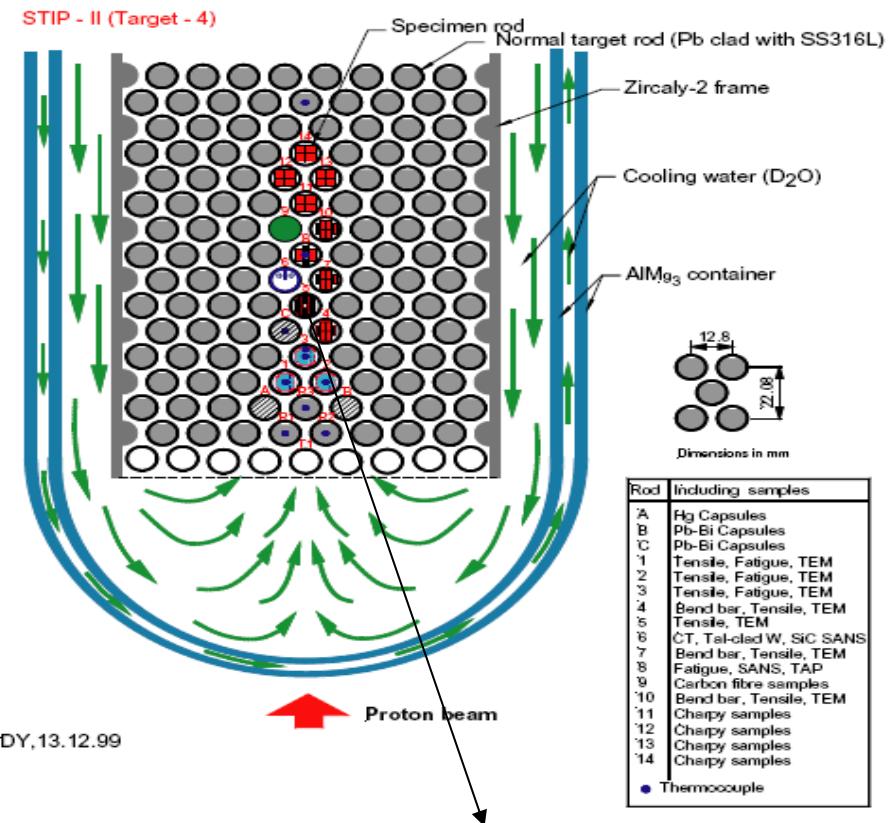
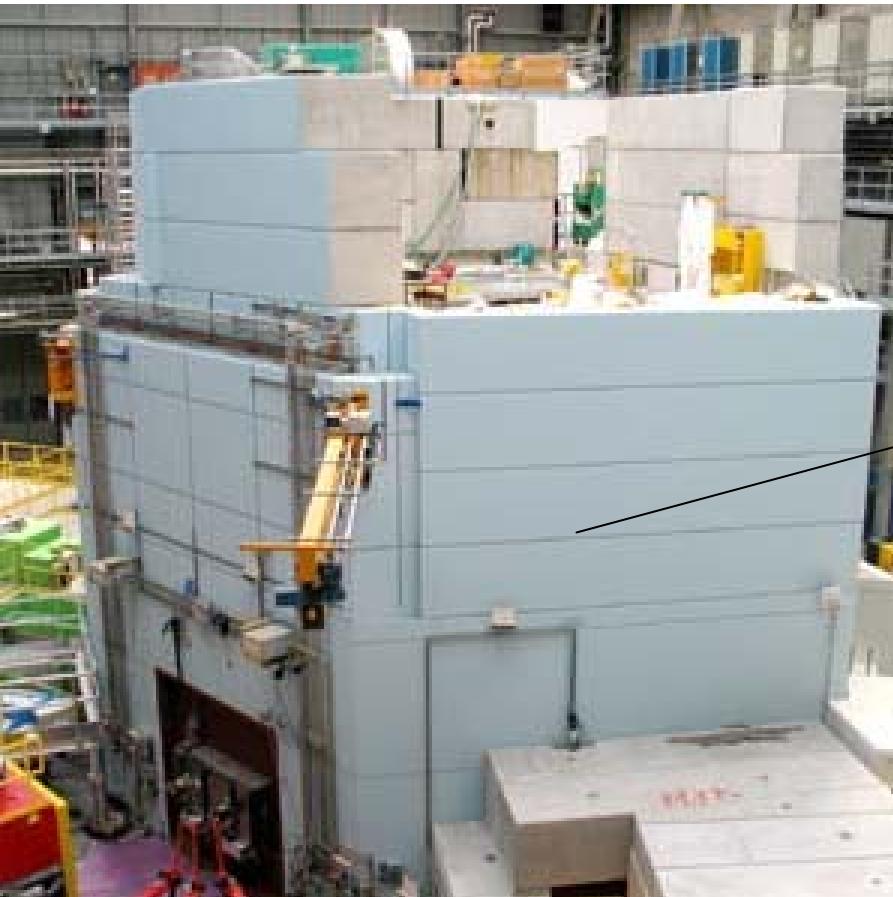
Experiments are performed at temperature.

- Thermal creep
- Thermal stability
- Aging

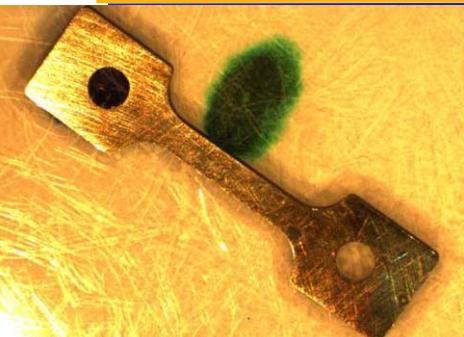
• Radiation environment.

- Radiation induced creep
- Radiation induced hardening
- Radiation induced segregation
- Swelling

The SINQ at PSI and the STIP irradiation program



Sample preparation on active STIP samples/dose rate and gamma spectrum estimations



~400mR/h at
10cm

~200mR/h at
10cm

~50mR/h 10cm

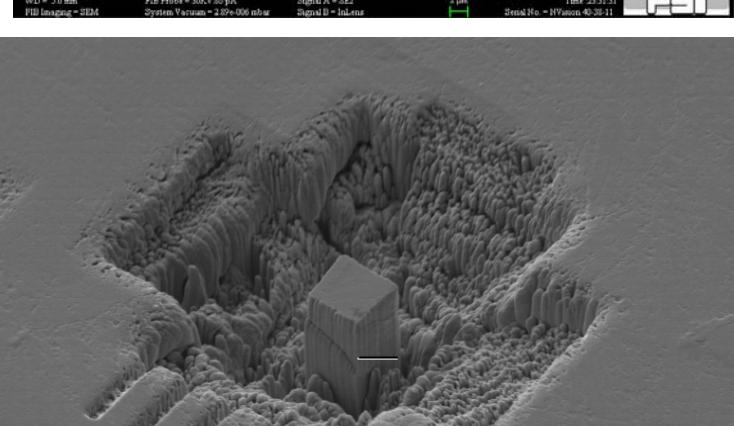
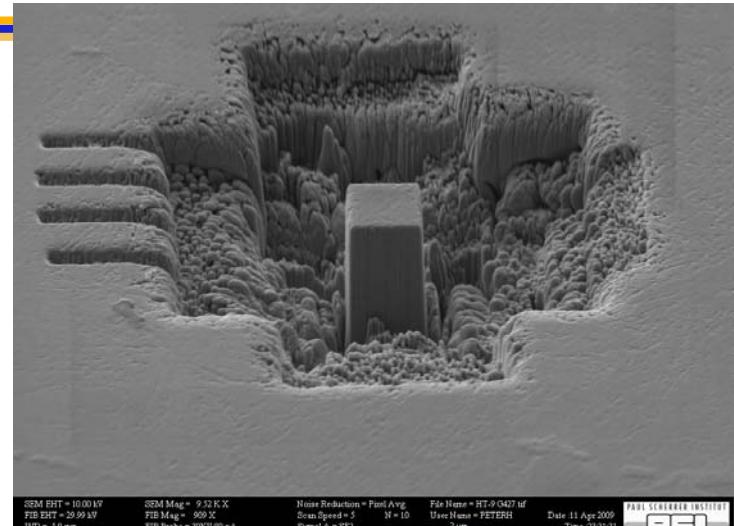
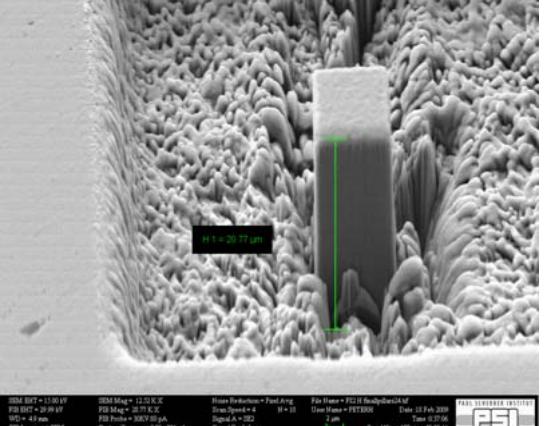
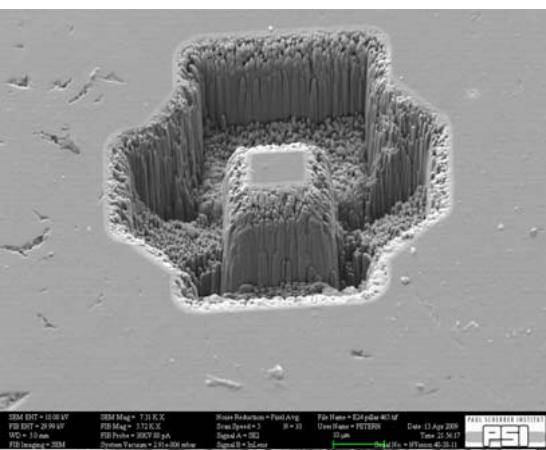
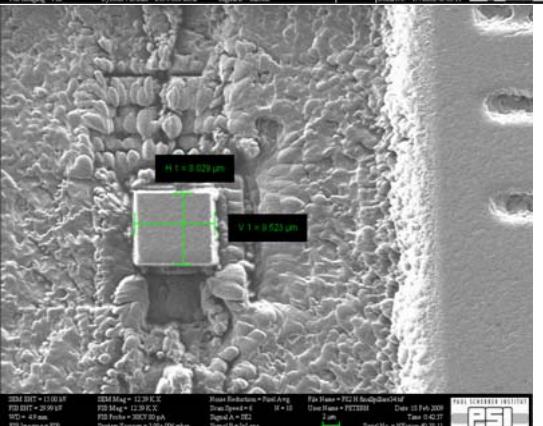
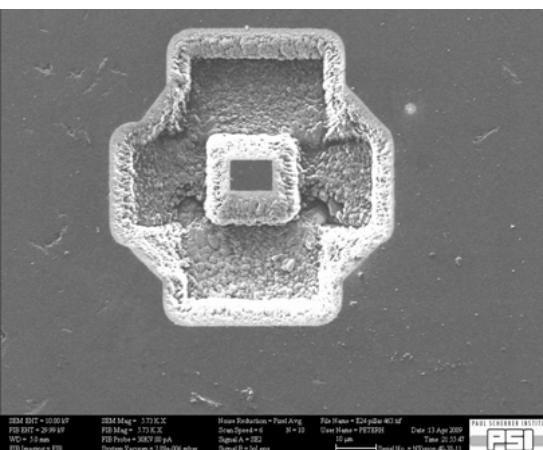
~20mR/h 10cm

Preparation of FIB samples



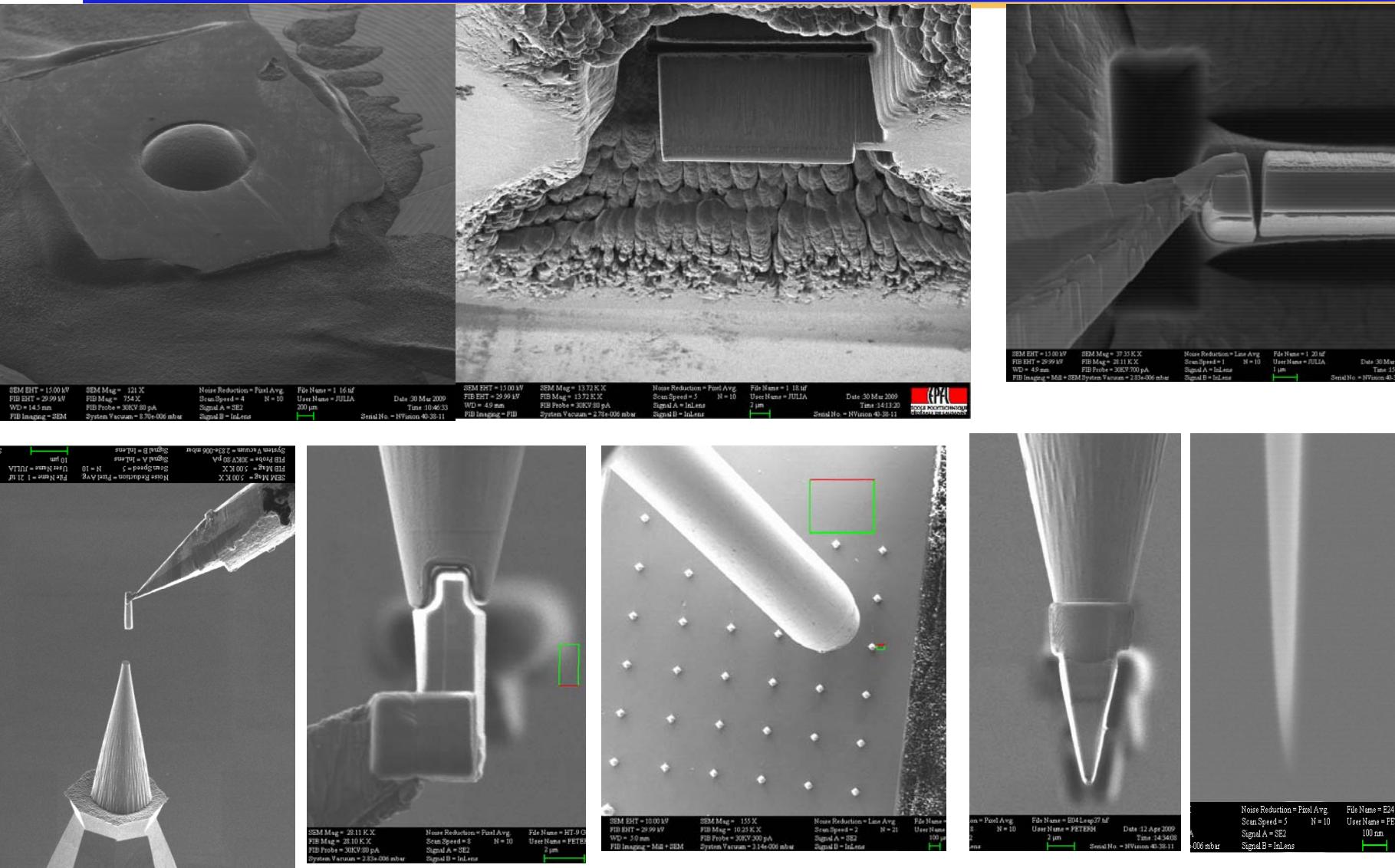
Isotop	decay	halflife	Activity [Bq]	Activity calc. [Bq]
			Tensile sample	LEAP sample
Na22	β/γ	2.6Y	6.56E+05	1.68E-05
Mn54	γ	312.5d	5.05E+07	1.29E-03
Co57	β/γ	271.79d	7.04E+05	1.80E-05
Co58	γ	70.86d	M. to Low	M. to Low
Co60	β/γ	5.27y	2.19E+07	5.60E-04
Tc95	β/γ	61d	M. to Low	M. to Low
Hf172	β	1.87y	4.57E+05	1.17E-05
Lu172	ε	6.7d	7.36E+05	1.88E-05
Lu173	β	1.37y	1.09E+06	2.79E-05
Re186	γ	3.7d	M. to Low	M. to Low
total			7.60E+07	1.95E-03
total [dpm]			4.56E+09	1.17E-01
number of LEAP needles until 200dpm				1.71E+03
mSv/h 10cm				3.6 9.28E-11

Micro Pillar fabrication in the Focused Ion Beam (FIB) instrument

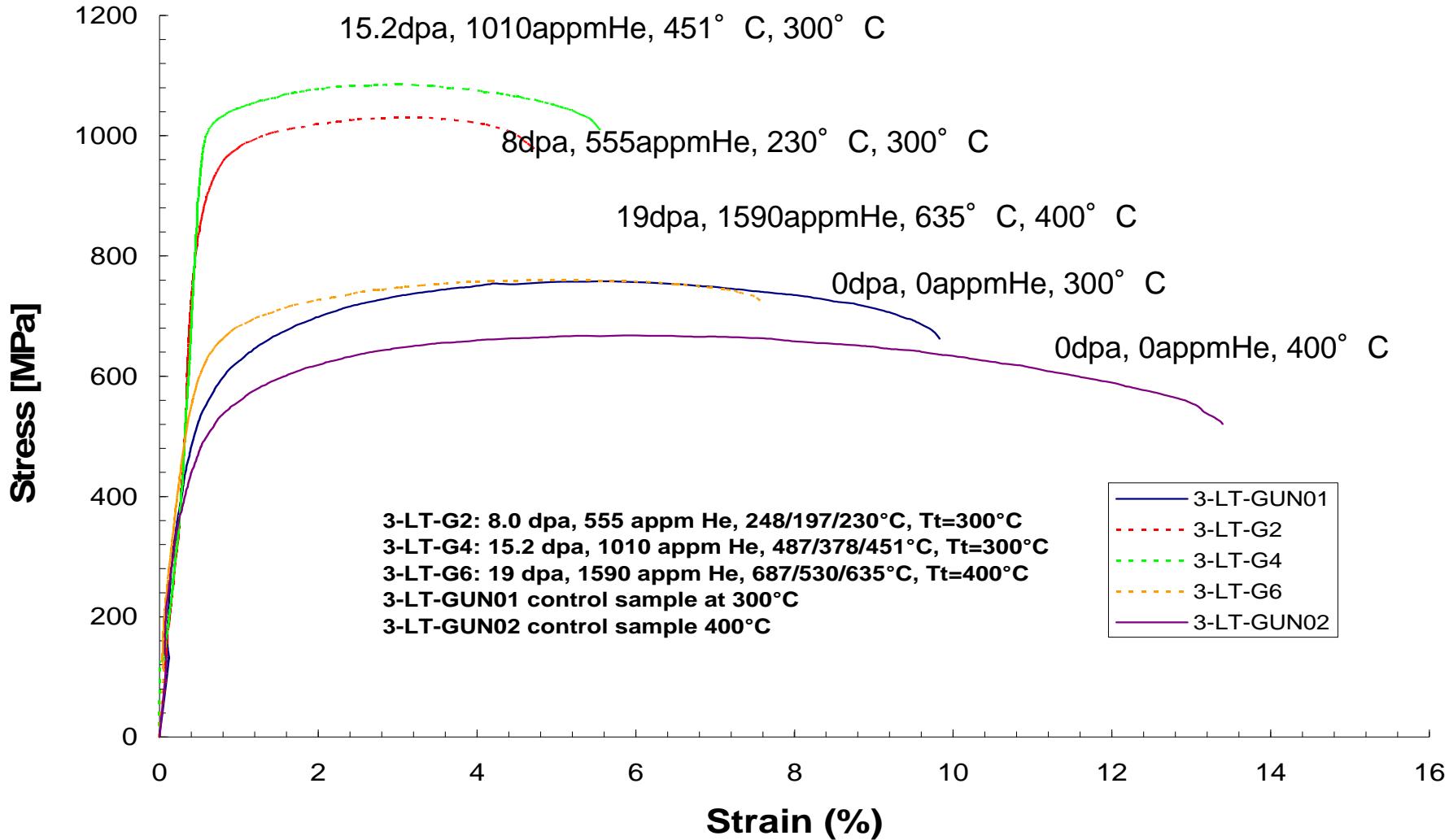


SEM Mag = 572 KX
FIB Mag = 575 KX
FIB Probe = 30KV 20 pA
System Vacuum = 3.87e-006 mbar
Noise Reduction = Pixel Avg N = 10
Scan Speed = 5
User Name = PETERH
File Name = G04 LEAP85.tif
Signal A = SEE
Signal B = InLens
10 μm
Time 19:49:09
Serial No. = NVision 40-38-11
Date 14 Apr 2009

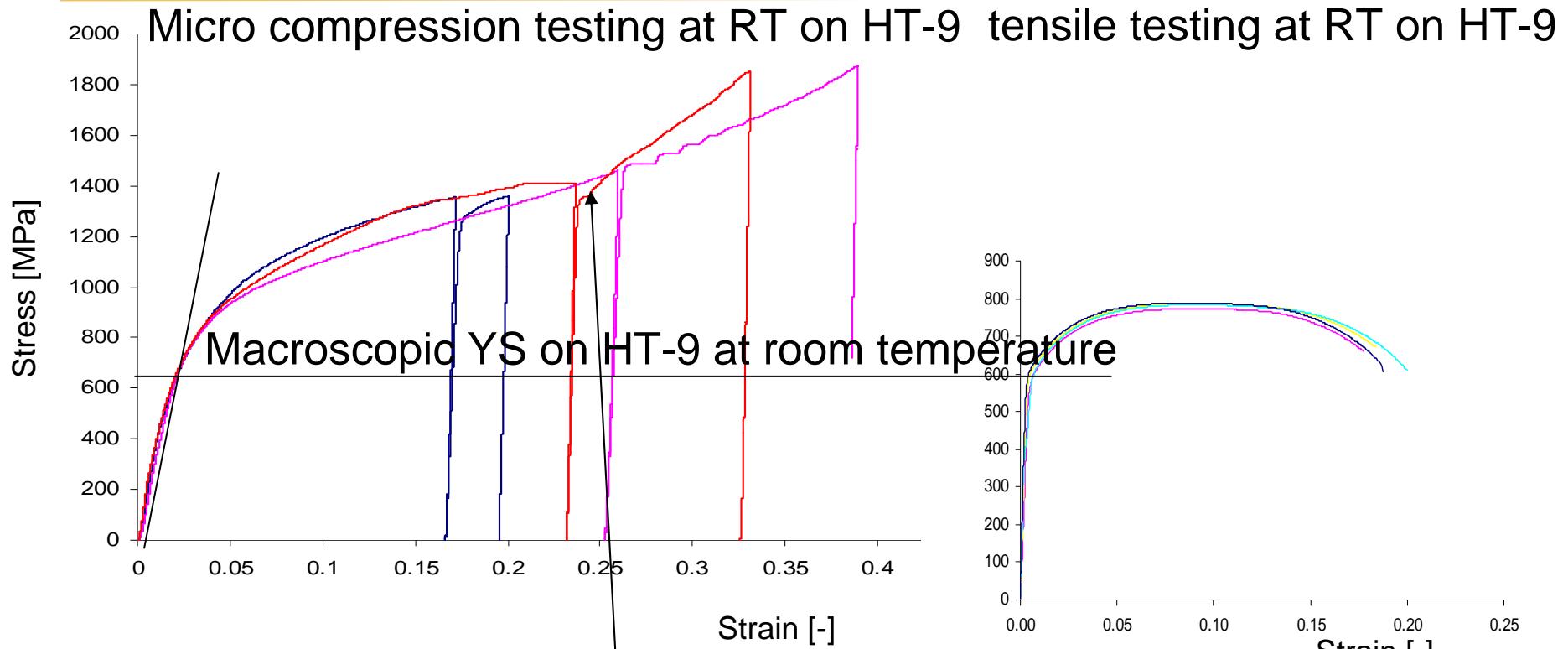
Preparing local electrode atom probe (LEAP) samples



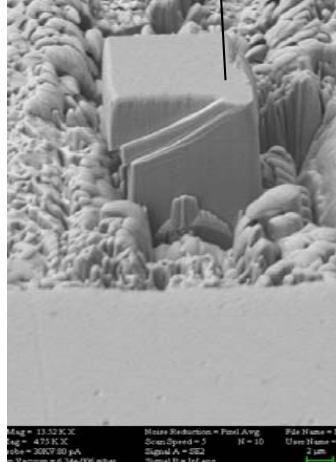
Tensile test results on HT-9 irradiated in STIP



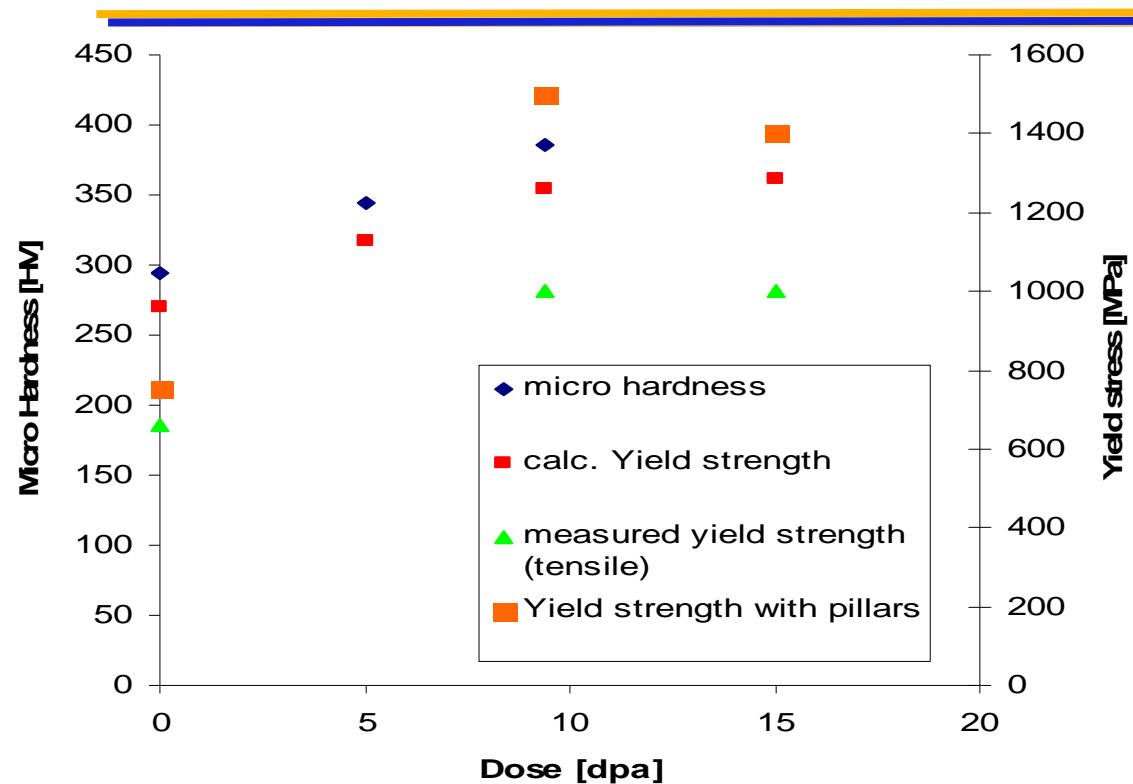
Typical results from micro compression testing (HT-9)



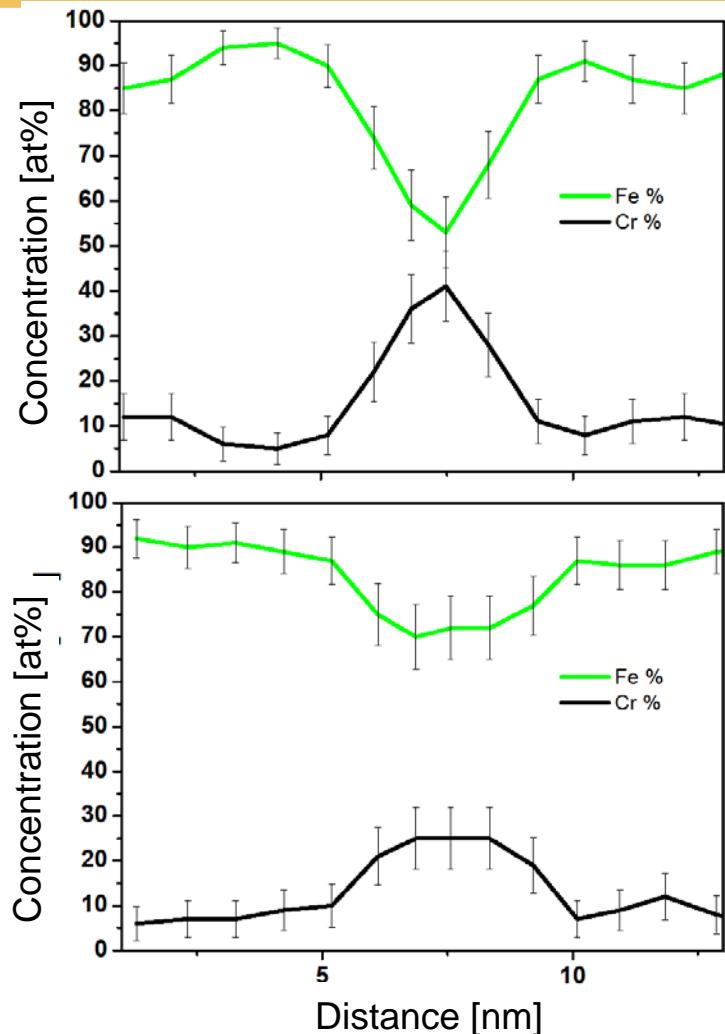
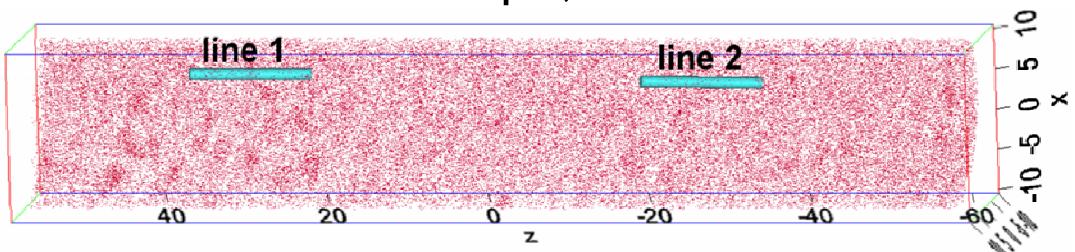
Surface area
increase



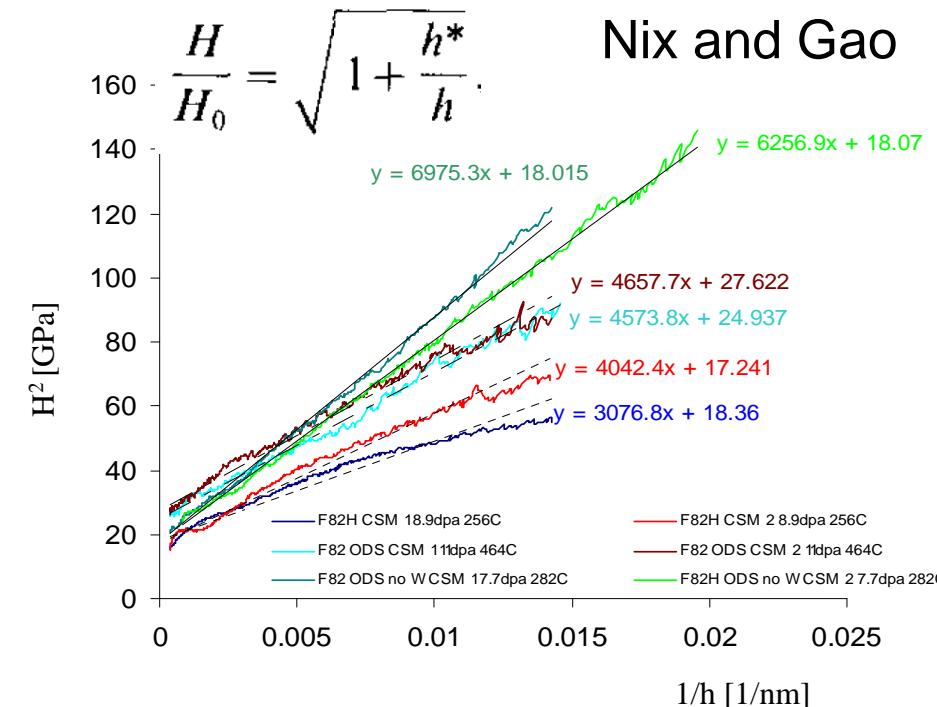
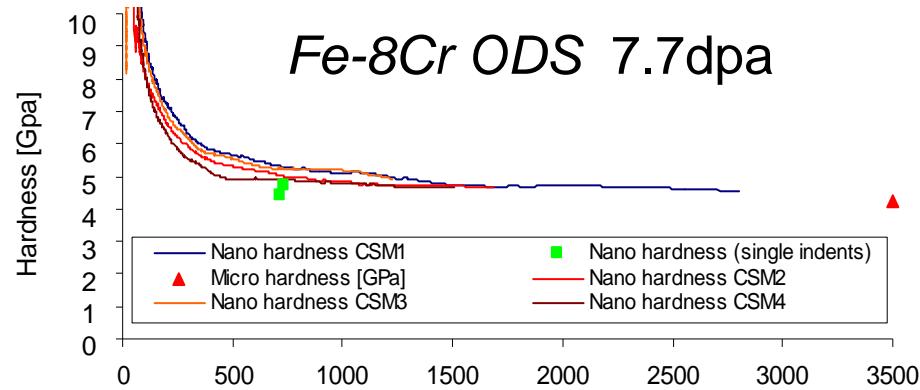
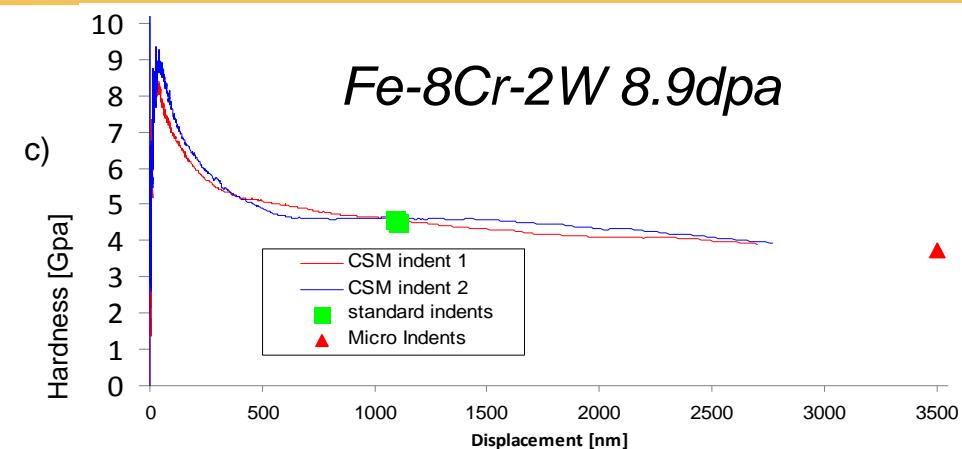
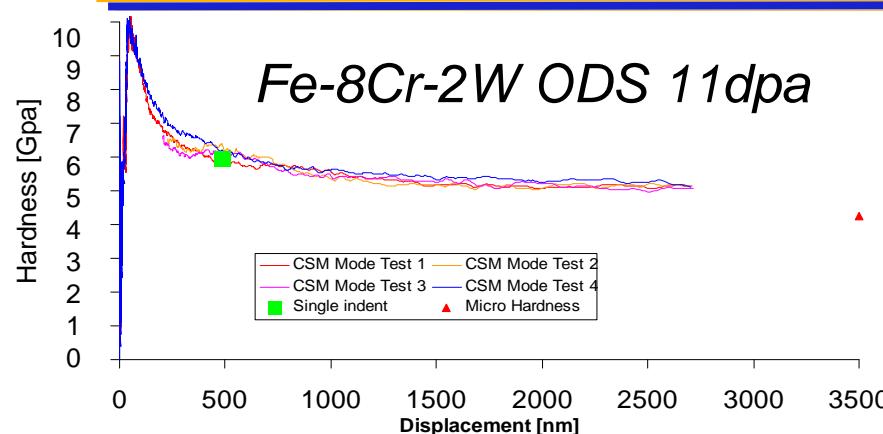
Results on HT-9, (12Cr F/M steel)



8dpa, 230C



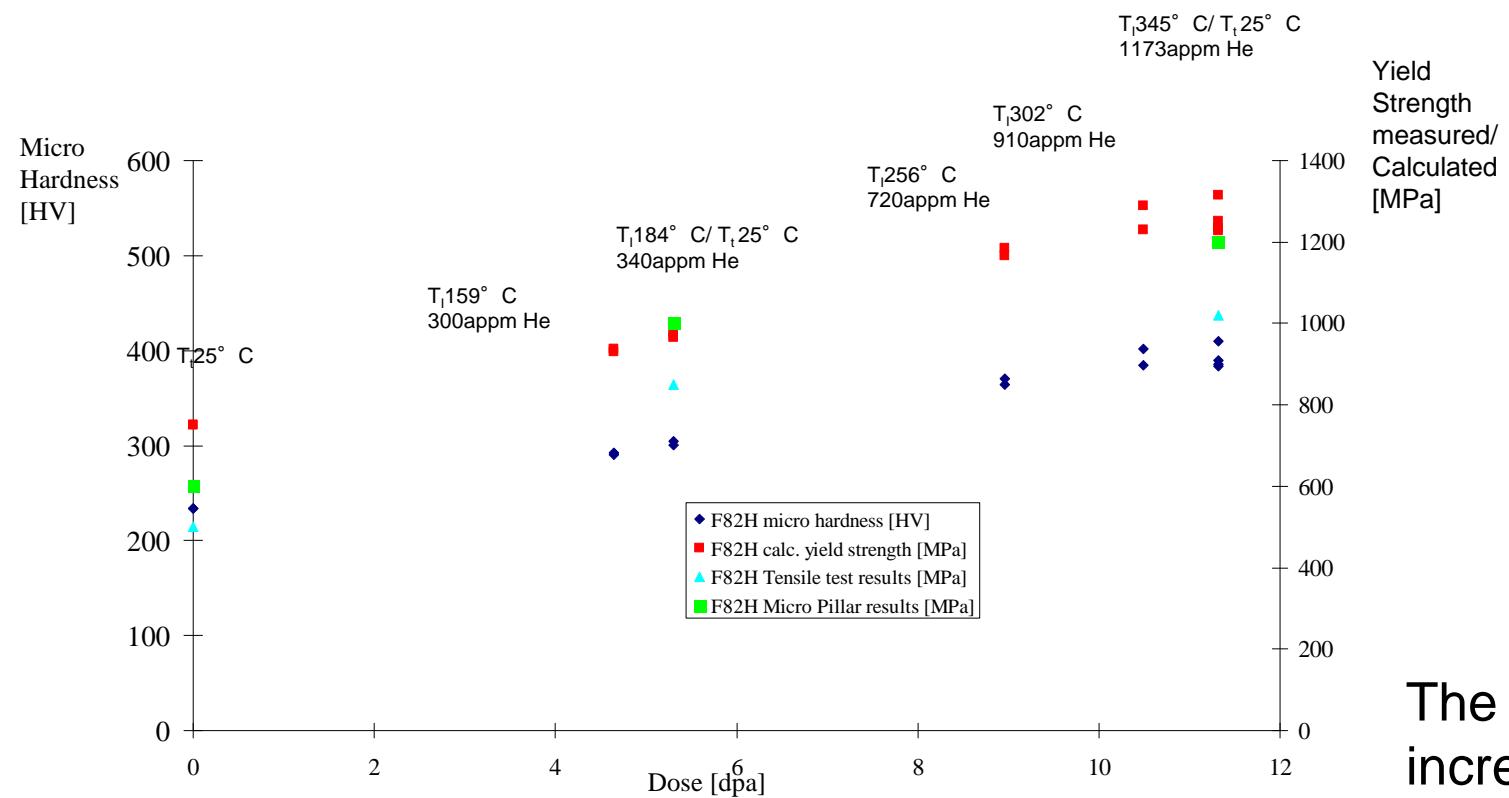
Nanoindentation/size effects on STIP irradiated F82H type specimen



H_0 =is the hardness that would arise from the statistically stored dislocations alone, in the absence of any geometrically necessary dislocations

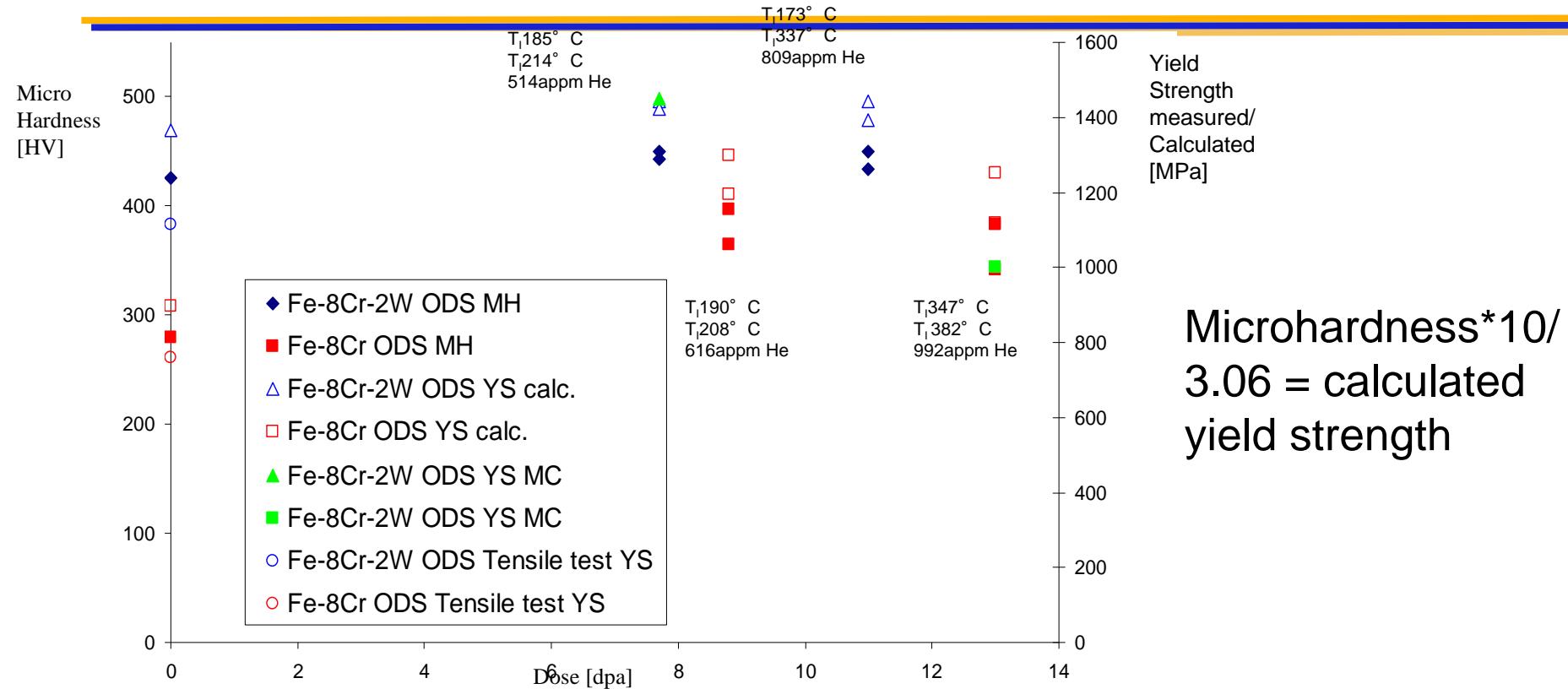
h^* =is a length that characterizes the depth dependence of the hardness.

Micro and macro mechanical test results on F82H (Fe-8Cr-2W)



The strength increase shows a strong dose and He content dependence on F82H

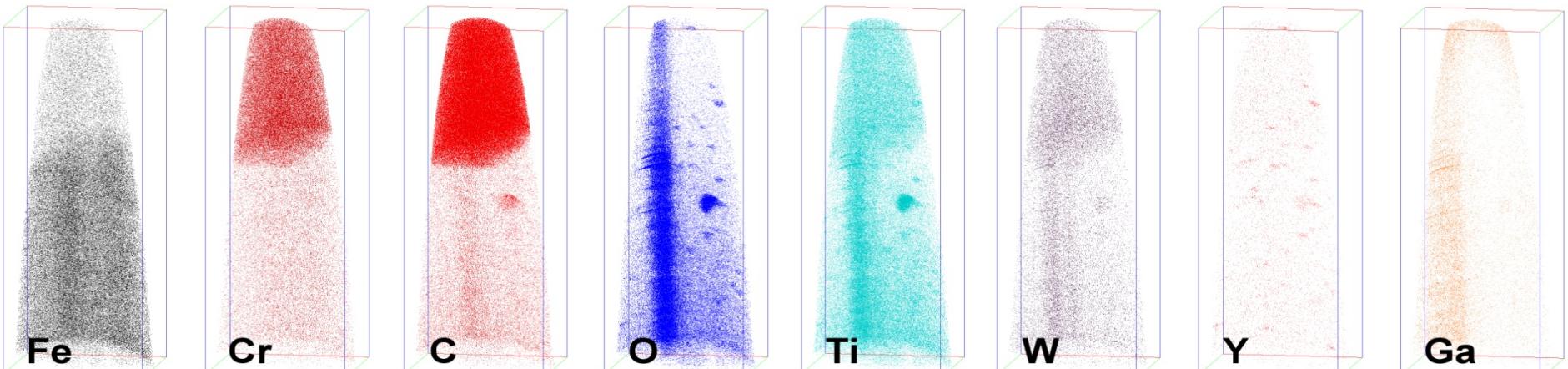
Micro and macro mechanical test results on F82H ODS with W and without W.



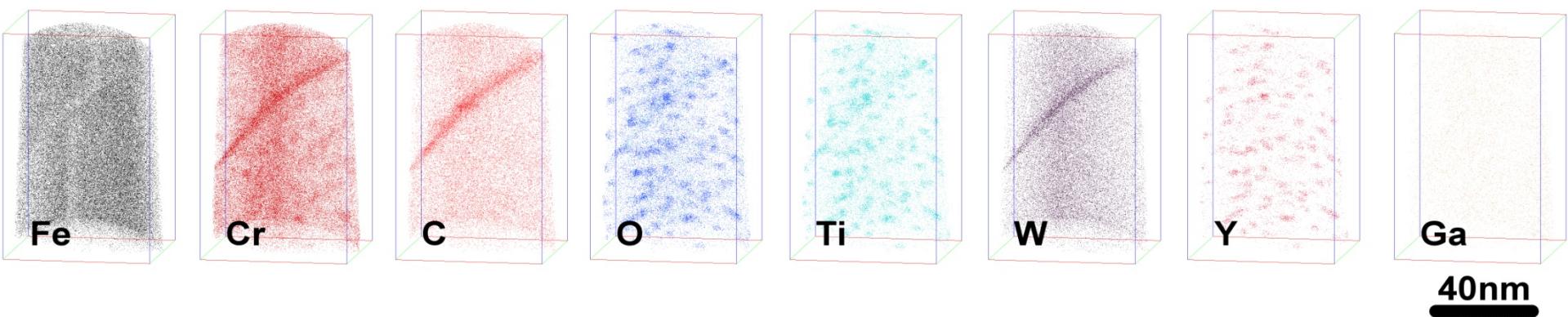
Very little change in YS and hardness
due to irradiation on the F82H ODS
alloy

Results on LEAP measurements of F82H ODS

F82H ODS no W

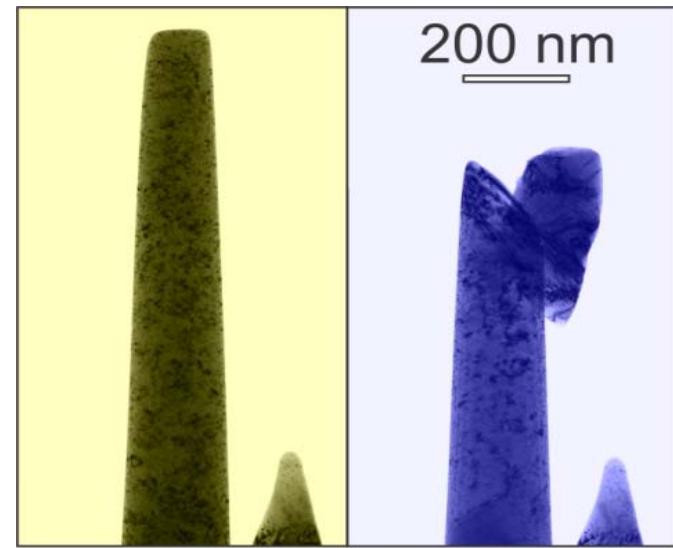
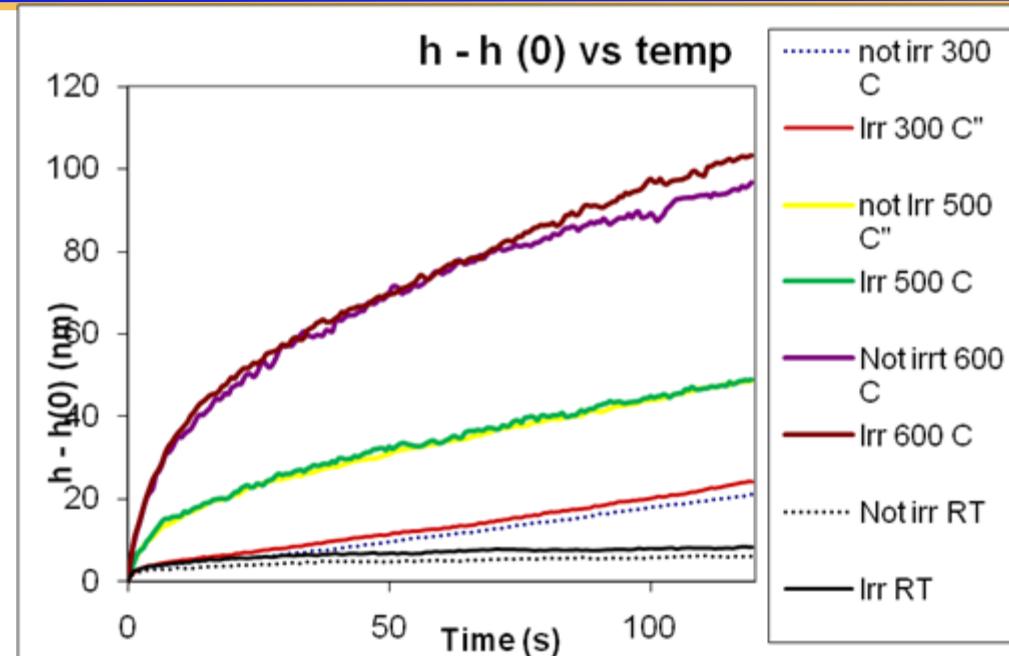


F82H ODS



Current and future work on small scale testing for spallation application

- Influence of irradiation on creep investigated using indentation creep. Initial results on PM2000 appear to show a strong effect.
- Nanoscale mechanical testing: how small can we go. In-situ mechanical testing on Cu is performed.
- Ion beam irradiation on intermetallic forming materials is conducted to answer the questions if we can use other particles than intermetallics to trap defects.



SUMMARY

- Small scale mechanical tests were performed and it can be shown that if done properly we can see the exact same trend in property changes due to irradiation in the small scale as in the large scale.
- Local Electron Atom Probe was performed on FIBed STIP samples. No radioactivity was measured. We could see segregation towards grain boundaries, and prove that the oxide particles are still present on a nm scale after irradiation.
- This work helps establish new advanced materials testing techniques for radioactive and ion beam irradiated samples.
- It was found that the ODS alloy shows virtually no changes in YS and hardness due to irradiation.
- LEAP shows clearly local Cr enrichment due to irradiation.

Acknowledgement



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Leoben, Austria**
*E. Stergar
H. Leitner*

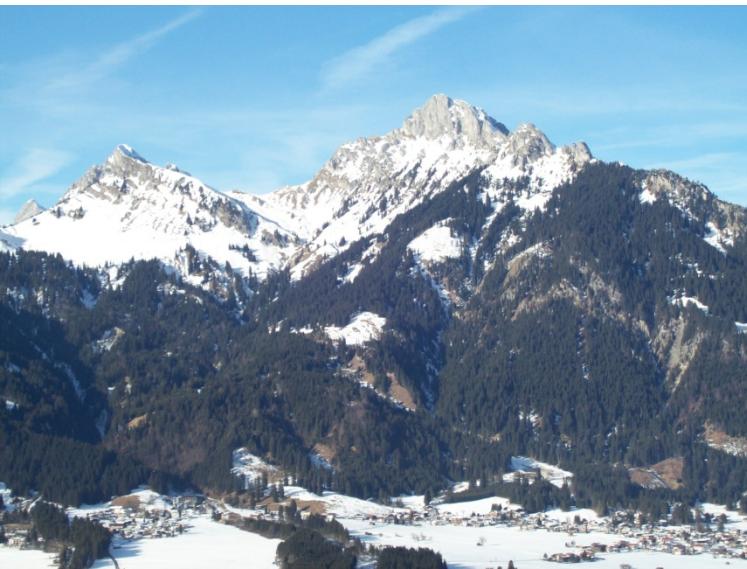
LANL

S.A. Maloy

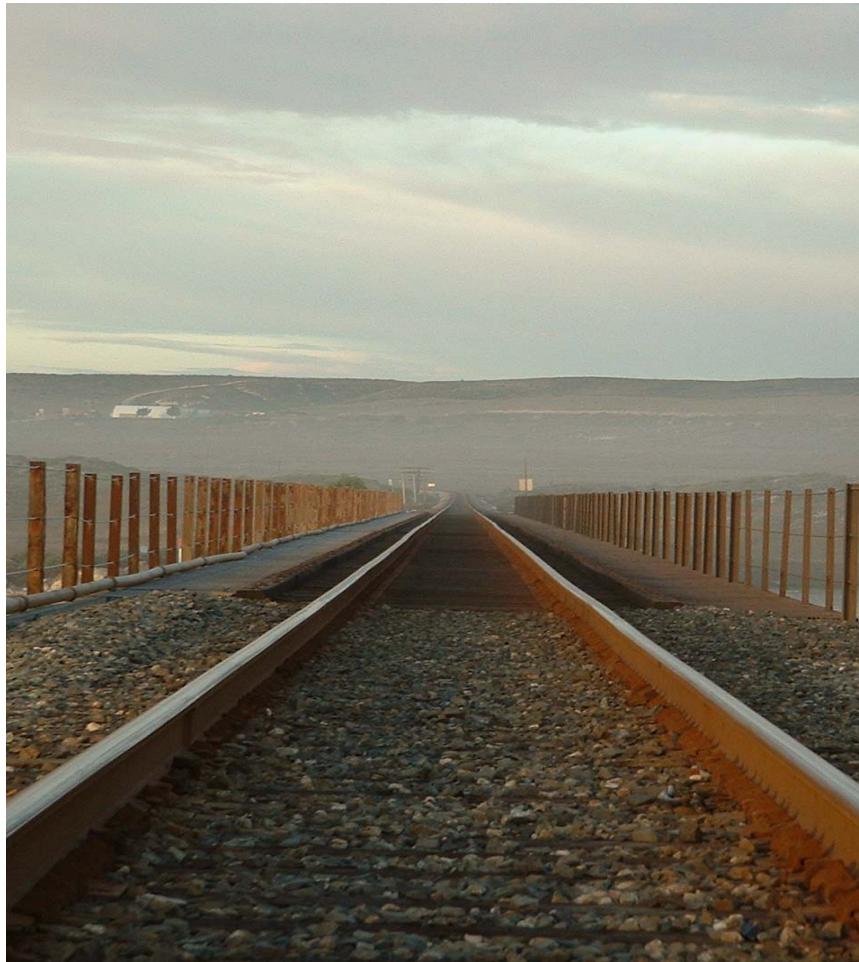
PSI

Y. Dai

R. Brun



Questions?

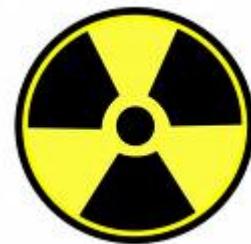


Materials property changes under irradiation

Various Phenomena can take place:

Creation of new isotopes

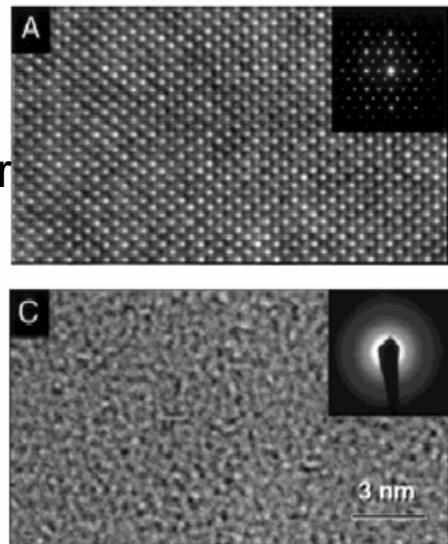
Swelling (volume increase due to irradiation)



Radiation induced hardening/embrittlement

Phase changes

Fe-Cr oxide spinel
before and after
irradiation



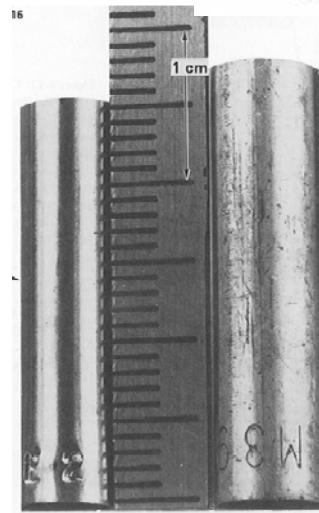
Wang et al. *J. Am. Ceram. Soc.*, **82** [12]
3321–29 (1999)



316L steel pipe after irradiation

D.L. Porter, F. A. Garner

J. Nuc. Mat. 159 (1988) 117-121



316L before and after
irradiation

L. Mansur *J. Nuc. Mat.* 216 (1994) 97