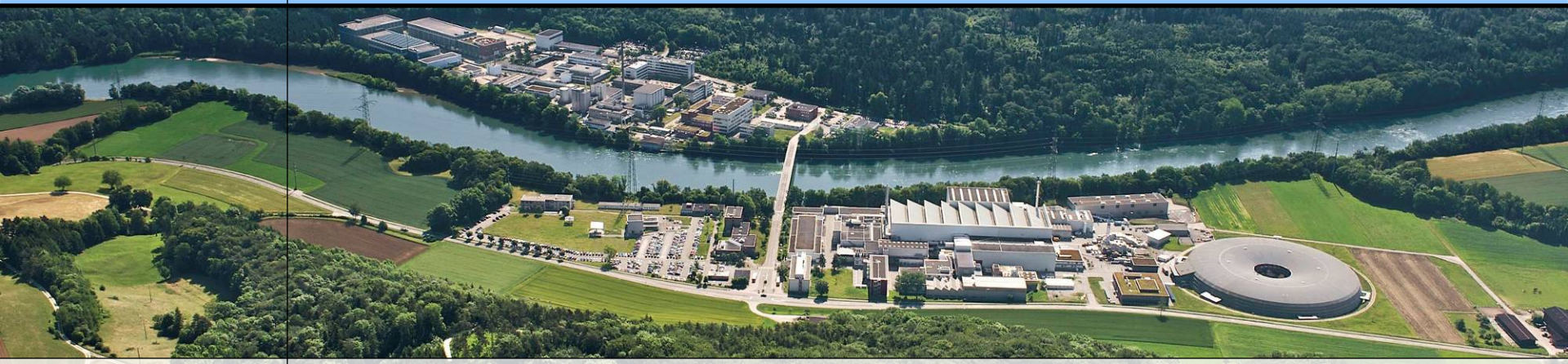
PAUL SCHERRER INSTITUT

PSI

The 12th International Workshop on Spallation Materials Technology
October 20 – 23, 2014, Bregenz, Austria



Wir schaffen Wissen – heute für morgen

Overview of Spallation Materials Research at the Paul Scherrer Institute

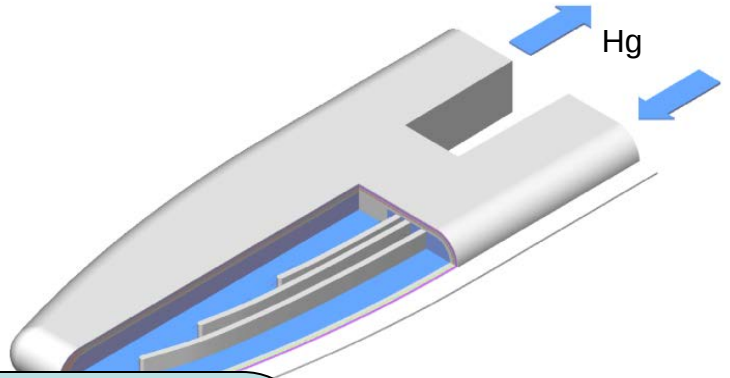
Yong Dai

Paul Scherrer Institut, Switzerland

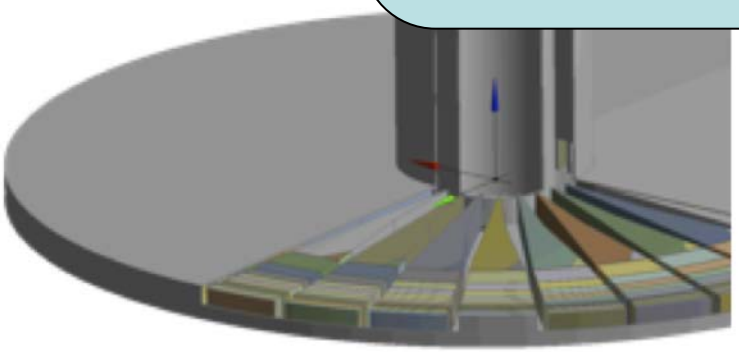
Laboratory for
Nuclear Materials

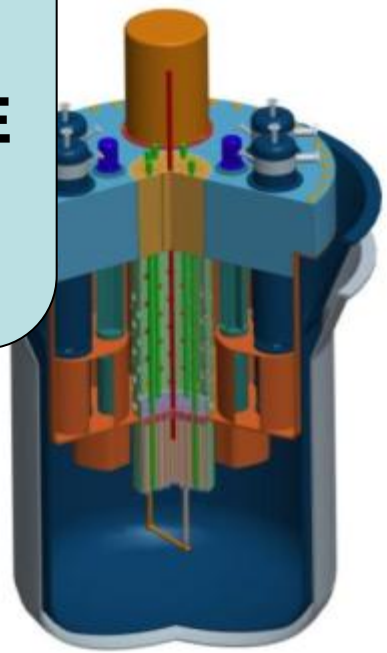
Nuclear Energy
and Safety

Main Materials Issues



- **Radiation damage**
- **Corrosion, erosion, LME**
- **Mechanical loading**





Main Materials Issues

Radiation damage

- High damage rate: 15 dpa/y
- Transmutation products: 100 appm He/dpa, 500 appm H/dpa, <1 appm P, S/dpa

Effects

- Change in chemical composition
- Change in physical properties
  - thermal conductivity
- Change in microstructure
  - defect clusters, dislocation loops
  - cavities (bubbles, voids)
  - precipitates, GB segregation
- Change in mechanical properties
  - hardening and softening
  - embrittlement => reduction of ductility, fracture toughness, DBTT shift
- Change in dimension
  - swelling
  - irradiation creep

Investigations at PSI

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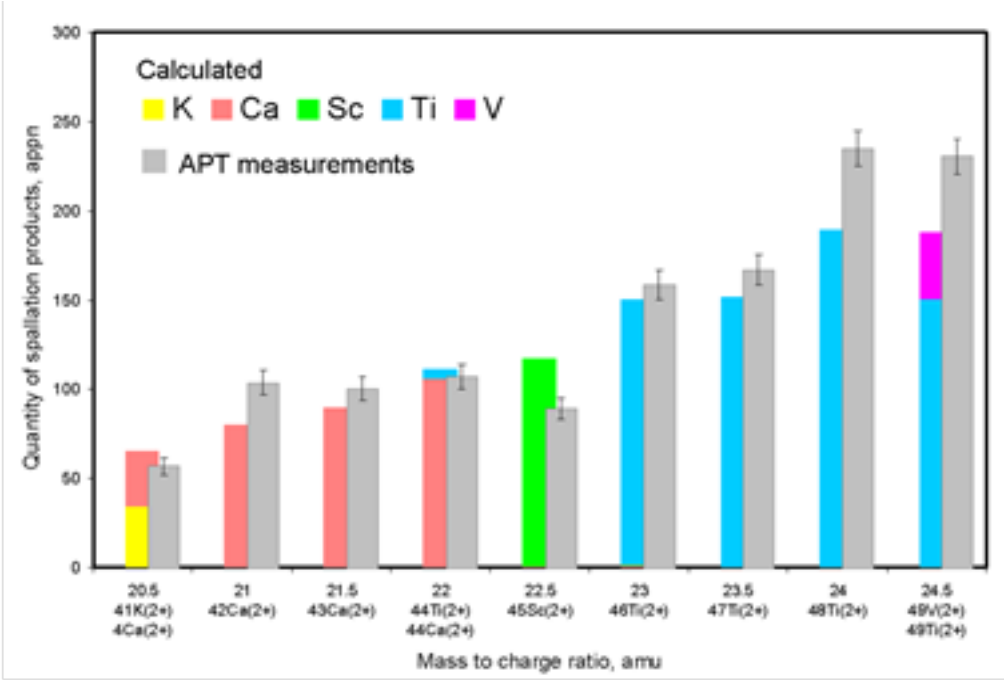
Investigations

- Gamma spectroscopy
- TDS analysis of He and H
- EDX analysis
- Atom probe analysis



Kuksenko, et al. JNM 447 (2014) 189

O5-2, C. Pareige (Tuesday)

Investigations at PSI

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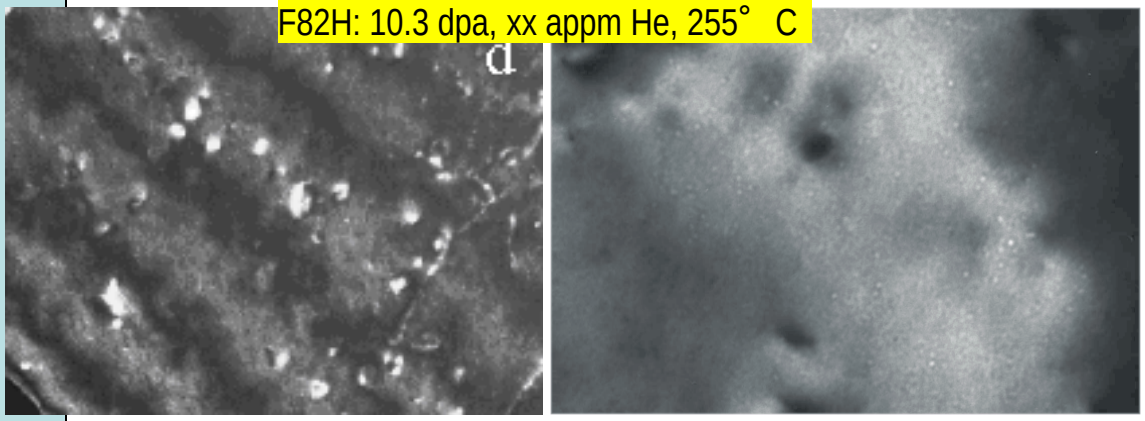
Investigations

- TEM observations
- PAS analysis
- APT analysis



Jia & Dai, JNM 305 (2002) 1

O5-1, K. Wang (Tuesday)
O10-2, C. Vieh (Wednesday)
O8-1, L. Peng, (Wednesday)
Poster 03, H. Ge
Poster 12, T.L. Sheng,
Poster 15, C. Vieh

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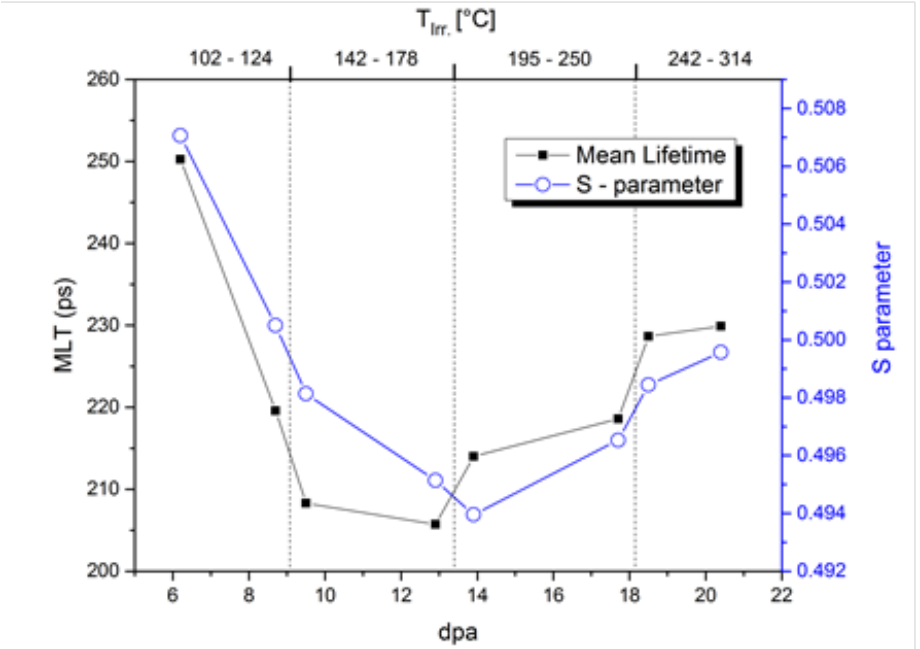

Krsjak, et al. , JNM in print

O10-3, K. Sato (Wednesday) O10-4, V. Krsjak, (Wednesday)
O8-4, H. Ge (Wednesday) Poster 03, H. Ge Poster 05, K. Krsjak

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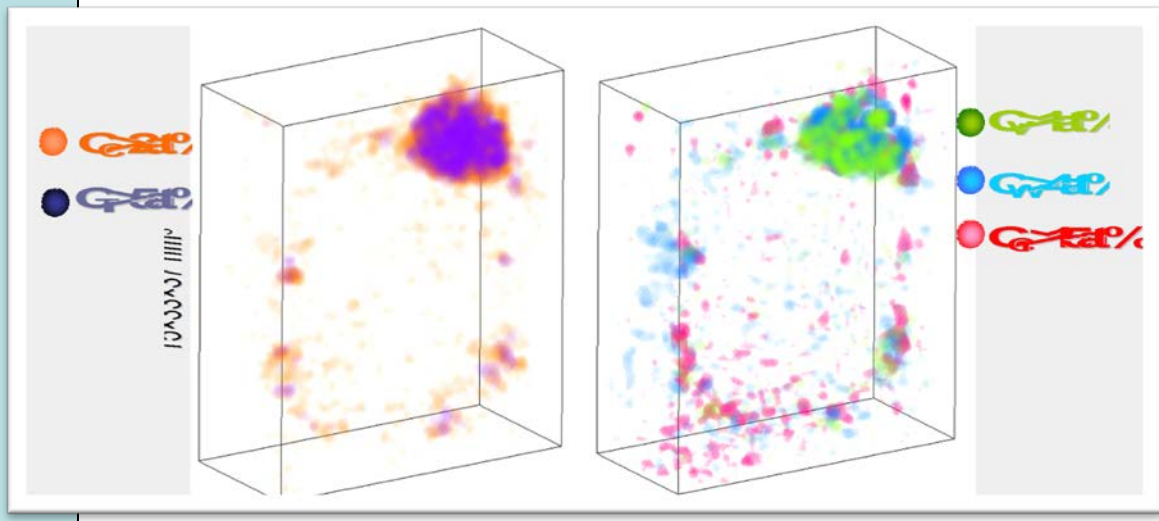

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O5-2, C. Pareige (Tuesday)

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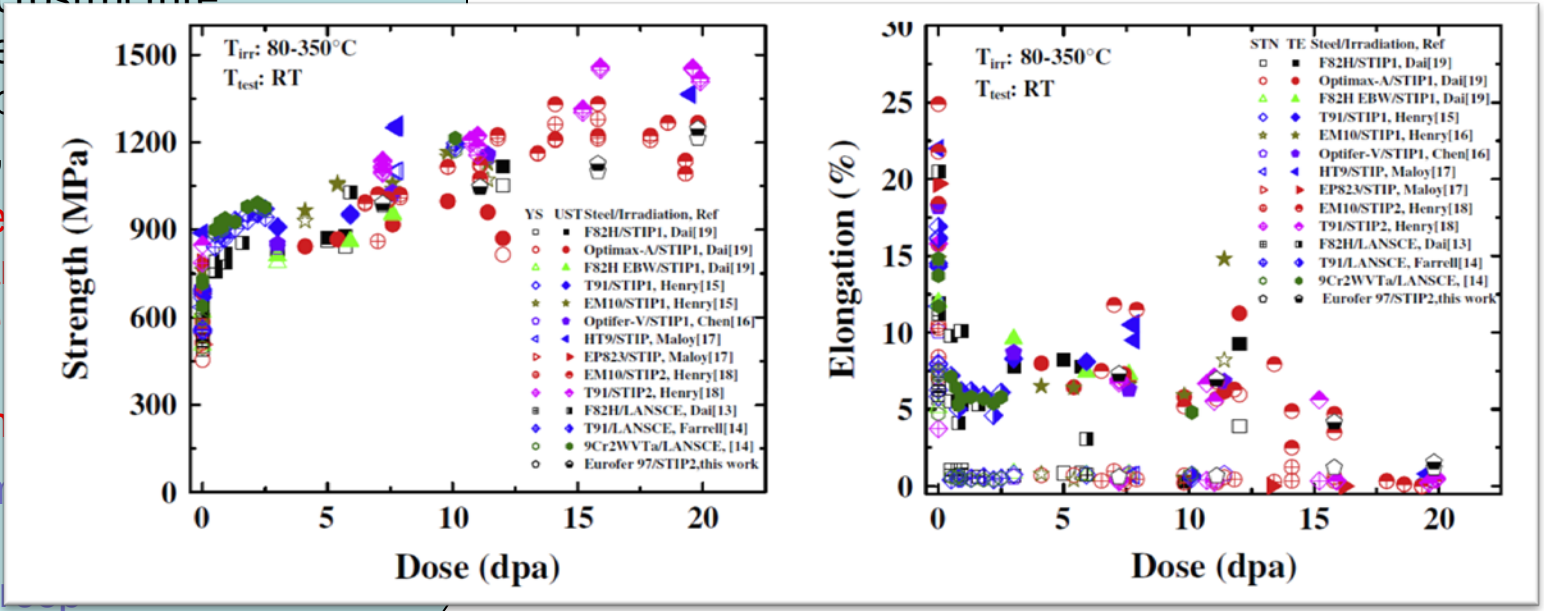
- Tensile test
- Hardness measurement
- 3 Point Bend test (fracture toughness)
- Small Punch, Charpy impact tests



Zhang, et al. , JNM 450 (2014) 48

O5-1, K. Wang (Tuesday), O6-3, T.L.. Sheng (Tuesday)
O8-1, L. Peng (Wednesday), Poster 03, H, Ge, Poster 10, L. Peng

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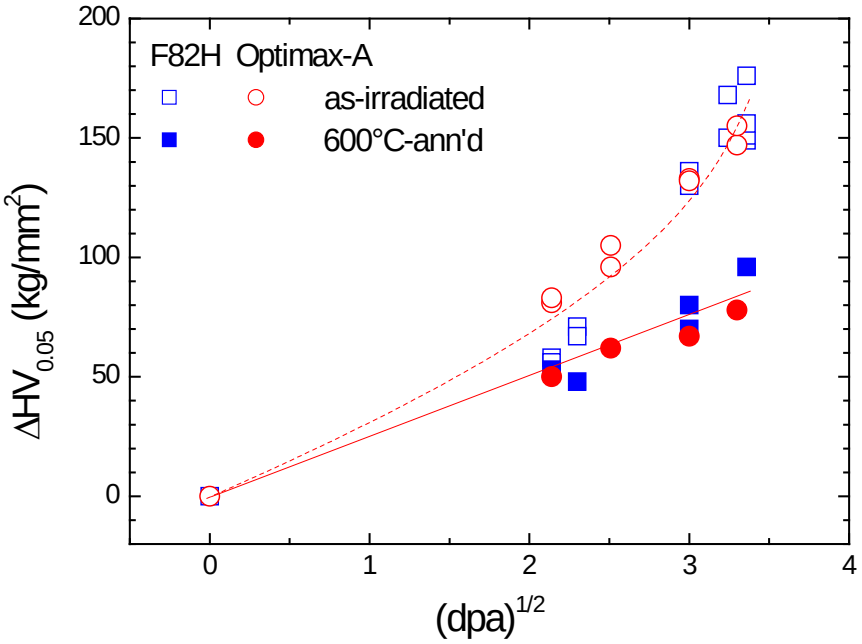

Peng, Dai, JNM 396 (2011)

O10-2, C. Vieh (Wednesday), O10-4, H. Ge (Wednesday),
O8-1, L. Peng (Wednesday), Poster 03, H, Ge, Poster 10, L. Peng

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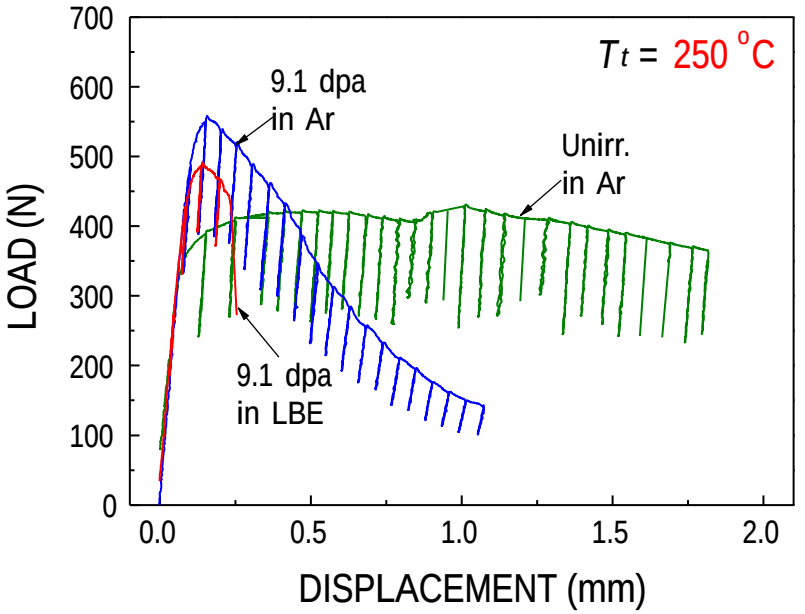

Long, EPFL PhD Thesis No 4355 (2008)

O6-3, T.L. Sheng (Tuesday)

Investigations at PSI

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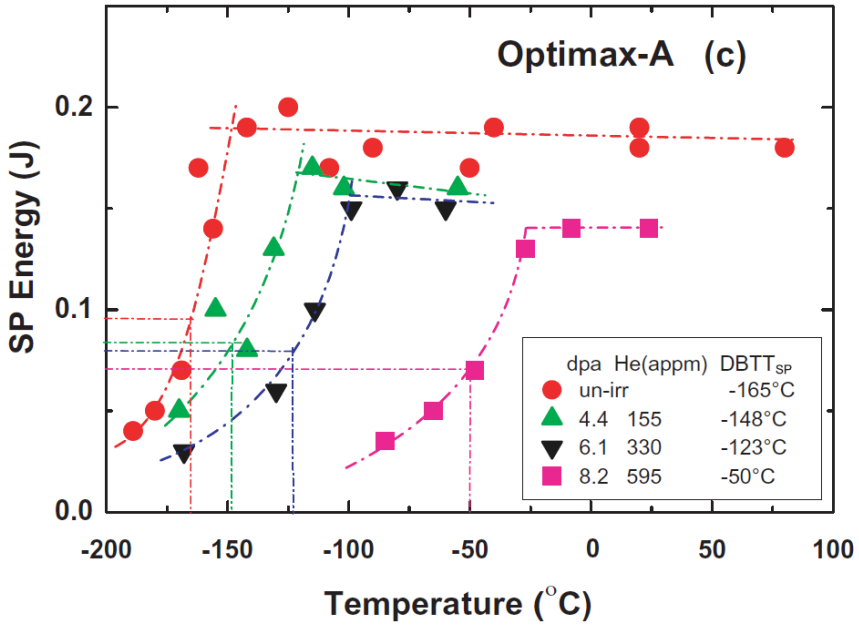
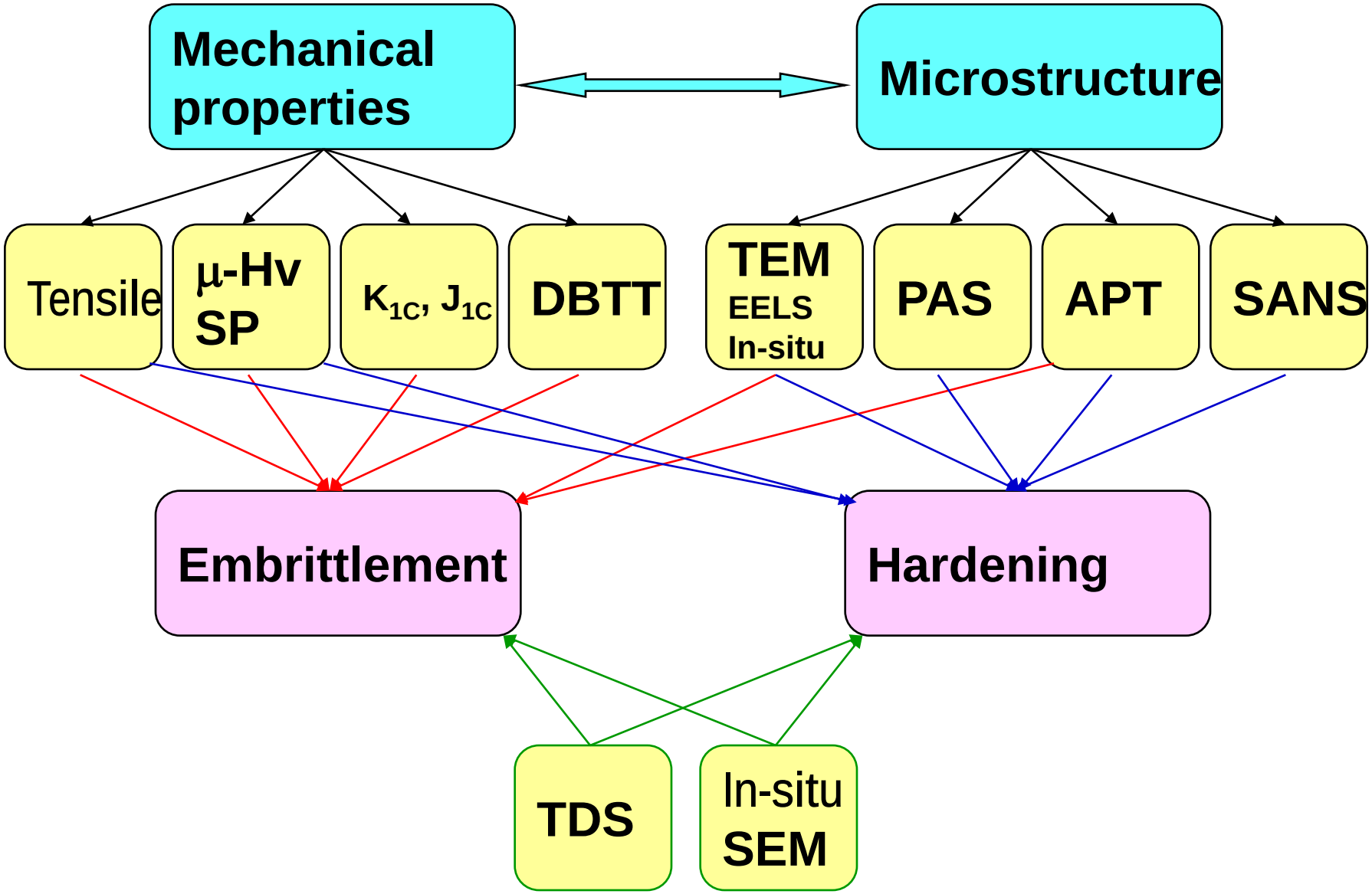


Jia, Dai, JNM 323 (20003) 60

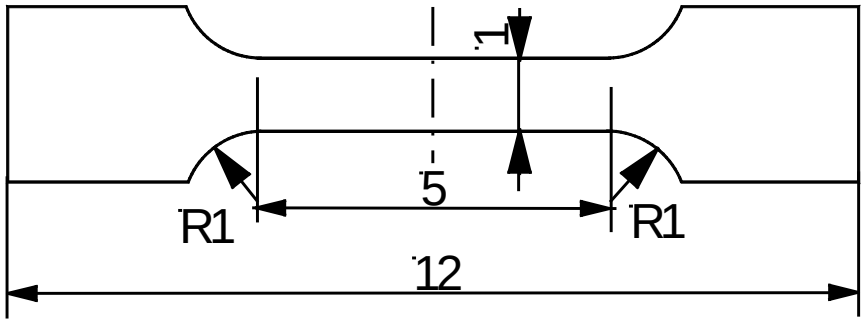
O8-4, H. Ge (Wednesday)

Understanding hardening and embrittlement effects



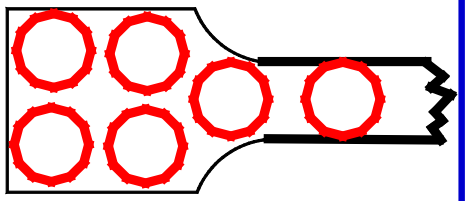
Understanding hardening and embrittlement effects

As-irradiated



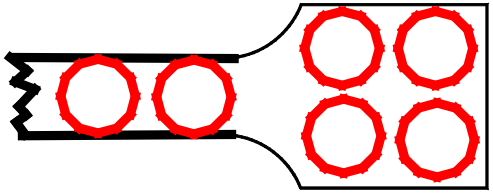
Density
PAS
APT
Hardness
(SANS on 16x4 mm sample)

Tested



SEM
TEM
(TDS)

Tested / Annealed



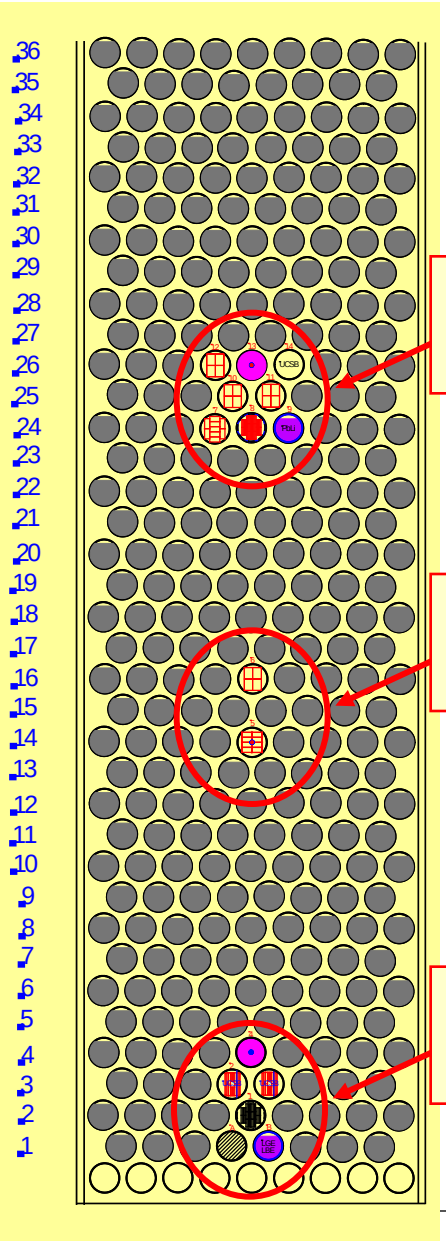
TEM
PAS
APT
Hardness
(Density)

Overview of STIP

Materials	STIP-I 1998-99	STIP-II 2000-01	STIP-III 2002-03	STIP-IV 2004-05	STIP-V 2007-08	STIP-VI 2011-12	STIP-VII 2013-14
Austenitic steels	≤ 12 dpa ≤ 400°C	≤ 20 dpa ≤ 400°C	≤ 20 dpa ≤ 400°C	≤ 25 dpa < 400°C(?)	≤ 25 dpa ≤ 400°C	≤ 28 dpa ≤ 600°C	≤ 30 dpa 600°C
FM steels (FMS)	≤ 12 dpa ≤ 360°C	≤ 20 dpa ≤ 400°C	≤ 20 dpa ≤ 800°C	≤ 25 dpa < 600°C(?)	≤ 20 dpa ≤ 400°C	≤ 28 dpa 600°C	≤ 30 dpa 600°C
FMS-ODS		≤ 20 dpa < 400°C	≤ 20 dpa ≤ 800°C	≤ 25 dpa < 600°C(?)	≤ 20 dpa ≤ 600°C	≤ 28 dpa ≤ 600°C	≤ 30 dpa 600°C
Al-alloy	≤ 3 dpa ≤ 60°C	≤ 6 dpa ≤ 60°C				Yes	Yes
Zr-alloy / Ti-alloy	≤ 22 dpa < 300°C	≤ 35 dpa < 300°C	≤ 35 dpa < 300°C	Yes			Yes
W, Mo, Ta alloys	Yes (no results)	Yes (no results)		Yes	Yes ≤ 800°C	Yes ≤ 500°C	Yes 500°C
SiCf/SiC, CMC		Yes (to be tested)		Yes	Yes 800°C		

Some samples irradiated in contact with liquid metals.

RAFMS irradiated in STIP-VI (2011-12)



Materials	Tensile S	Tensile L	HT-1/3 CVN	KLST Charpy	SP	TEM	Other types	Supplier	Sum	Irr Zone	Intended irr. Temp (°C)
Eurofer 97	44		12			18		PSI	74	1	250, 450
						18		PSI	18	2	250, 450
			12			18		PSI	30	3	250, 450
CLAM	73		8					ASIPP	81	1	300, 450
			8			12		ASIPP	20	3	300, 450
CLAM HIP			8					ASIPP	8	3	300, 450
CLAM-EBW	12					12		ASIPP	24	3	300, 450
CLAM HIP			8					ASIPP	8	3	300, 450
F82H-IEA							16	UCSB	16	1	300, 600
							13	UCSB	13	3	300, 600
F82H-mod3							20	UCSB	20	1	300, 600
							18	UCSB	18	3	300, 600
F82H-TiG							9	UCSB	9	1	300, 600
							8	UCSB	8	3	300, 600
NF616							33	UCSB	33	1	300, 600
							6	UCSB	6	3	300, 600
ODS-15CRA-3	20							PSI	20	1	300, 600
ODS-SOCP-3	50	30						PSI	80	1	300, 600
ODS Eurofer-PL	50	20	12			18		PSI	100	1	300, 600
			6			18		PSI	24	3	300, 600
12CrWTi ODS						18		PSI	18	1	300, 600
						18		PSI	18	2	300, 600
						18		PSI	18	3	300, 600
UP ODS		20	24	16		24		CRPP	84	3	300, 600
MA957							69	UCSB	69	1	300, 600
							9	UCSB	9	3	300, 600
15Cr-Kimura							14	UCSB	14	1	300, 600
14YWT1150-UCSB							22	UCSB	22	1	300, 600
								Total	862		


Thank you