

SINQ Target Irradiation Program STIP

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PSI: *X. Jia, R. Thermer, D. Hamaguchi, B. Long
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Hotlab members*

CEA: *J. Henry*

FZJ: *G.S. Bauer, J. Chen, F. Carsughi, H. Ullmaier*

JAERI: *K. Kikuchi*

LANL: *S.A. Maloy, M.R. James*

ORNL: *L.K. Mansur, K. Farrell*

Others: *M.S. Wechsler, W. Lu, Y. Foucher, H. Hou*

Outline

- Introduction
- Irradiation
- Few results
- Outlook

Introduction

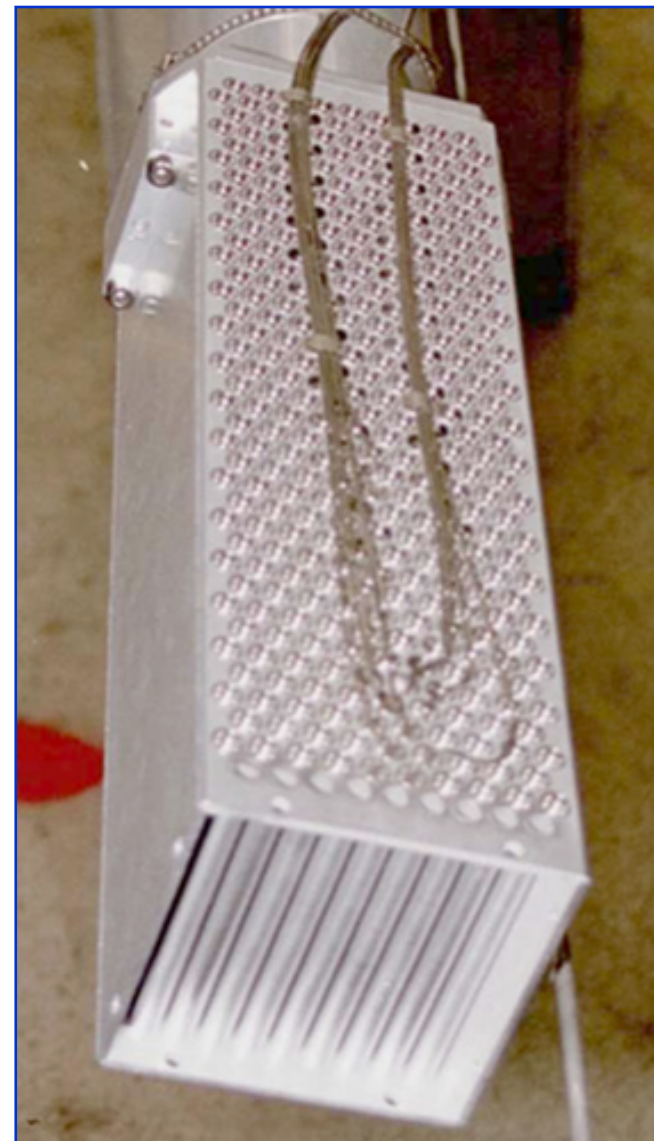
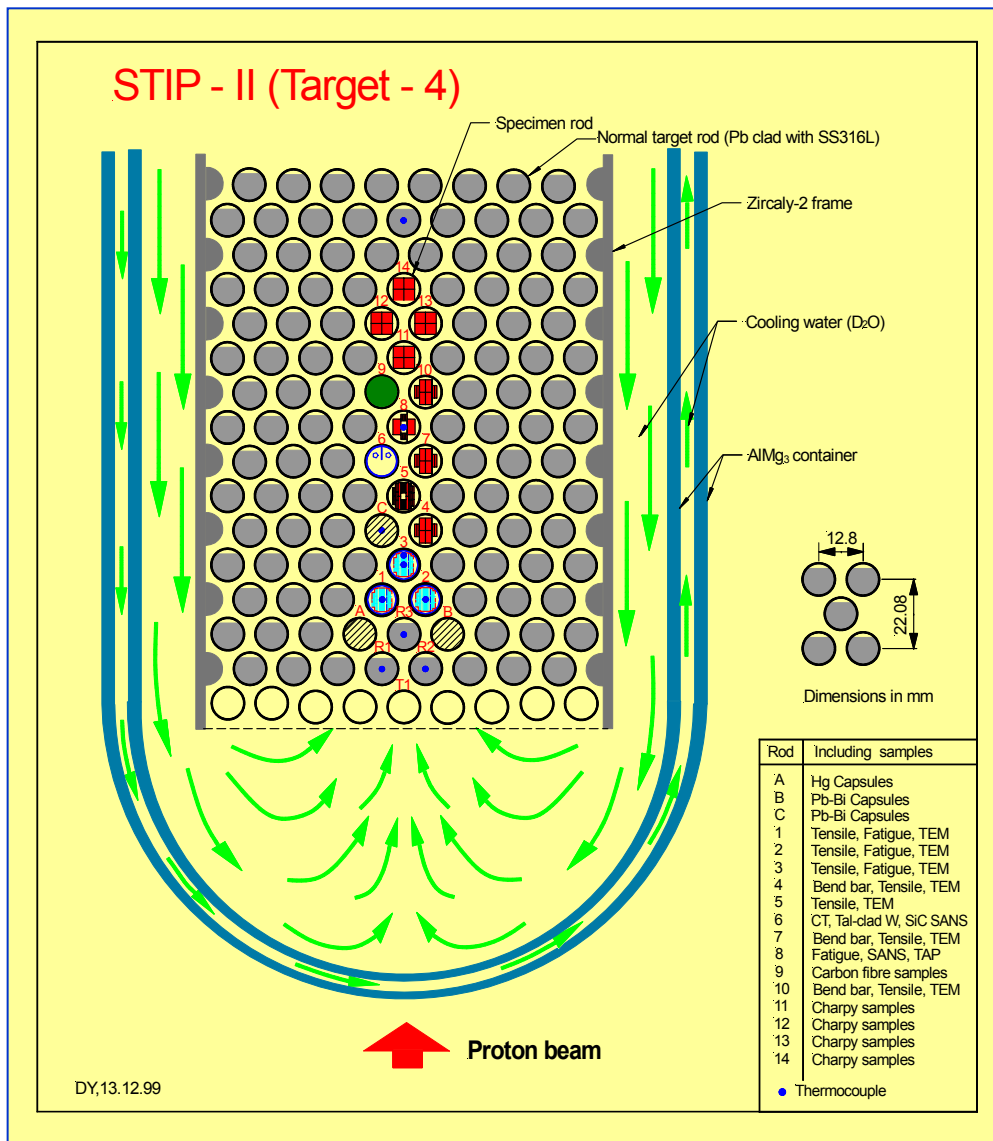
- ✧ SINQ Target Irradiation Program (STIP) was setup by G.S. Bauer in 1996 in Oak Ridge, joined by CEA, FZJ, JAERI, LANL and ORNL to irradiated test samples in SINQ (solid) targets.
- ✧ Now, the collaboration has been greatly enlarged, including CIAE(ADS), CSNS, CRPP/EPFL (fusion), LWV/PSI (Gen-4), UCSB (fusion).
- ✧ The goal: -- to establish necessary data base of mechanical properties of different structural and target materials;
-- to understand the changes in structural and target materials after irradiation under spallation spectrum in different environments in wide temperature range.

Introduction

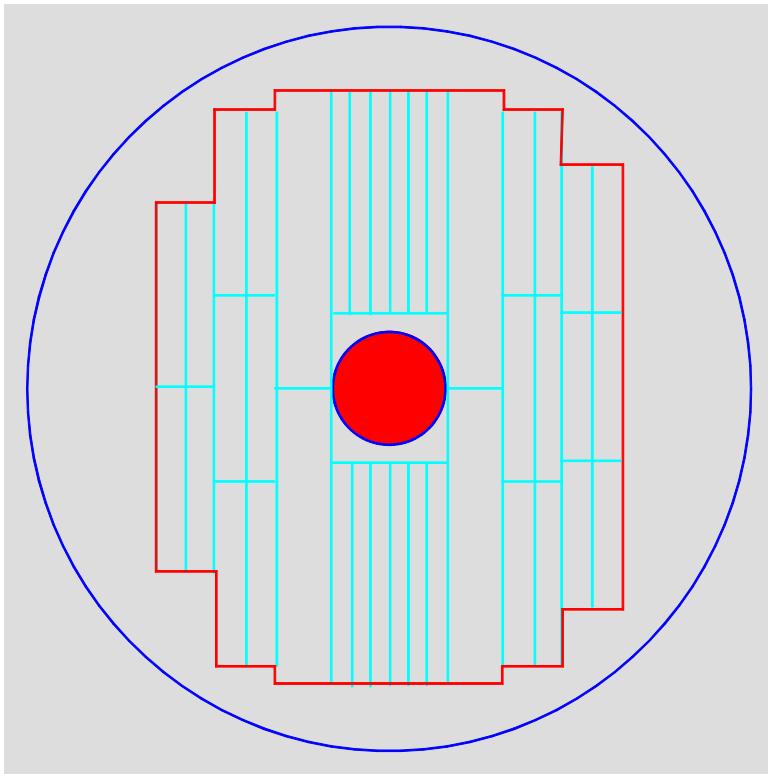
Activities up to date

Year	Preparation	Irradiation	Retrieving / Shipping	PIE
1997	STIP-I			
1998		STIP-I		
1999	STIP-II	STIP-I		
2000		STIP-II	STIP-I	
2001	STIP-III	STIP-II	STIP-I	STIP-I
2002		STIP-III	STIP-II	STIP-I
2003	STIP-IV	STIP-III	STIP-II	STIP-I, -II
2004		STIP-IV	STIP-II	STIP-I, -II
2005	STIP-V	STIP-IV	STIP-III	STIP-I, -II

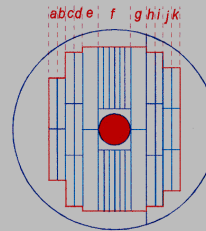
Irradiation



Irradiation



Rod 1



ID	Material	ID	Material	ID	Material
A	SA 316LN	M	EP823	Y	Au
B	CW 316	N	HT-9	Z	Pt
C	316LN EBW	O	MANET-II	IA	Nb
D	JPCA	P	MANET EBW	IB	Ta
E	Alloy 800H	Q	MA 957 (ODS)	IC	Cr
F	T91	R	MA 956 (ODS)	ID	W/Nb
G	EM10	S	Zircaloy-2	IE	W/Ta
H	EM10 EBW	T	Inc. 600	IF	W/Cr
I	Optifer-IX	U	Inc. 718 SPF	IG	W
J	Optifer EBW	V	Inc. 718 Ann	IH	SiC/SiC
K	F82H	W	Inc. 718 CW	IJ	Eurofer 97
L	F82H EBW	X	Inc. 718 EBW	IK	9Cr-1W/Ta

a	H 1 01 H 3 03 H 5 05 H 7 07 P 9 01 P 11 03 P 13 05 P 15 07	
b	L 1 01 L 3 03 L 5 05 L 7 07 J 9 01 J 11 03 J 13 05 J 15 07	
c	I 1 01 I 3 03 I 5 05 I 7 07 I 9 01 I 11 03 I 13 05 I 15 07	
d	IK 1 01 IK 3 03 IK 5 05 IK 7 07 IK 9 01 IK 11 03 IK 13 05 IK 15 07	
e	N 1 01 N 3 03 N 5 05 N 7 07 N 9 01 N 11 03 N 13 05 N 15 07	
f	Gr 1 01 Gr 3 03 Gr 5 05 Gr 7 07 Gr 9 01 Gr 11 03 Gr 13 05 Gr 15 07	
g	K 1 01 K 3 03 K 5 05 K 7 07 K 9 01 K 11 03 K 13 05 K 15 07	
h	F 1 01 F 3 03 F 5 05 F 7 07 F 9 01 F 11 03 F 13 05 F 15 07	
i	K 1 01 K 3 03 K 5 05 K 7 07 K 9 01 K 11 03 K 13 05 K 15 07	
j	IB 91 1 IB 92 3 IB 93 5 IB 94 7 IB 95 9 IB 96 11 IB 97 13 IB 98 15	
k	M 21 1 M 22 3 M 23 5 M 24 7 M 25 9 M 26 11 M 27 13 M 28 15	

Notes: (a) ID "10" was not marked on samples. Only numbers and with two lines at each end of gauge area were marked. "15" was marked as "15"!

(b) ID "R" was not marked on samples. Only numbers were "EDM" marked.

(c) "XID", X number of samples of material "ID".

Irradiation



Irradiation

- STIP-I:** More than 1200 samples were irradiated up to 12 dpa / 1100 appm He at $\leq 360^{\circ}\text{C}$.
- STIP-II:** More than 2000 samples were irradiated up to 20 dpa / 1800 appm He at $\leq 430^{\circ}\text{C}$.
- STIP-III:** About 800 samples were irradiated up to 21.8 dpa / 1950 appm He at $\leq \sim 500^{\circ}\text{C}$.
- STIP-IV:** About 1100 samples are being irradiated up to 20 dpa at $\leq \sim 600^{\circ}\text{C}$.

Irradiation

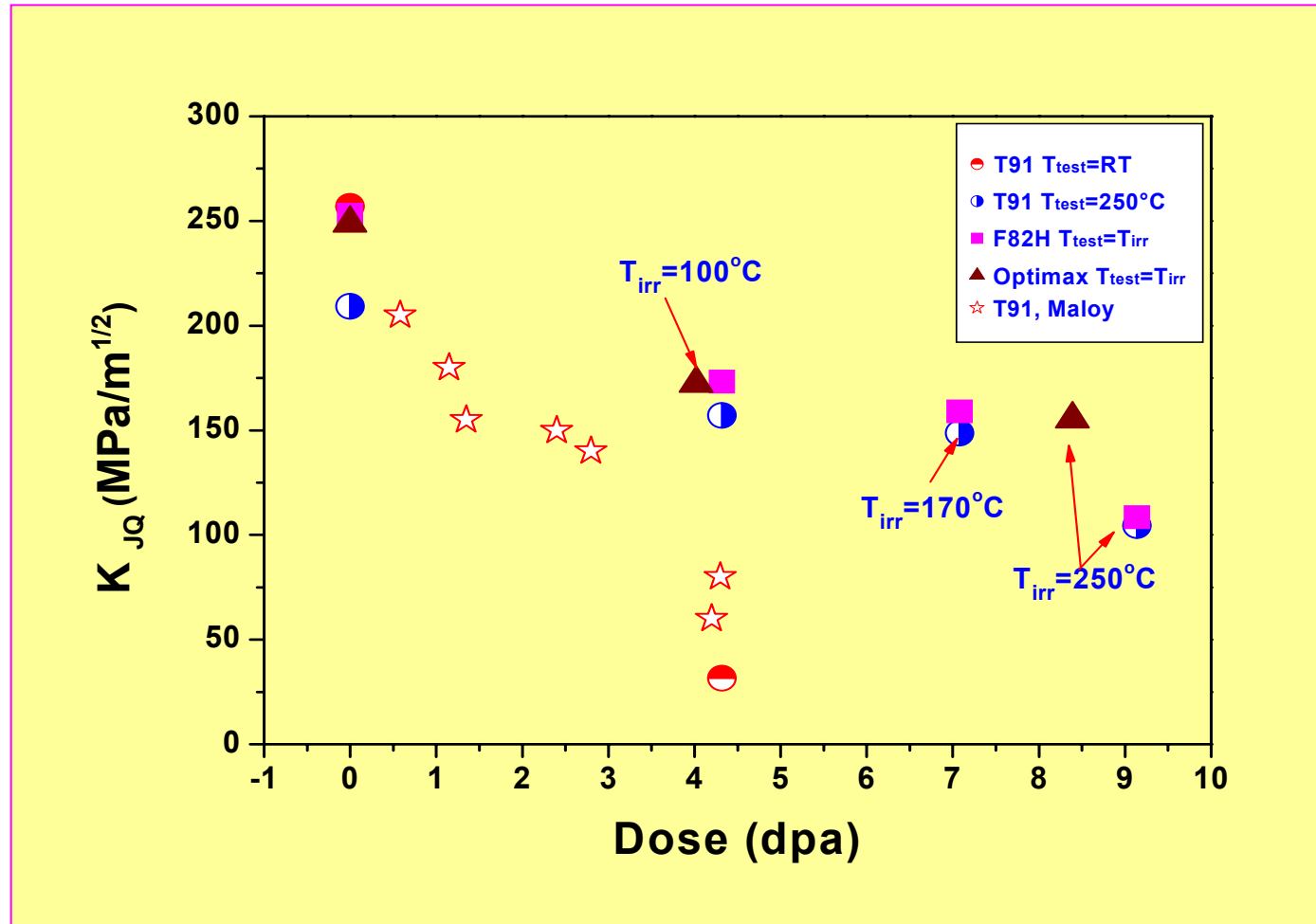
Materials / specimens irradiated up to $\sim 6 \times 10^{25}$ p/m² and 9×10^{25} n/m² (~ 22 dpa / 2000 appm He in steels)

Materials	Tensile $T_{\max}$ (°C)	Bend/Fracture $T_{\max}$ (°C)	Fatigue $T_{\max}$ (°C)	Impact $T_{\max}$ (°C)	TEM $T_{\max}$ (°C)
FM steels	430	400	400	350	450
FM steels ODS	450	450	400	400	450
SS 316L (LN)	400	300	300		430
Inconel 718	400	300	300		400
W, W-alloys	350				400
Ta	400	300	300	250	400
C-C/SiC, SiC/SiC		300			
Zircaloy-2	350		300		350
Au, Pt	400		300		400
AlMg3	60				60

Others: Au, Nb, Cu, Ni, Fe, Ti, Al, discs; Ta-clad-W rods; Graphite samples
Pb, PbBi, Hg

Few results

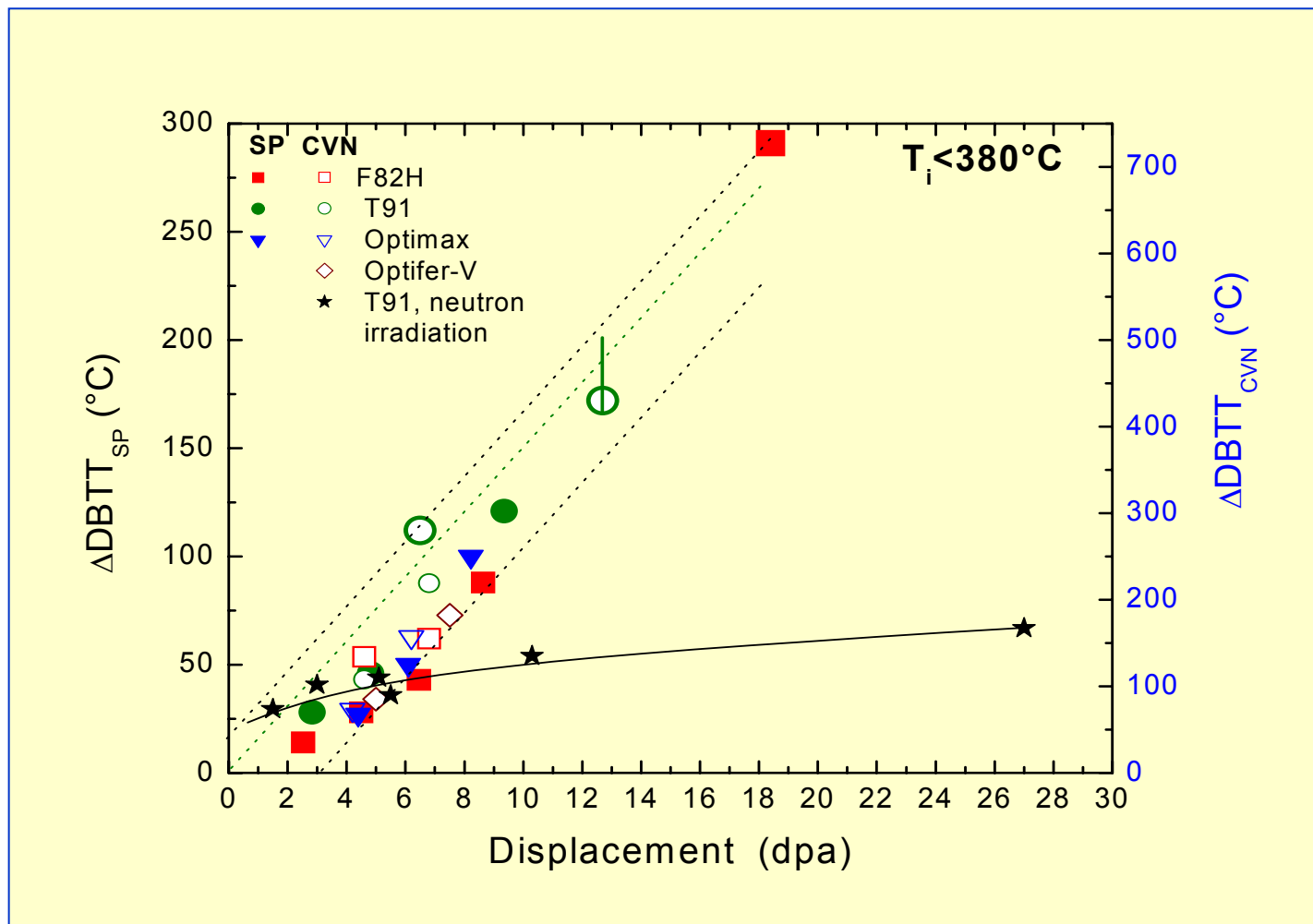
Fracture toughness of FM steels irradiated in STIP-I



Jia & Dai, IWSMT-7, Thun, 2005, to be published in JNM.

Few results

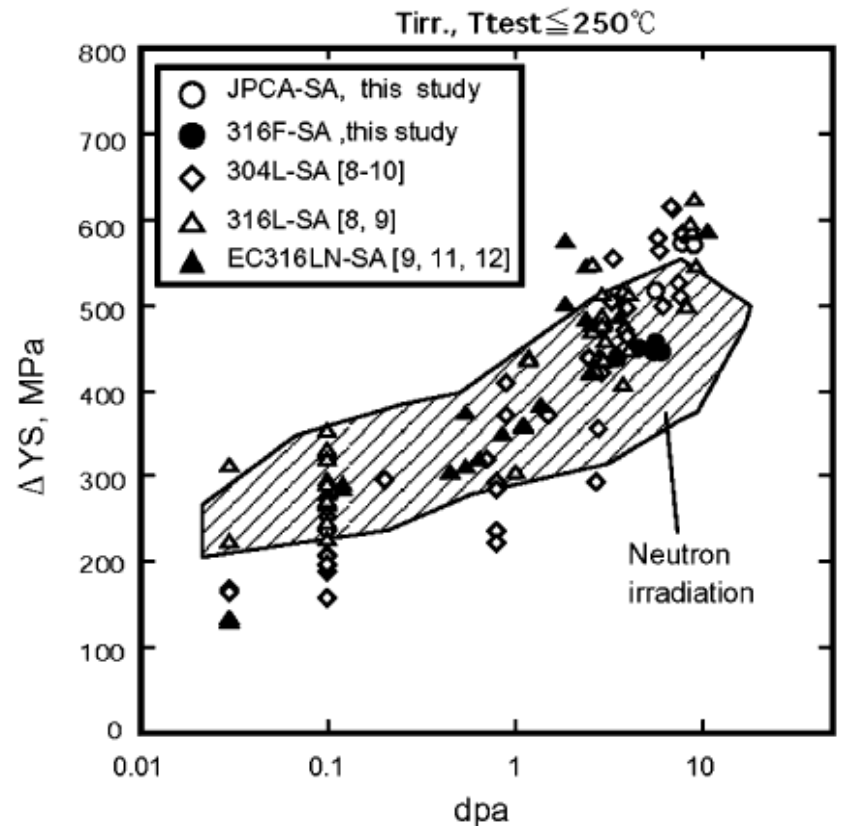
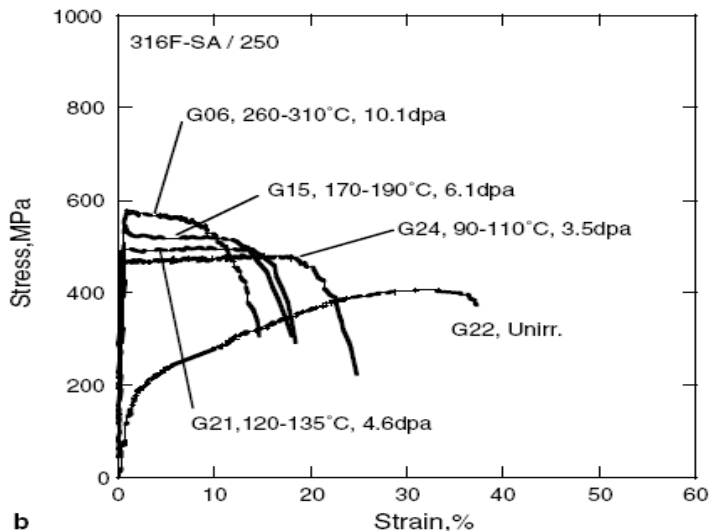
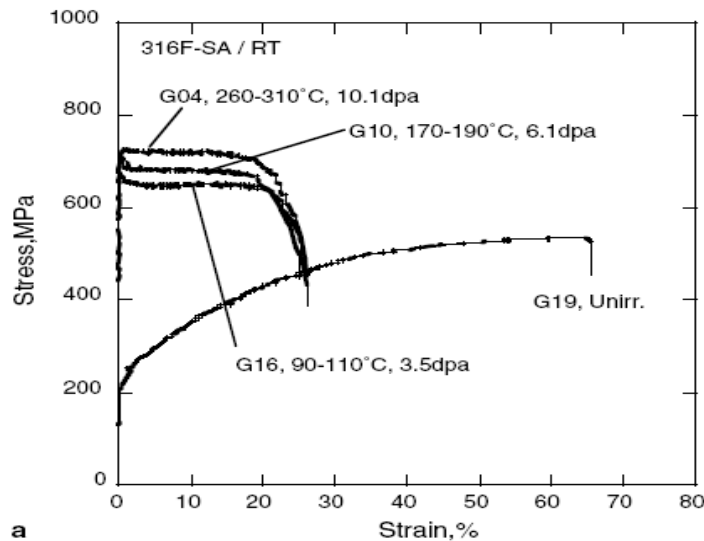
DBTT shift of FM steels irradiated in STIP-I and -II



Neutron irradiation data from Klueh et al, J. Nucl. Mater. 218 (1995) 151.

Few results

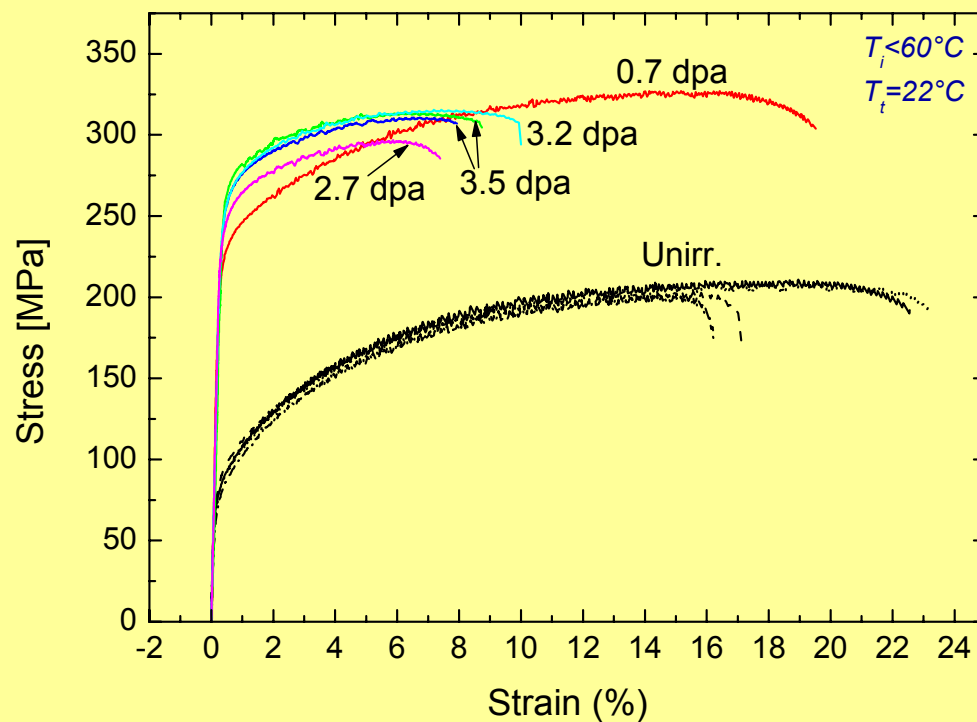
Tensile curves of SA 316F irradiated in STIP-I, - JAERI



Saito, et al. JNM 343 (2005) 253.

Few results

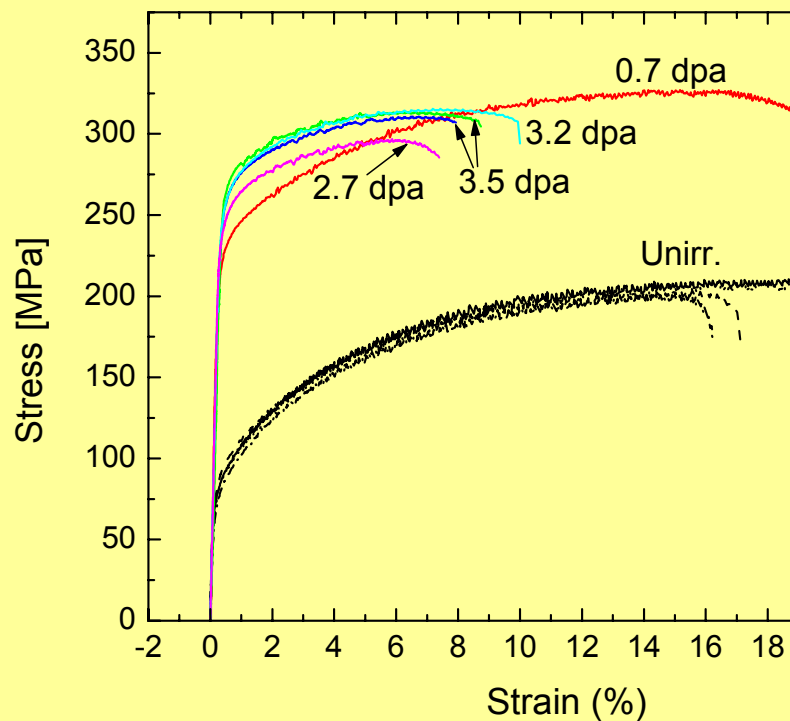
Tensile curves of AlMg₃ irradiated in STIP-I



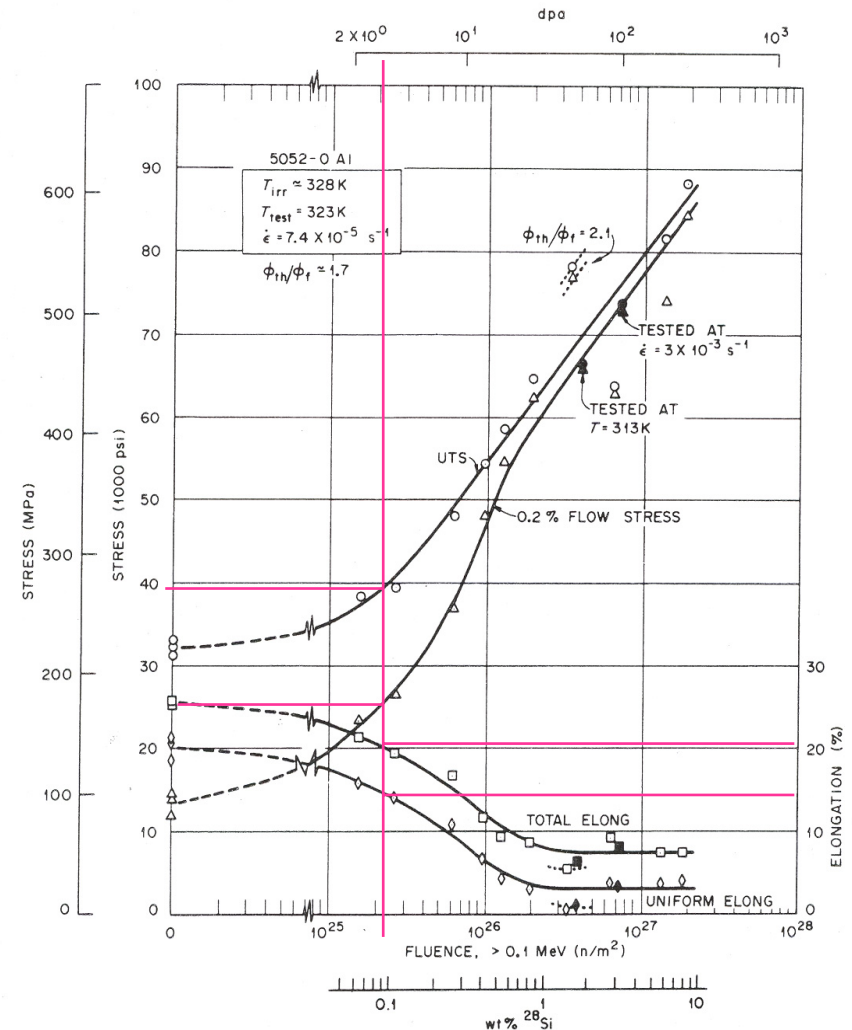
Dai & Hamaguchi, JNM 343 (2005) 184

Few results

Tensile curves of AlMg₃ irradiated in STIP-I



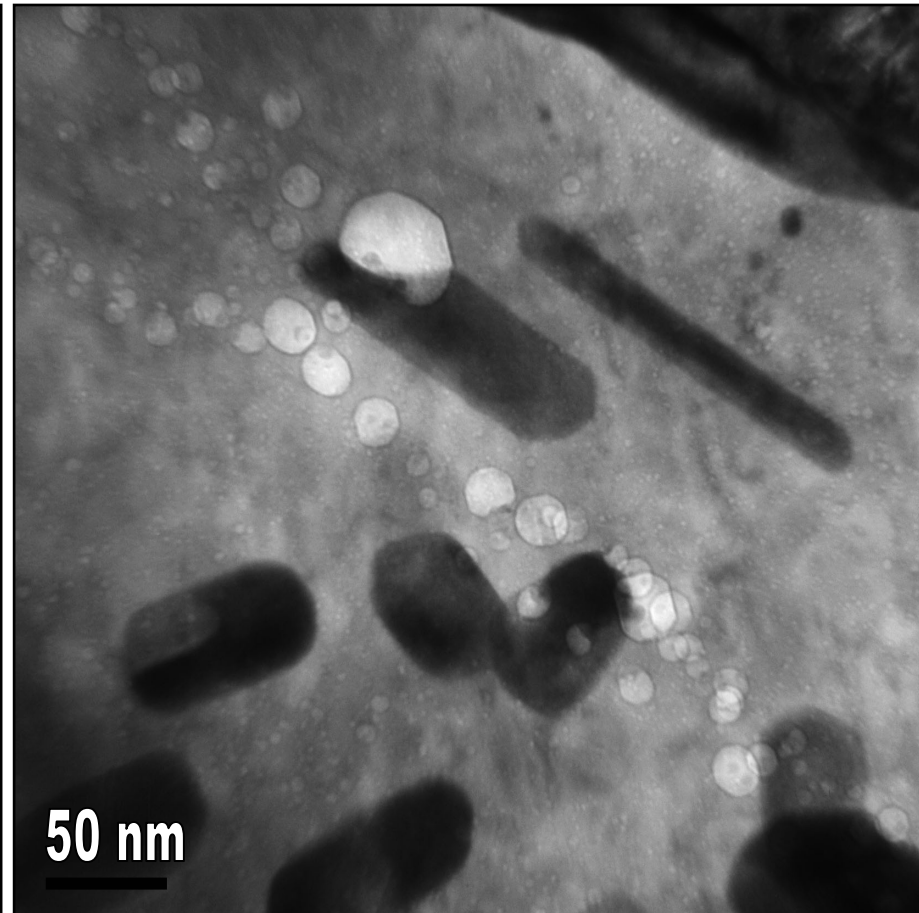
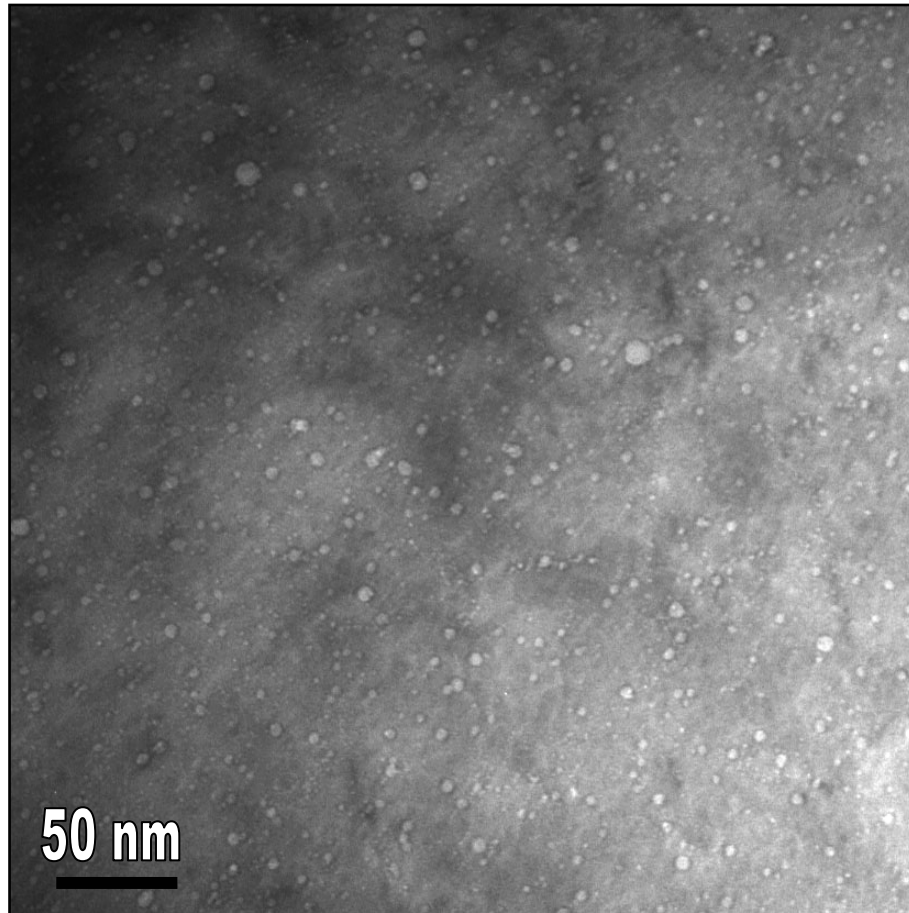
Dai & Hamaguchi, JNM 343 (2005) 184



Few results

TEM observations on microstructure in F82H steel

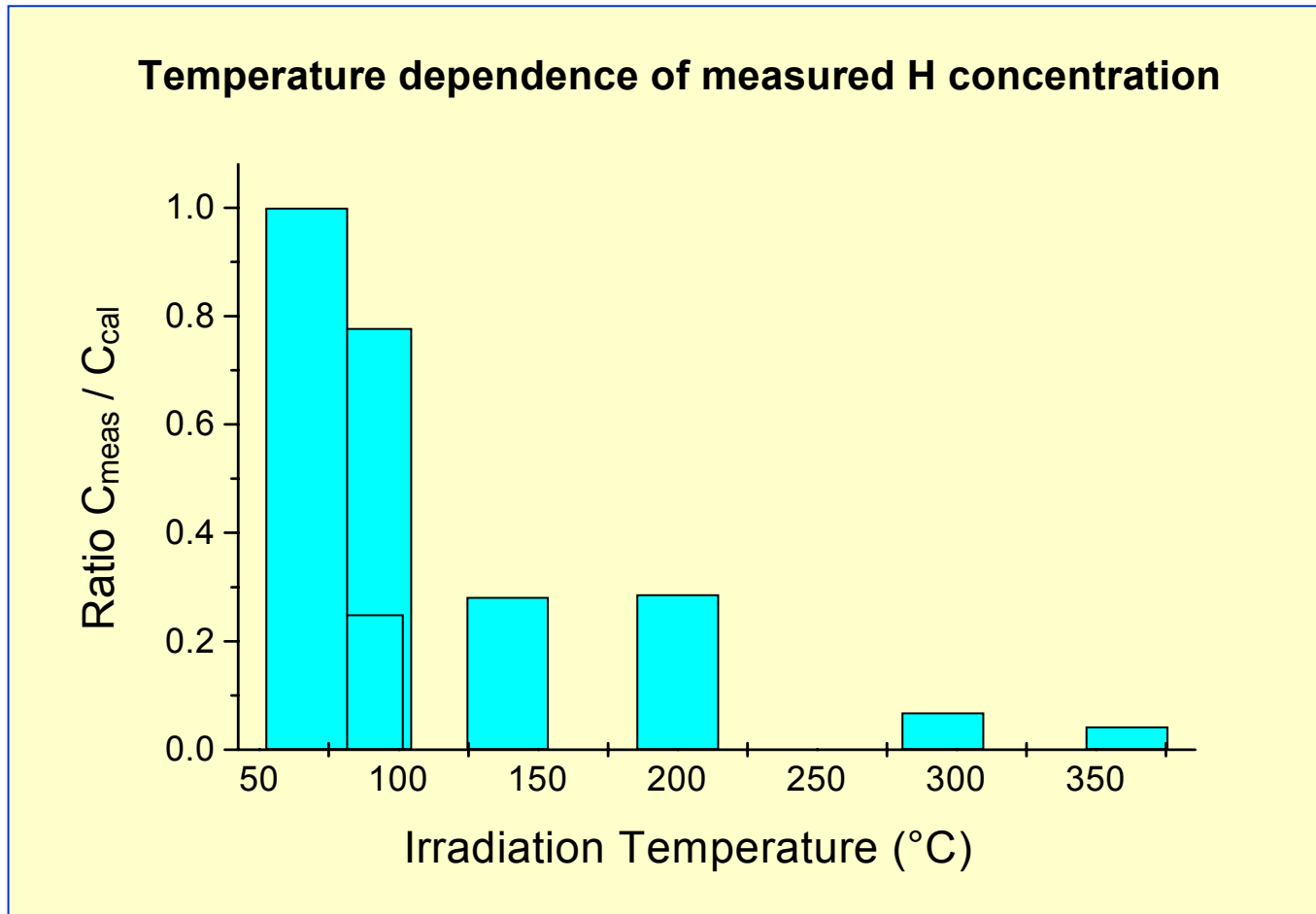
20.3 dpa, 1790 appm He, $T_i = 400 \pm 50^\circ\text{C}$



Jia & Dai, IWSMT-7, Thun, 2005, to be published in JNM.

Few results

FM steels and SS 316 irradiated in STIP-I

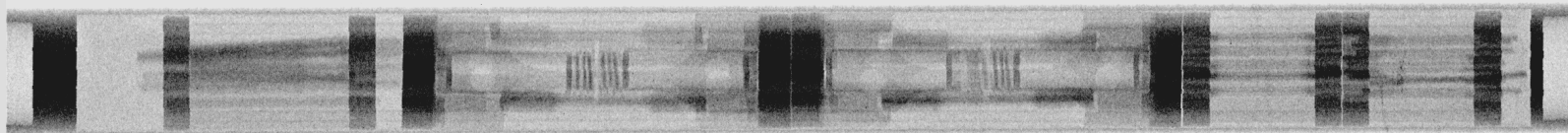


Dai et al, JNM 318 (2003) 167

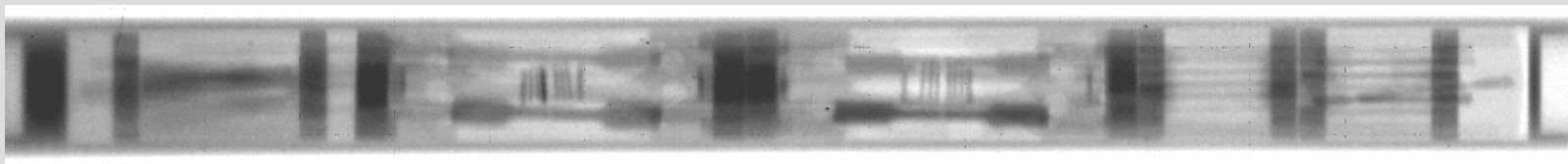
Few results

Inspection on STIP-II Pb-Bi Rod

Before irradiation



After irradiation (max dose: 19 dpa)



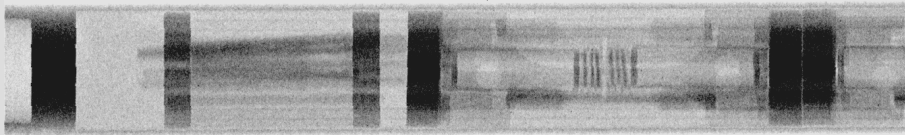
Target Rod B:

It contains a PbBi (about 38 g) filled T91 capsule. Inside PbBi there are about 50 test samples for studying irradiation assisted corrosion effects of PbBi on different kinds of materials.

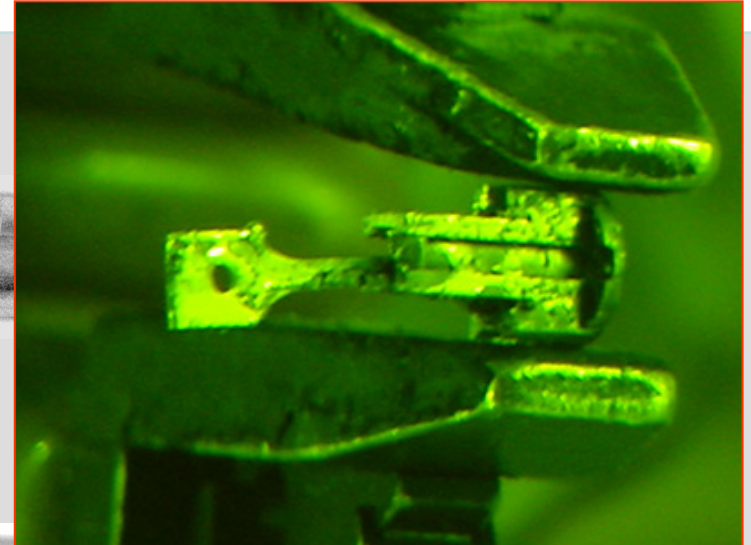
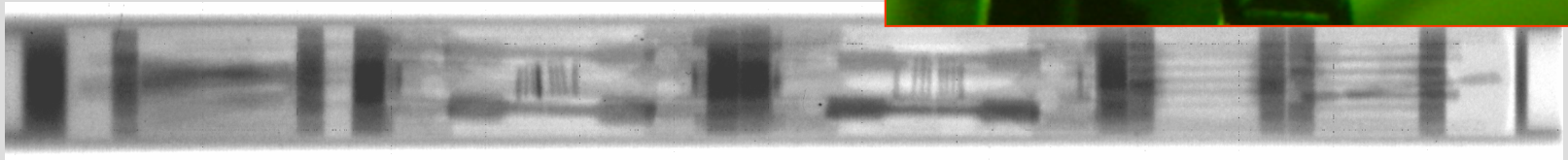
Few results

Inspection on STIP-II Pb-Bi Rod

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After irradiation (max dose: 19 dpa)



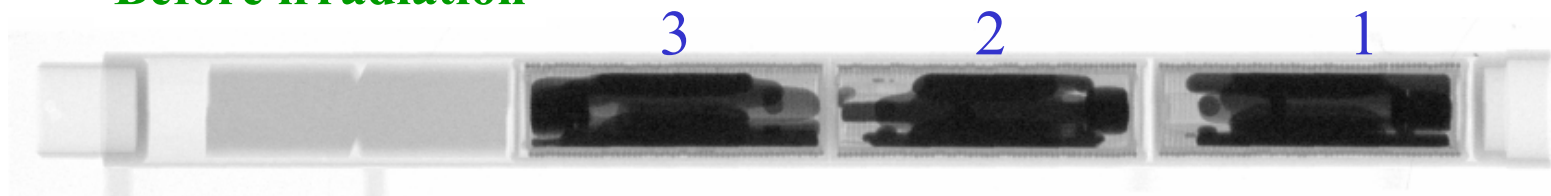
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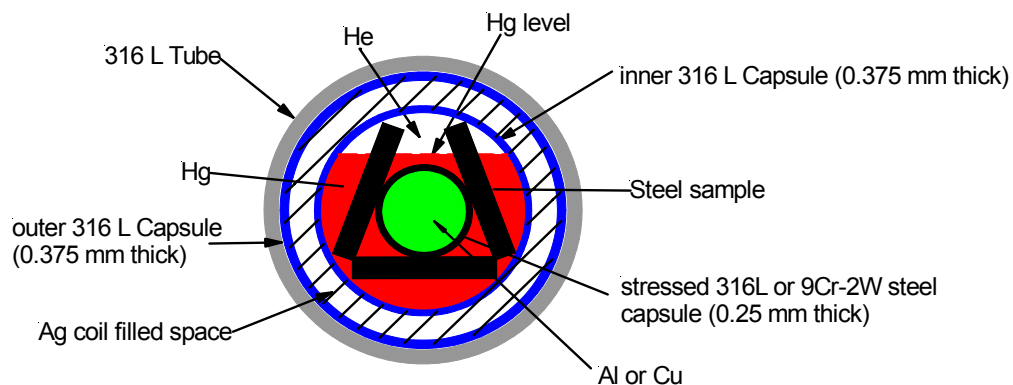
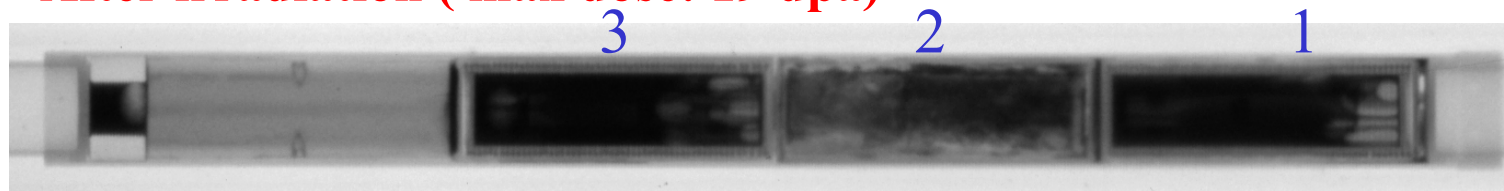
Few results

Inspection on STIP-II Hg Rod

Before irradiation



After irradiation (max dose: 19 dpa)



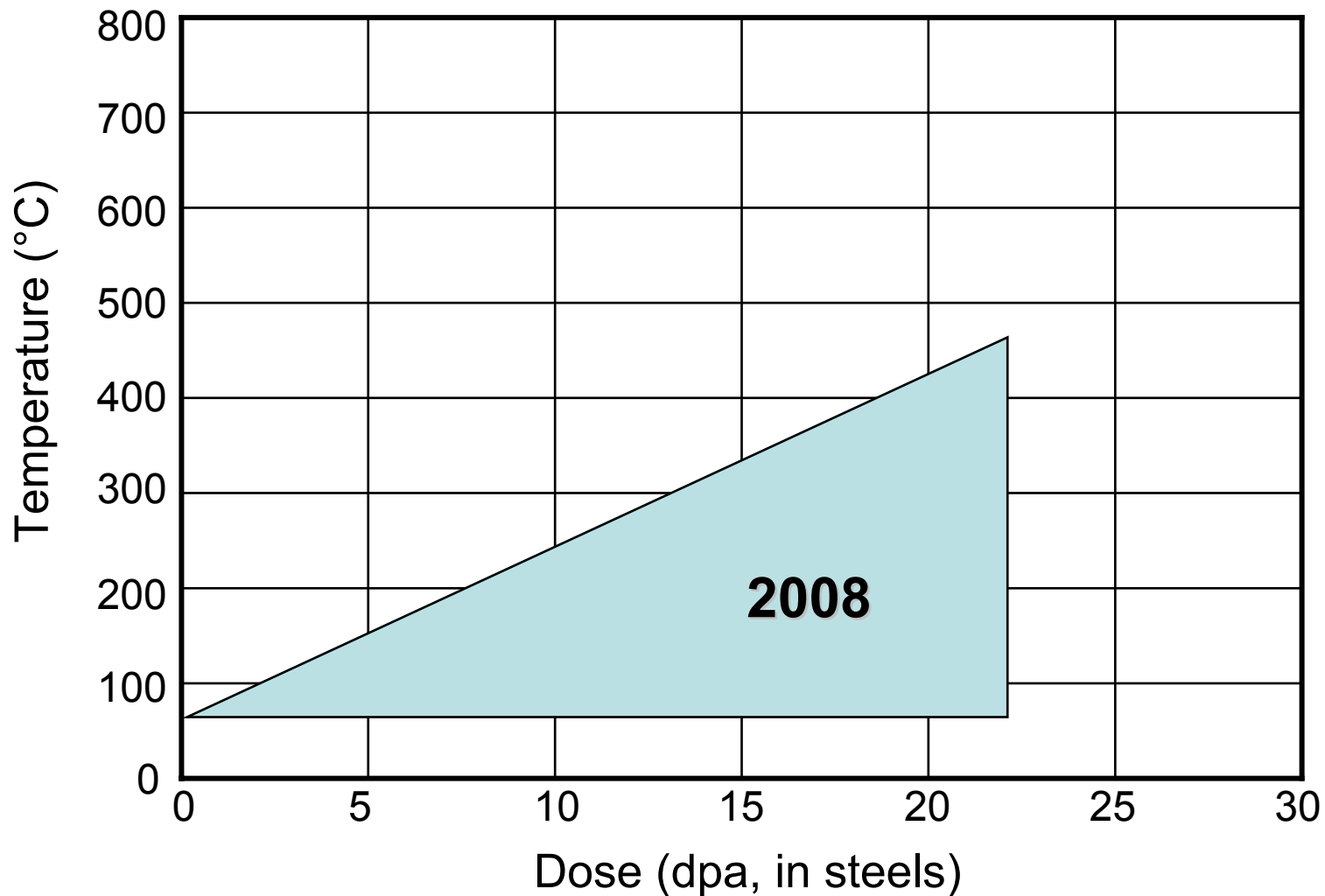
Outlook

STIP-V to be irradiated in 2007 and 2008 to ~25 dpa (in steel)

Materials	Tensile $T_{\max}$ (°C)	Bend/Fracture $T_{\max}$ (°C)	Fatigue $T_{\max}$ (°C)	Impact $T_{\max}$ (°C)	TEM $T_{\max}$ (°C)
FM steels	500	500		450	500
FM steels ODS	600	600		400	450
SS 316L (LN)	600				600
Inconel 718	600				600
W	800				
C-C/SiC, SiC/SiC		700			

Outlook

Foreseen STIP data



Outlook

Foreseen STIP data

