

Post irradiation examination of the MEGAPIE samples at JAEA

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- Tensile tests**
- Surface observation**
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4. Summary

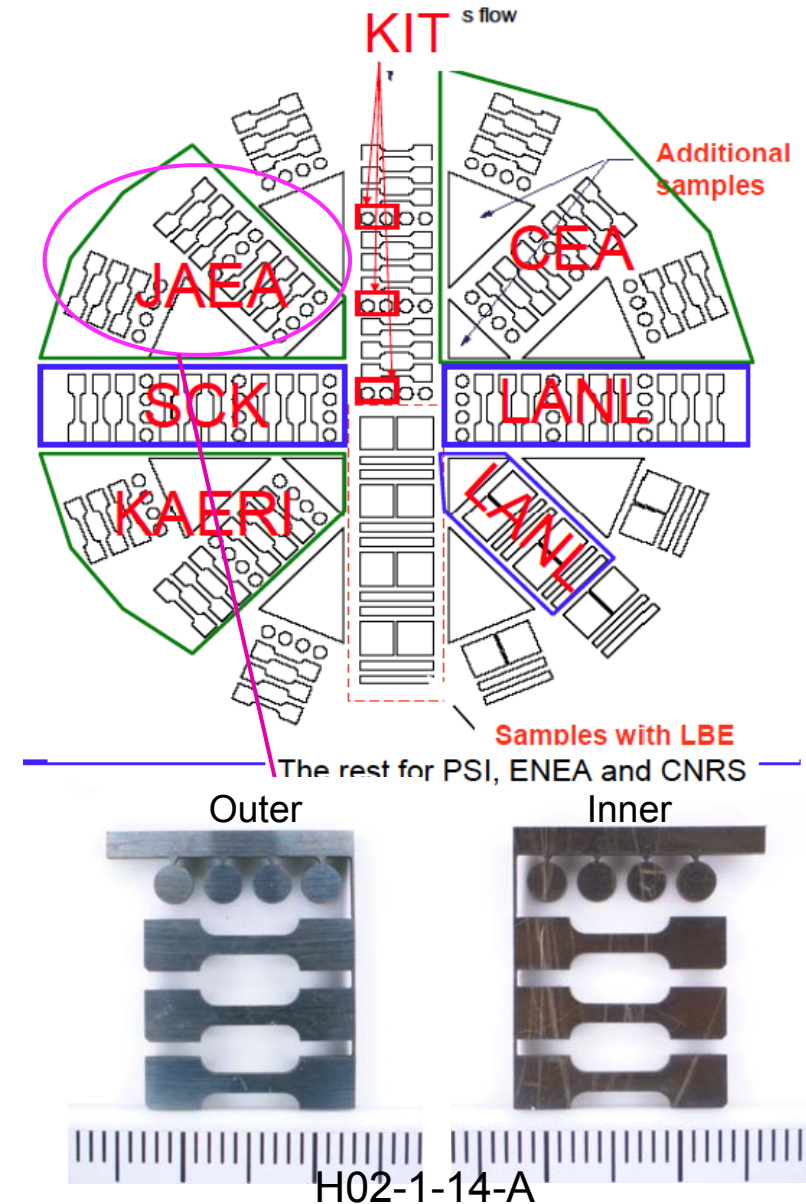
1. JAEA Samples (1)



JAEA samples : Beam window
Flow guide tube (FGT)
All samples are without LBE.



Beam window (H02-1)
Material: T91

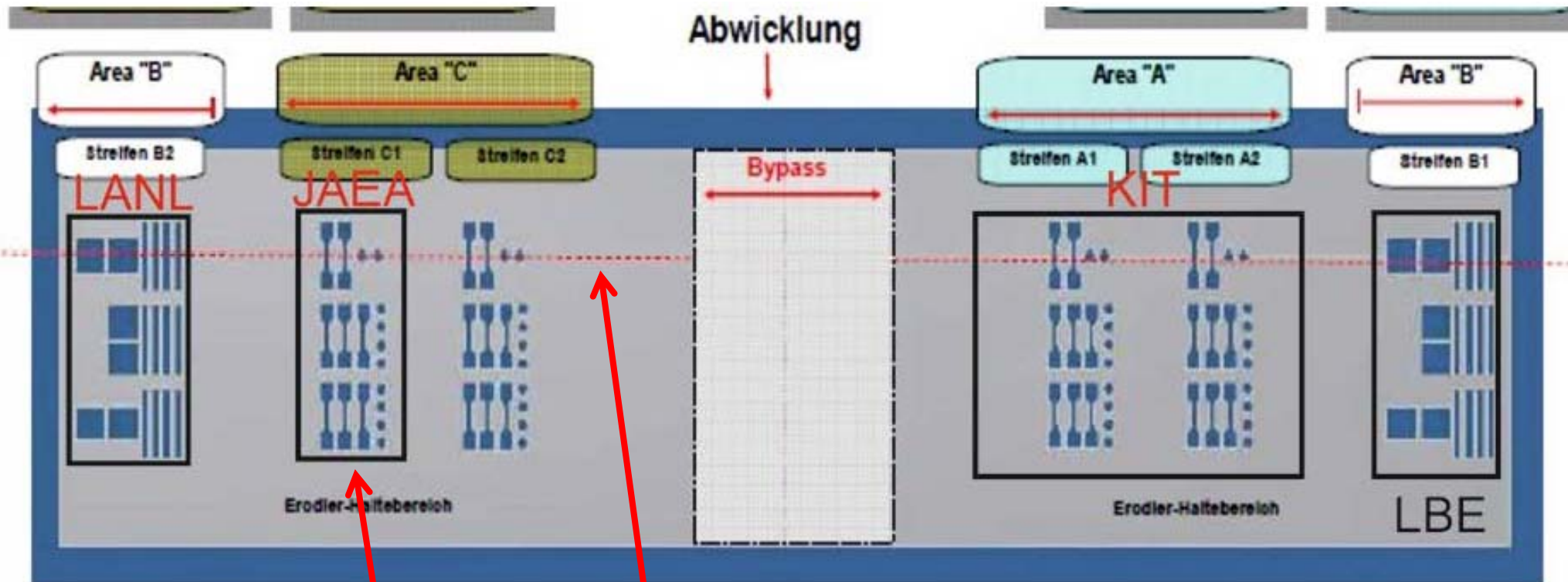


1. JAEA Samples (2)



Flow guide tube (FGT) (H03-2)

Material : SS316L



EB welding line

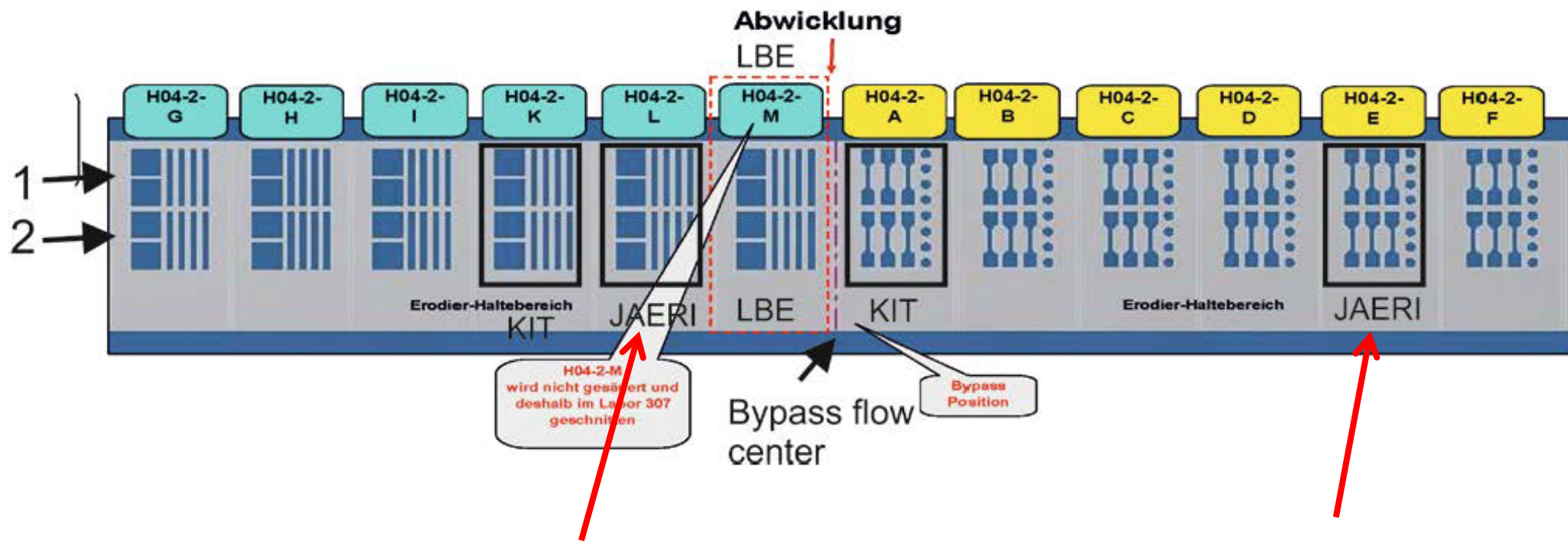
8 tensile specimens and 10 TEM discs

1. JAEA Samples (3)



Flow guide tube (FGT) (H04-2)

Material : SS316L



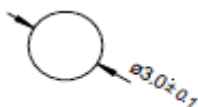
4 OM/SP specimens and 8 bending specimens

6 tensile specimens
and 8 TEM discs

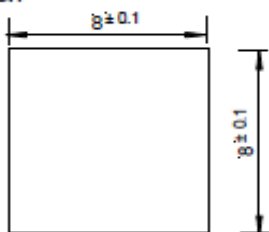
1. JAEA Samples (4)

Dimensions of the specimens

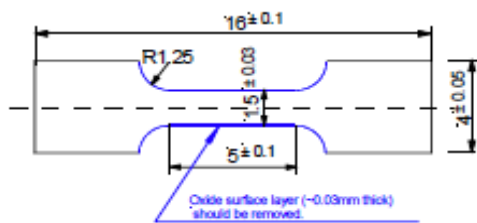
TEM specimen



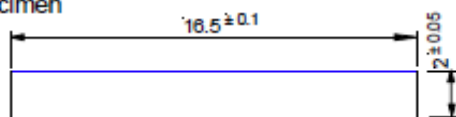
OM & SP specimen



Tensile specimen



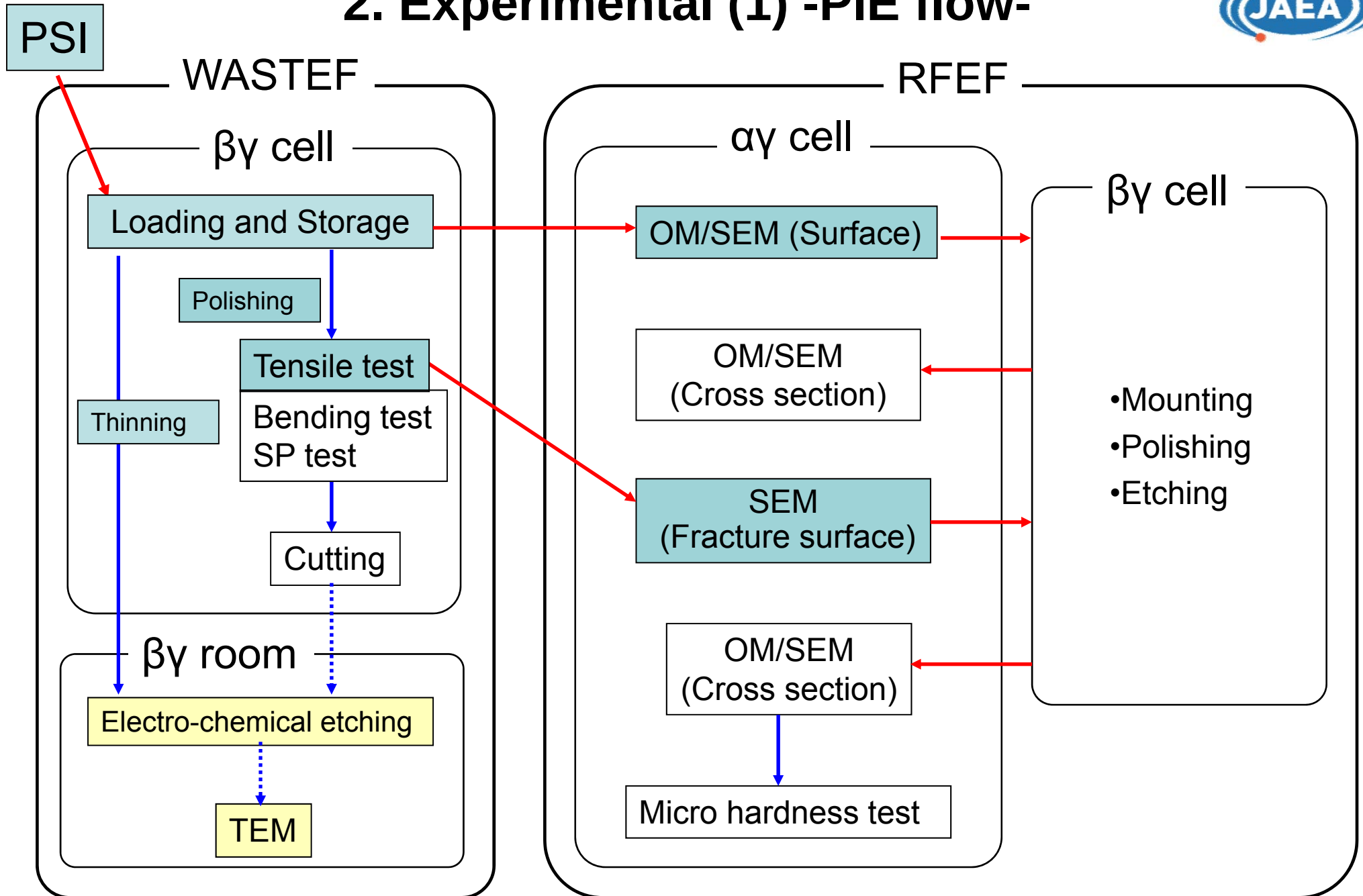
Bending specimen



	Beam window	Flow guide tube		
	H02-1	H03-2	H04-2	
	T91	SS316L		Total
Tensile	9	8	6	23
TEM	12	10	8	30
Bend bar	-	-	8	8
OM	2 (Spitze)	0	4	6
Total	23	18	26	<u>67</u>

Spitze:triangle part

2. Experimental (1) -PIE flow-



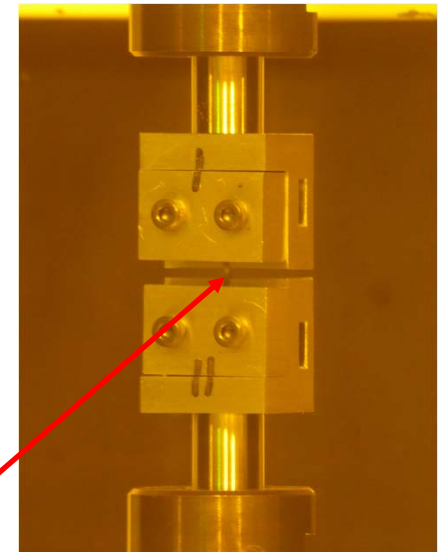
Experimental (2) –Tensile test -



- Tensile testing machine
Shimadzu 20 kN

Test conditions of 3 tensile specimens

- ① RT in air
 - ② 250°C (T91) and 300°C (SS316L) in Ar
 - ③ the specimens were ground flat.
250°C (T91) and 300°C (SS316L) in Ar
- To compare the existing data.
 - To eliminate effects of surface condition and to evaluate only irradiation effect.
 - Cross-head speed: 0.1 mm/min. (6×10^{-4} /s)
 - Measurement : Load, Displacement
 - SEM observation of fracture surface



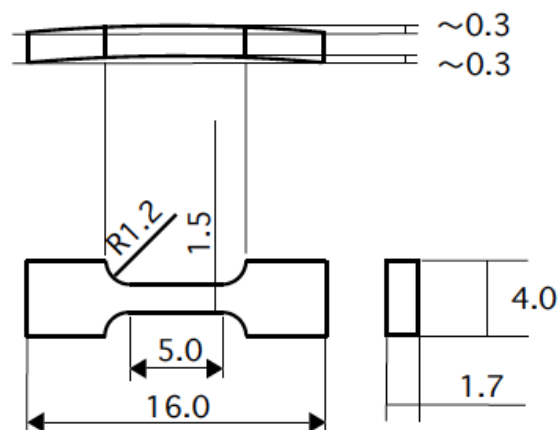
Specimen

Jigs (SUS630 (17-4PH, H900)) 8

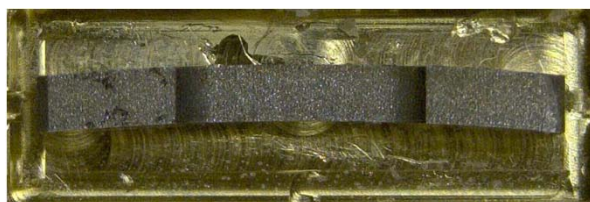
2. Experimental (3) -Tensile test-

Flat specimen

T91 (Beam window)

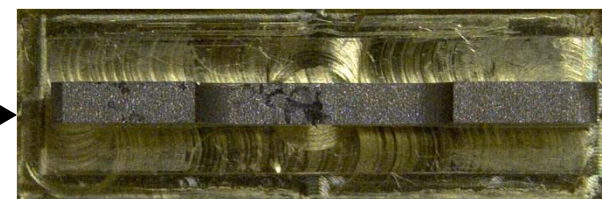


As-received



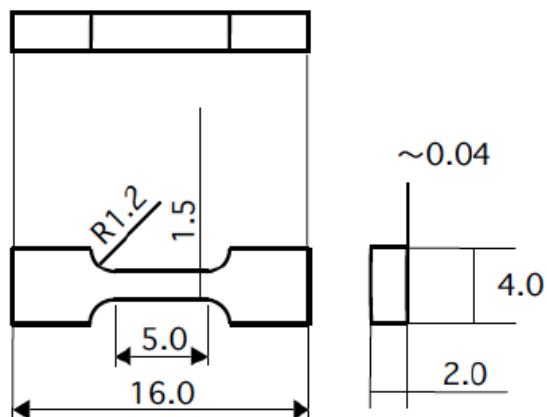
$t=1.58 \sim 1.75$ mm

Flat specimen



$t=1.16 \sim 1.40$ mm

SS316L (FGT)



$t=1.49 \sim 1.53$ mm

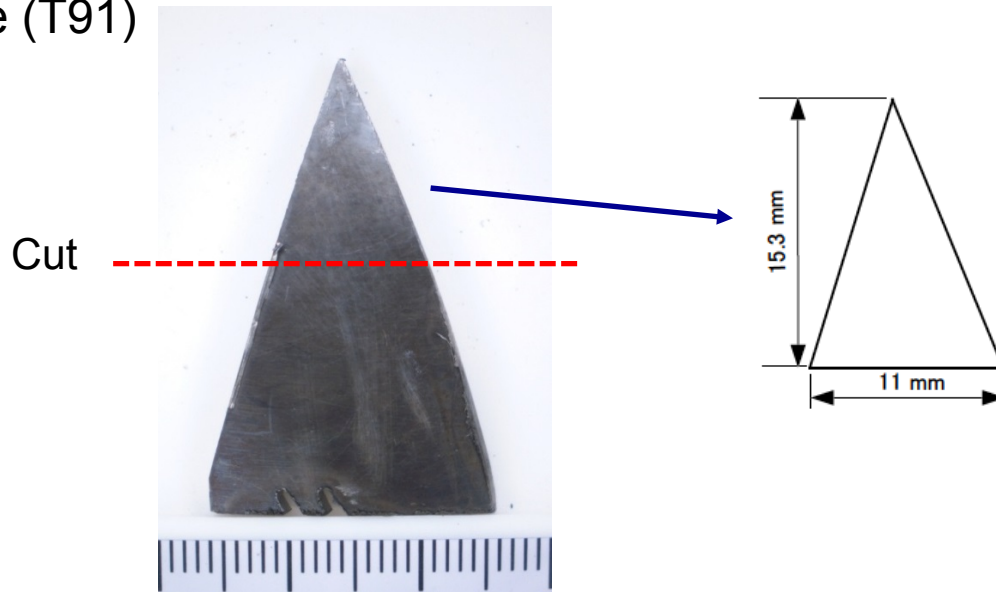


$t=1.34 \sim 1.37$ mm

2. Experimental (4) -Surface observation-

Specimens

Spitze (T91)

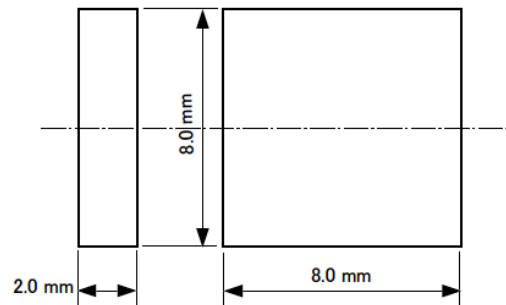
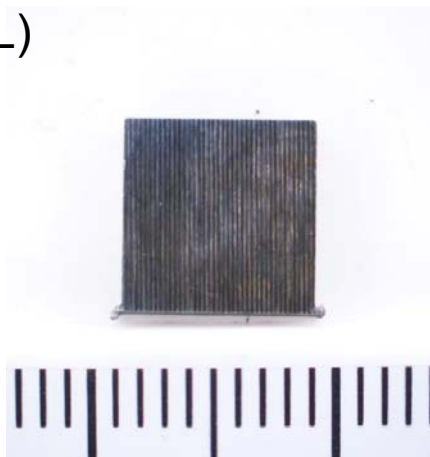


SEM



JEOL JSM-5410

OM (SS316L)



- $\times 50 - \times 2,000$
- Inner surface

2. Experimental (5) -Microstructural observation-

Sample preparation and TEM observation

- Specimens were thinned to 0.2 mm by mechanical polishing
- Twin jet electro-polishing
- Solution ; 95 vol.% Acetic acid + 5 vol.% Perchloric acid (conc.60%)

Table. List of MEGAPIE samples received by JAEA (TEM disk)

TEM disk	Group No.	ID	dpa	Irrad. Temp [°C]	Schedule
Beam window, T91	H02-1-14-A	TE04 – 07	0.81	252	2013
	H02-1-15-A	TE14 – 17	1.98	259	2014
	H02-1-15-B	TE24 – 27	0.94	251	2014
Flow guide tube, 316L SS	H03-2-C1-1	SE33, 34	1.36	316	2014
	H03-2-C1-2	SE44 – 47	1.46	311	2013
	H03-2-C1-3	SE54 – 57	1.57	308	2014
	H04-2-C1-1	SE64 – 67	0.19	341	2014
	H04-2-C1-1	SE74 - 77	0.16	335	2014

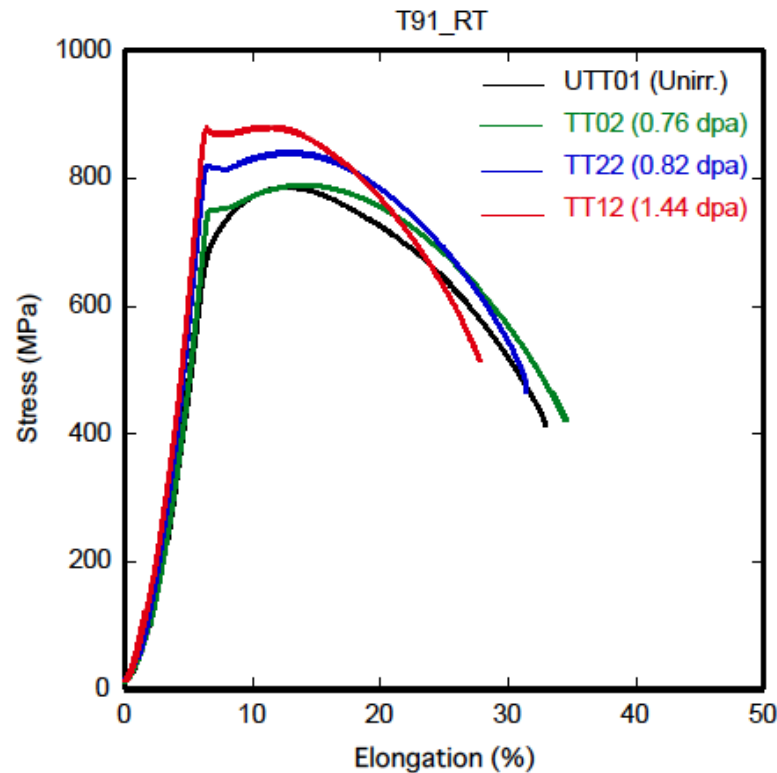
FE-TEM



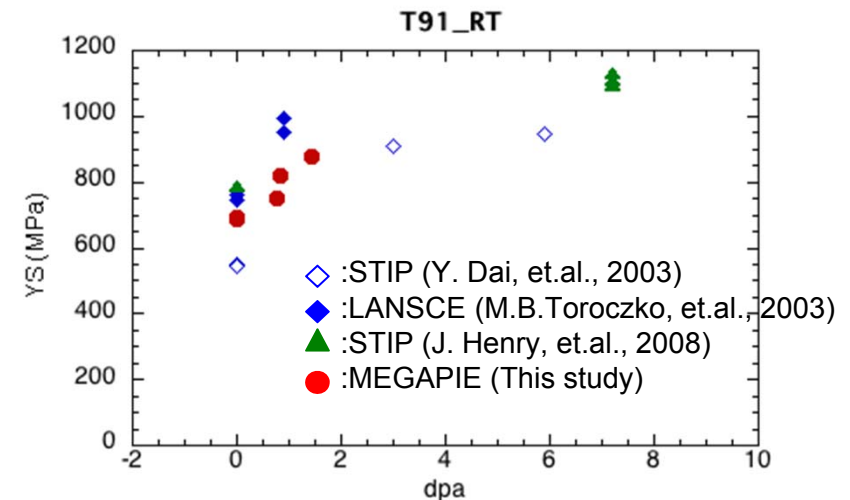
HITACHI HF-2000

3. PIE results -Tensile tests (1)-

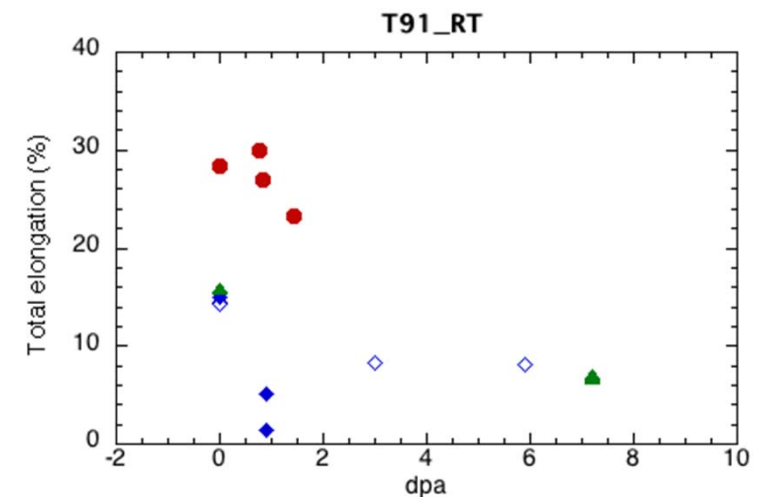
T91 (Beam window), RT tests



- YS increased with dose level by 10-30%.
- TE was not changed up to 0.82 dpa irradiation. After 1.44 dpa irradiation, TE decreased slightly.



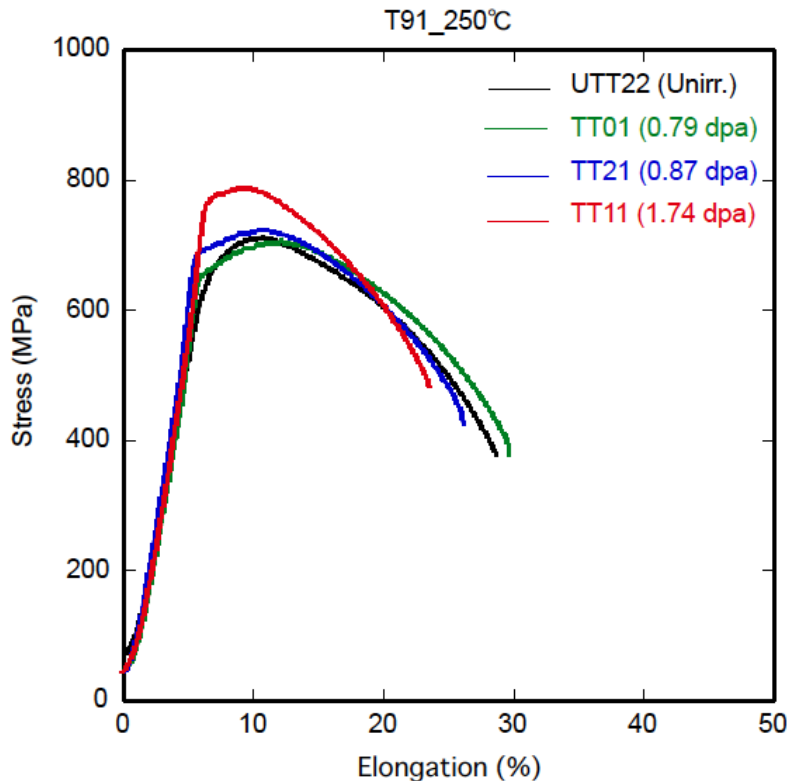
Comparing to the literature value, the YS value are almost same level.



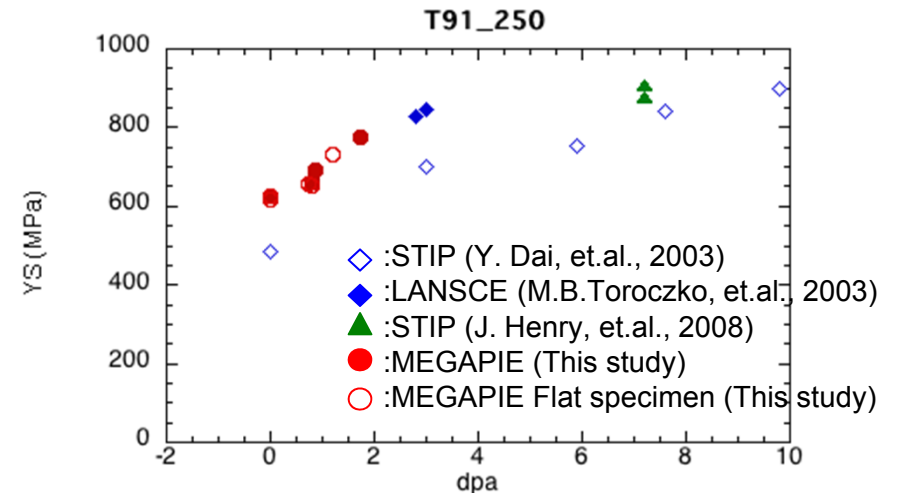
The TE value are larger than the literature value.

3. PIE results -Tensile tests (2)-

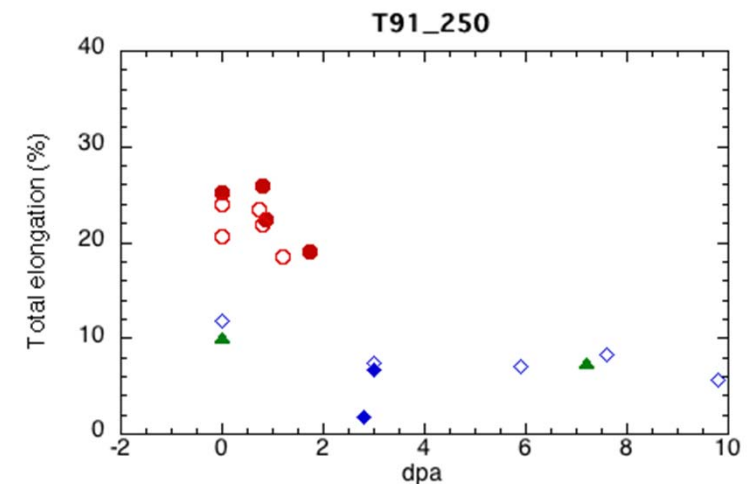
T91 (Beam window), 250°C tests



- Yield points were disappeared.
- YS increased with dose level by 5-20%.
- TE were not changed up to 0.82 dpa irradiation. After 1.74 dpa irradiation, TE decreased slightly.



The YS value are slightly larger than the literature value. The YS of flat specimens are almost same with that of as-received specimens.



TE of flat specimens are slightly smaller than that of as-received specimens.

3. PIE results -Tensile tests (3)-

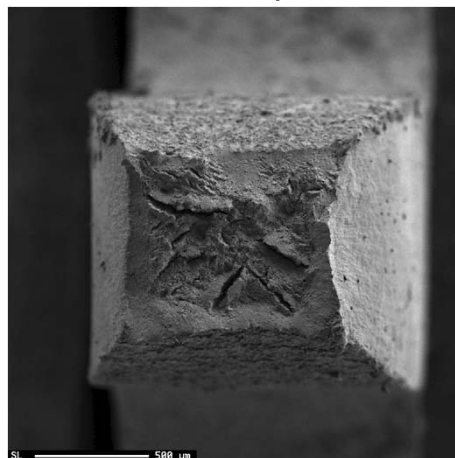
T91 (Beam window), Fracture surface

UTT12, Unirr., RT



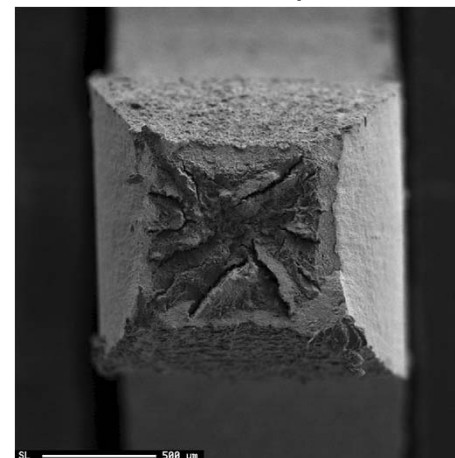
RA=70.6%

TT22, 0.82dpa, RT



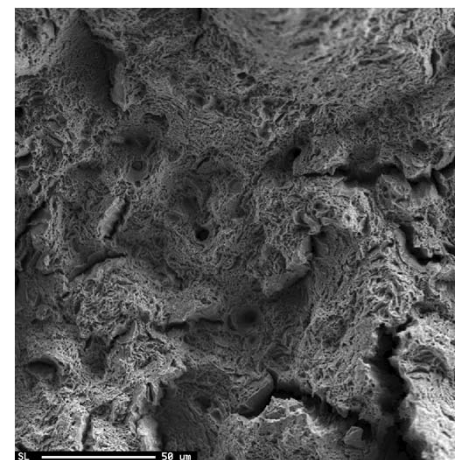
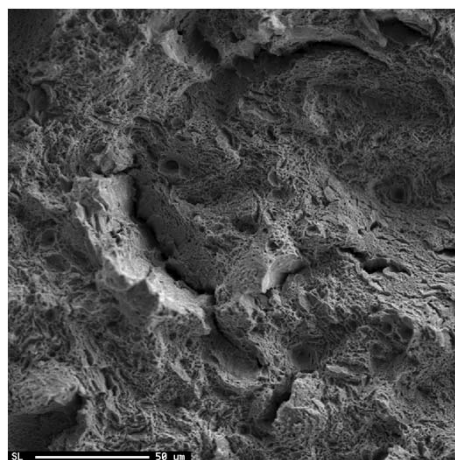
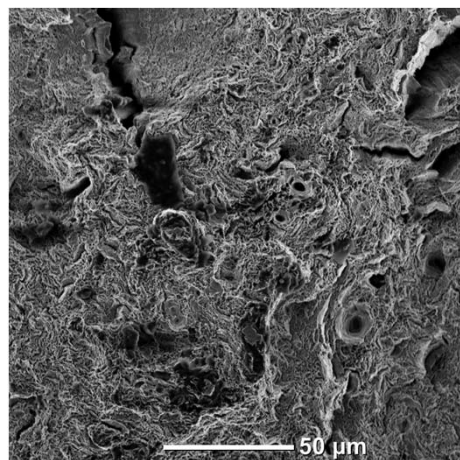
RA=73.3%

TT12, 1.44dpa, RT



RA=70.5%

500μm



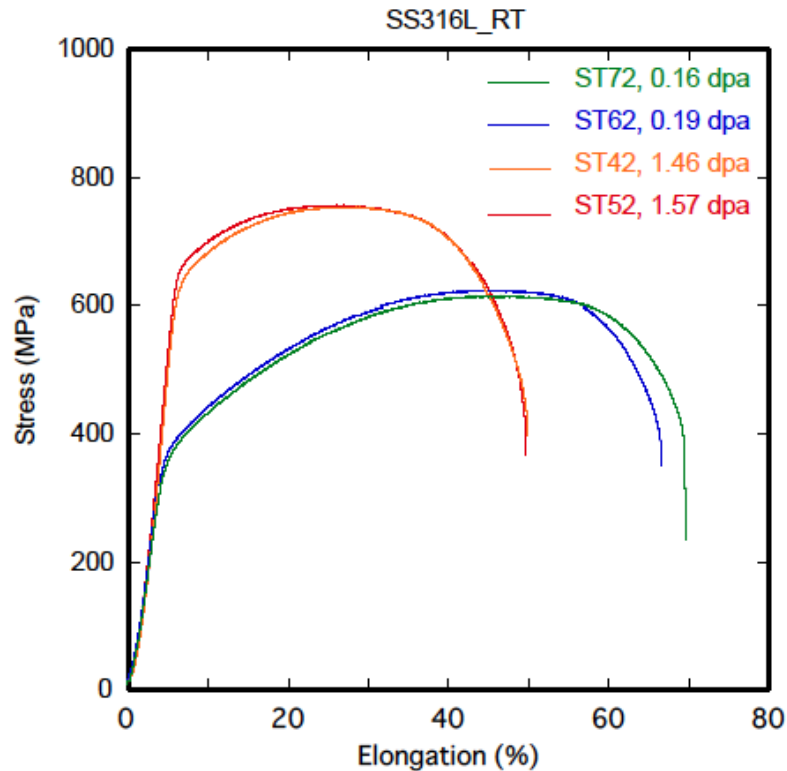
50μm

- Brittle fracture surface were not observed.
- RA value are not changed.

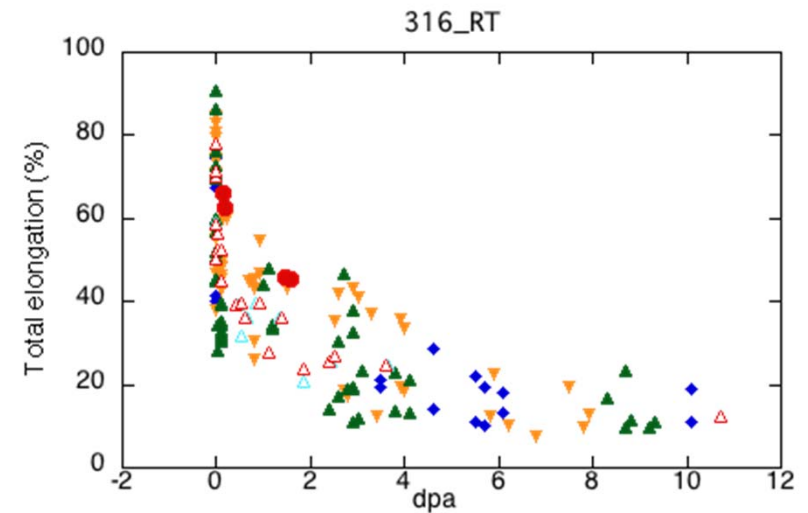
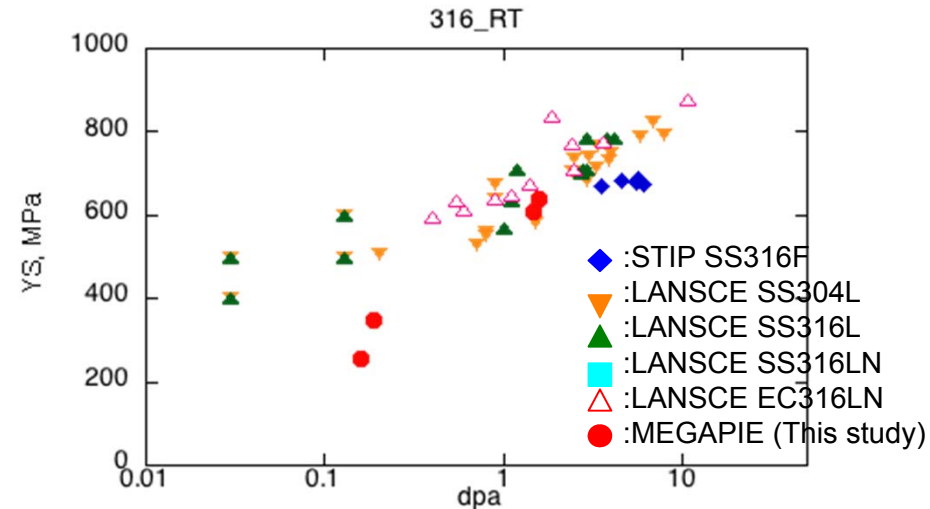
3. PIE results -Tensile tests (4)-



SS316L (FGT), RT tests



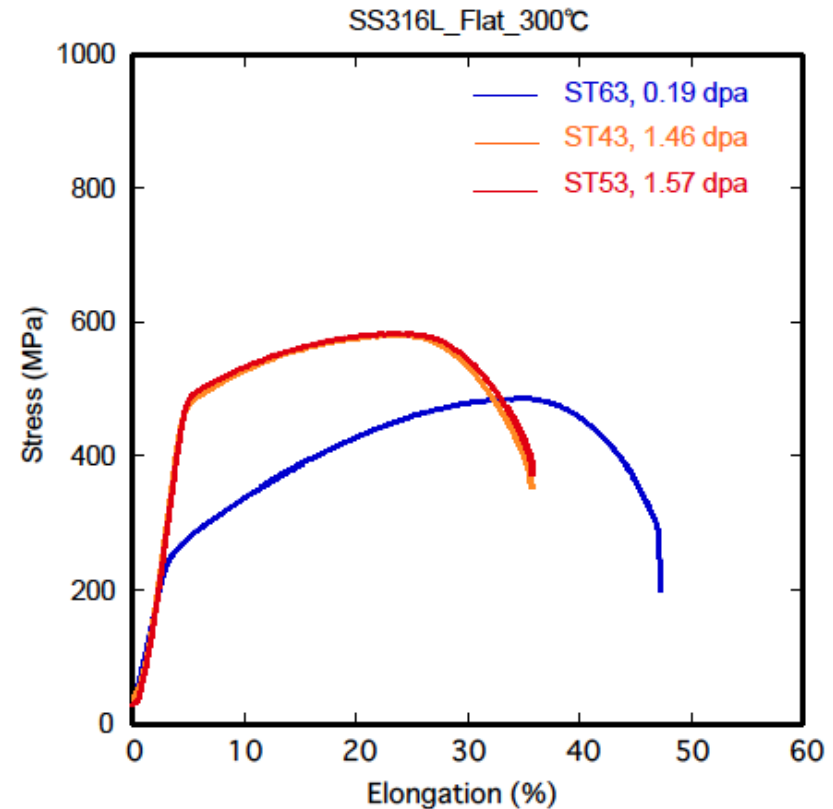
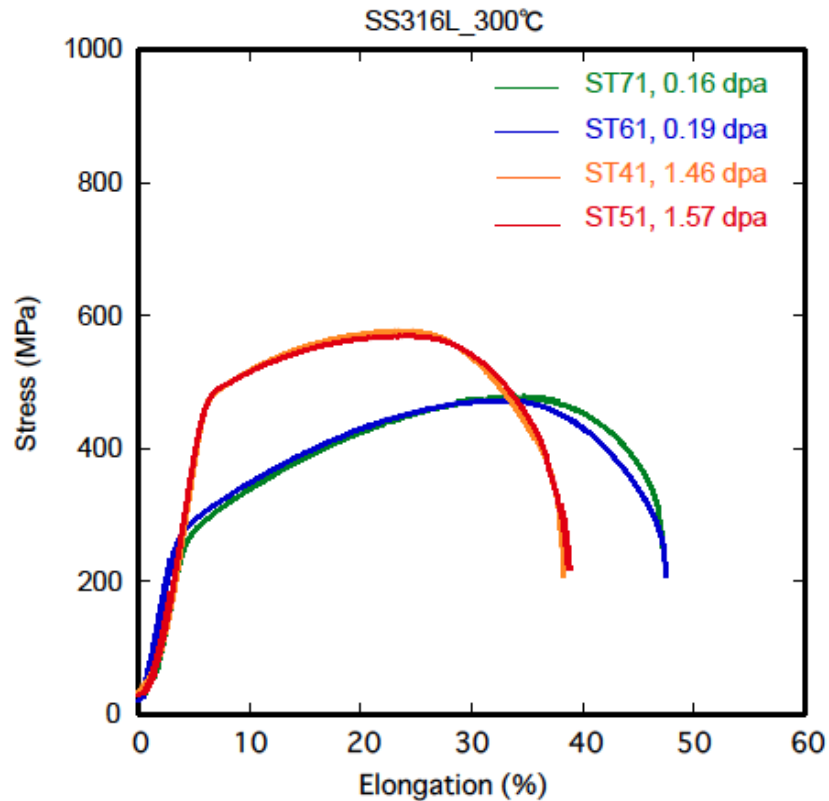
- Irradiation hardening and degradation of ductility are larger than T91.
- The YS of 0.16-0.19 dpa specimens are lower than that of the literature value. The YS of 1.46-1.57 dpa specimens are within data band.
- TE are within data band.



3. PIE results -Tensile tests (5)-



SS316L (FGT), 300°C tests

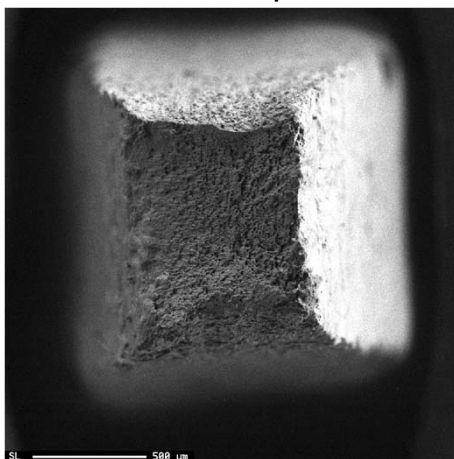


- Irradiation hardening and degradation of ductility are observed.
- YS of flat specimens are almost same with that of as-received specimens. TE of flat specimens are slightly smaller than that of as-received specimens.

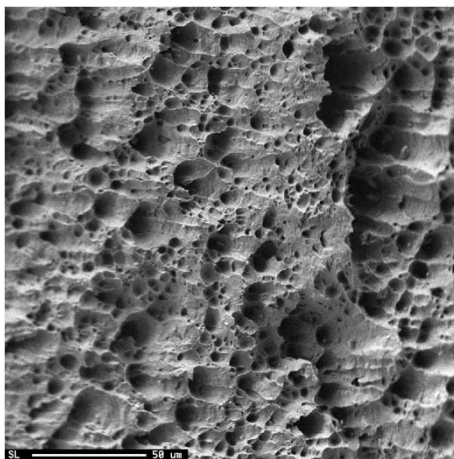
3. PIE results -Tensile tests (6)-

SS316L (FGT), Fracture surface

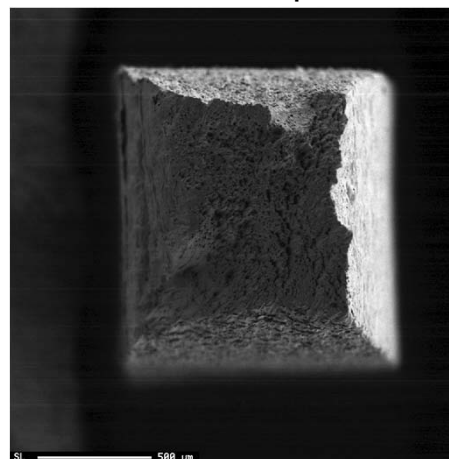
ST72, 0.16dpa, RT



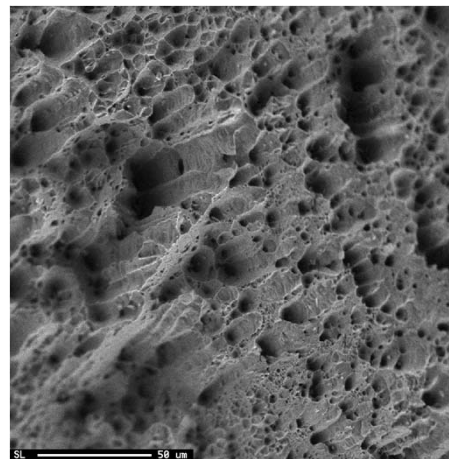
RA=72.5%



ST52, 1.57dpa, RT



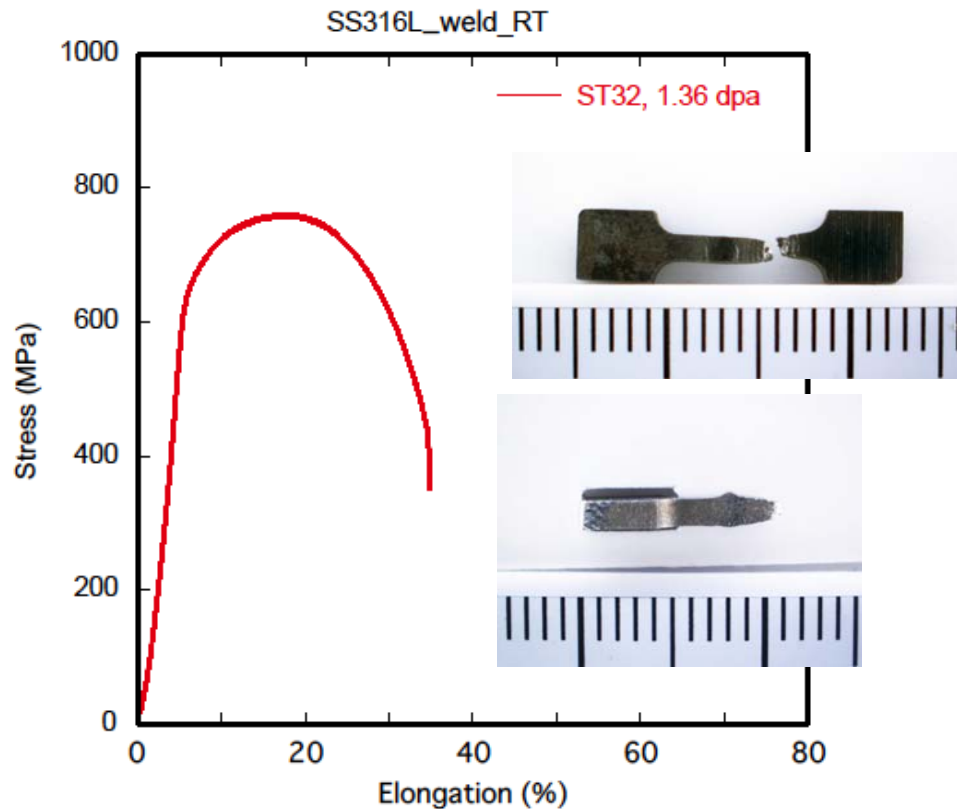
RA=64.2%



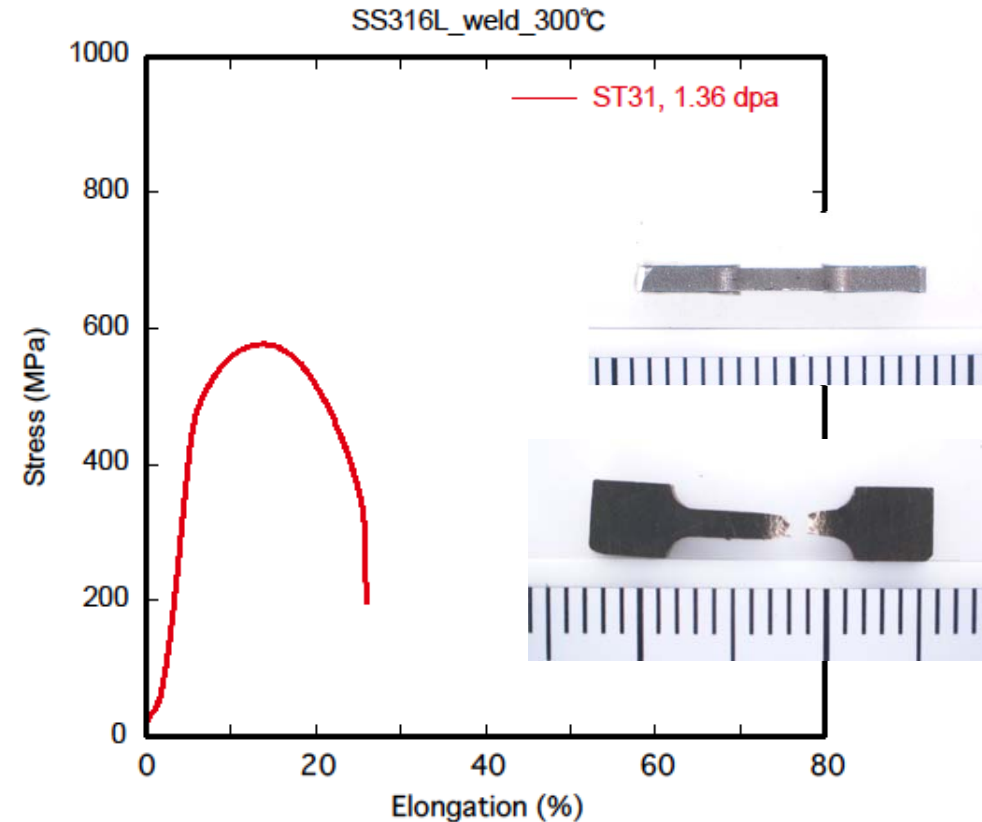
- Ductile elongated dimples were observed. Brittle fracture surface were not observed.
- RA value decreased.

3. PIE results -Tensile tests (7)-

SS316L weld (FGT), RT and 300°C tests



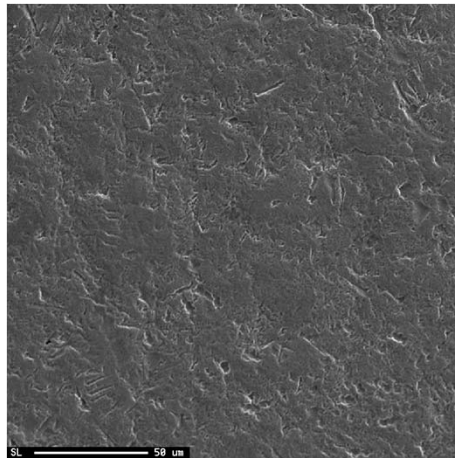
- The specimen was not ground flat.
- The specimen was fractured at HAZ/base metal.



- The specimen was ground flat.
- The specimen was fractured at HAZ/base metal.

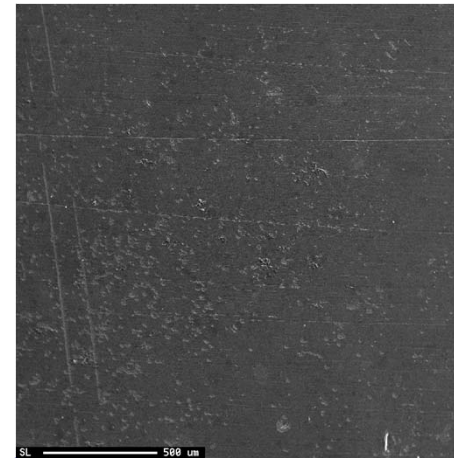
3. PIE results -Surface observation (1)-

Spitze (T91)

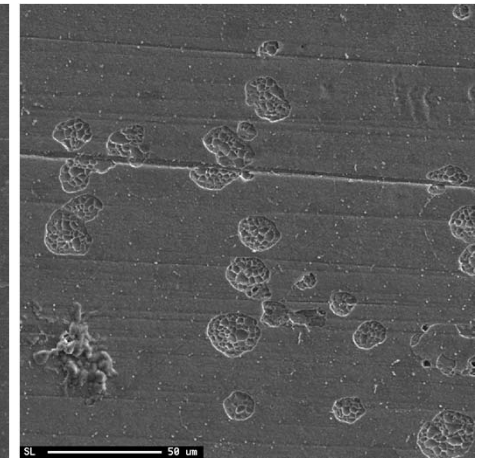


50µm

Corrosion?

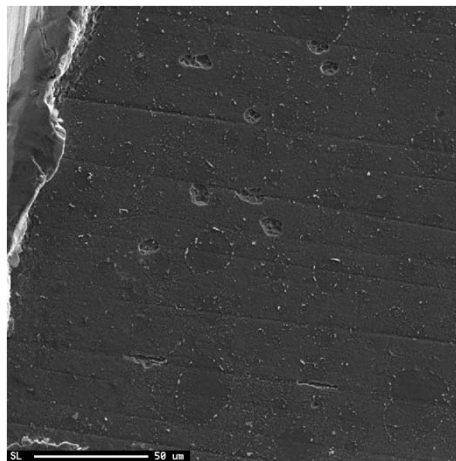


500µm



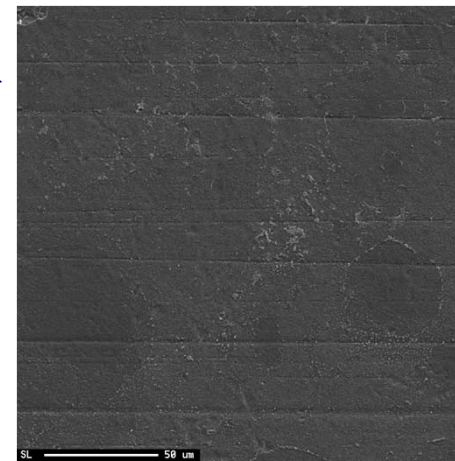
50µm

Large number of pits

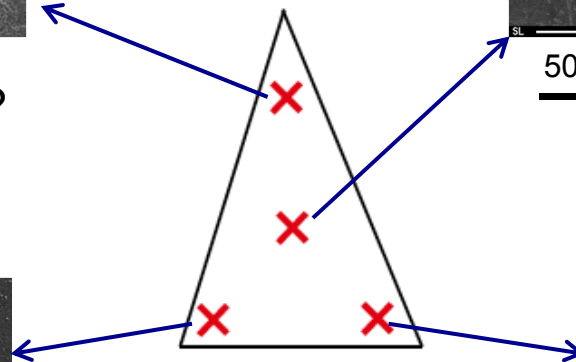


50µm

Small number of pits

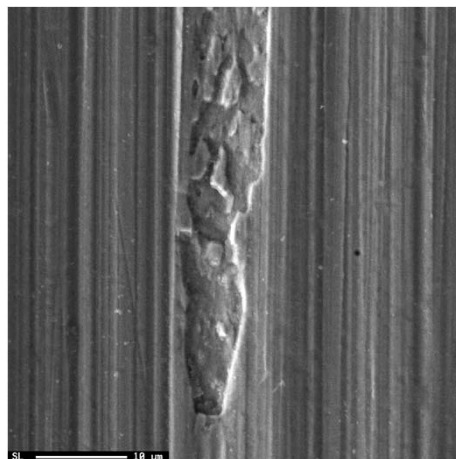


50µm

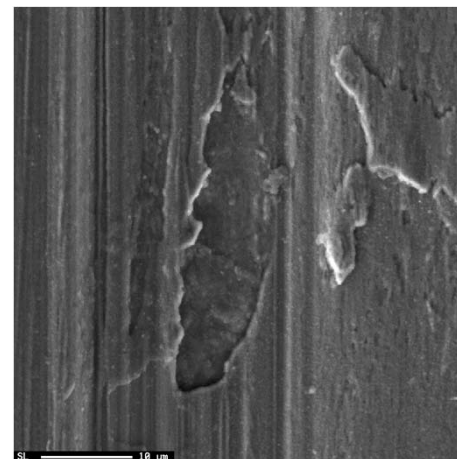


3. PIE results -Surface observation (2)-

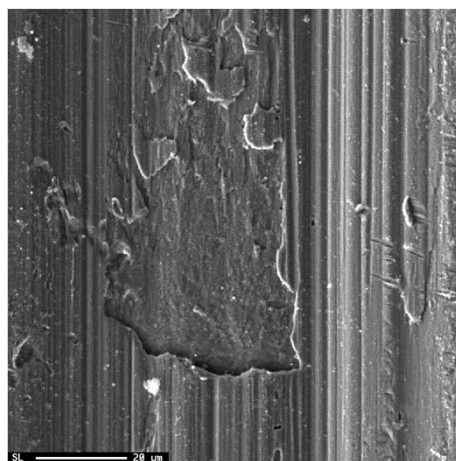
OM (SS316L)



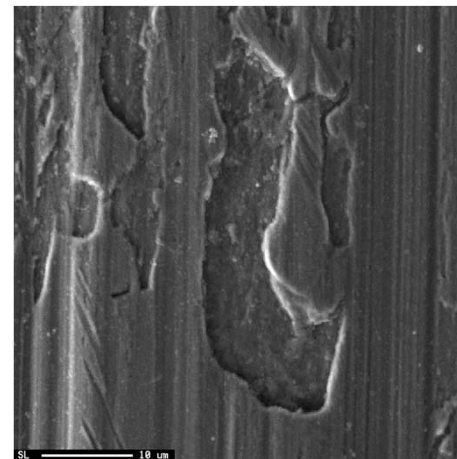
10μm



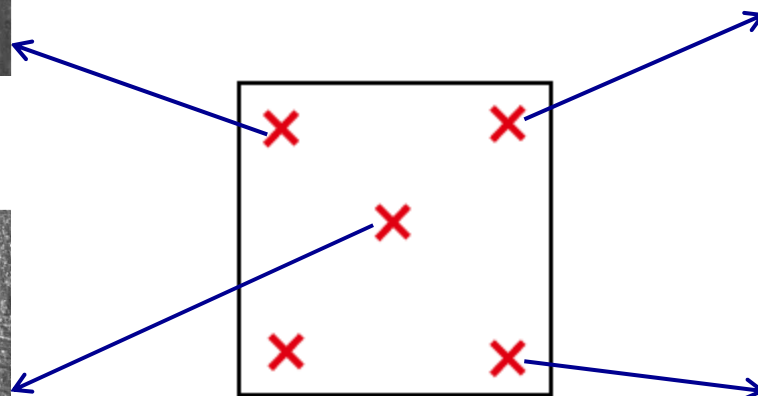
10μm



20μm



10μm



Partially surface peeled off.

3. PIE results -Microstructure observation (1)-

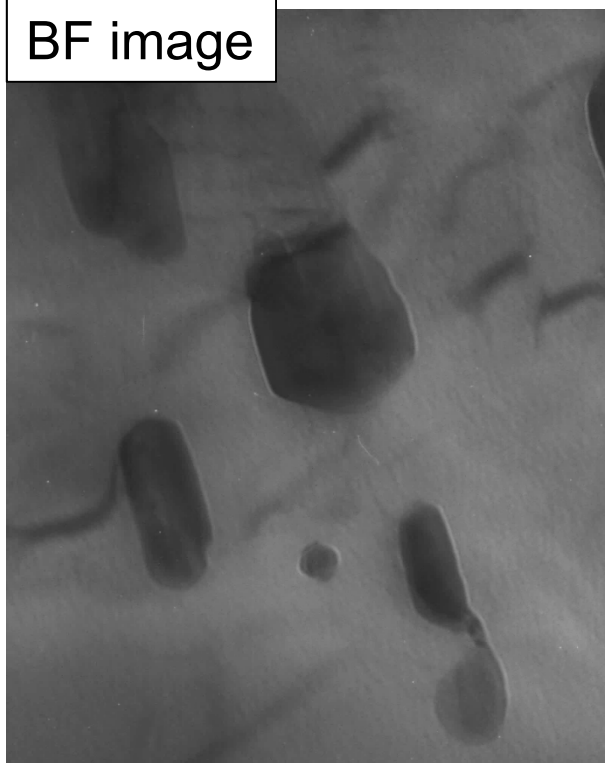


Typical irradiation microstructure

T91 (ID:TE04) 0.81 dpa, 252°C

Carbides ($M_{23}C_6$ and MC)

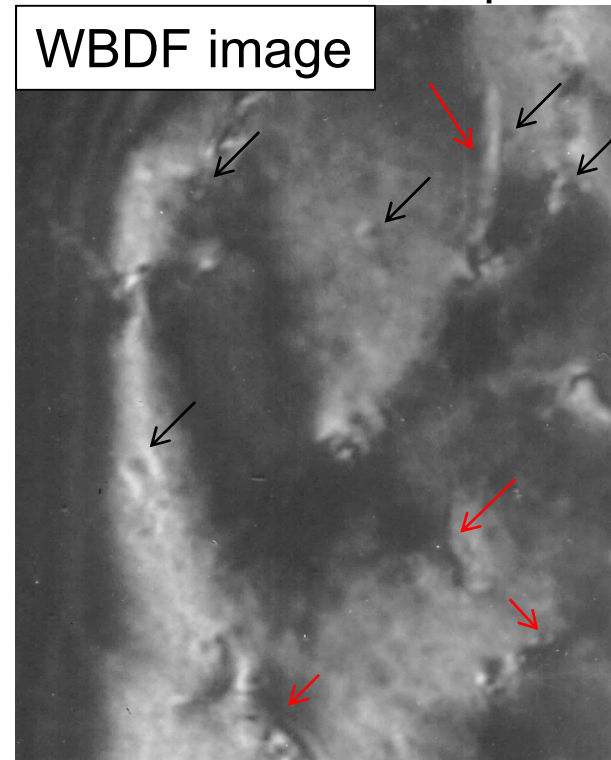
BF image



200nm

Intrinsic dislocations
and interstitial loops

WBDF image



↓ I-loop

↓ dislocation

100nm

- Interstitial loops ~ 10 nm size, but low density

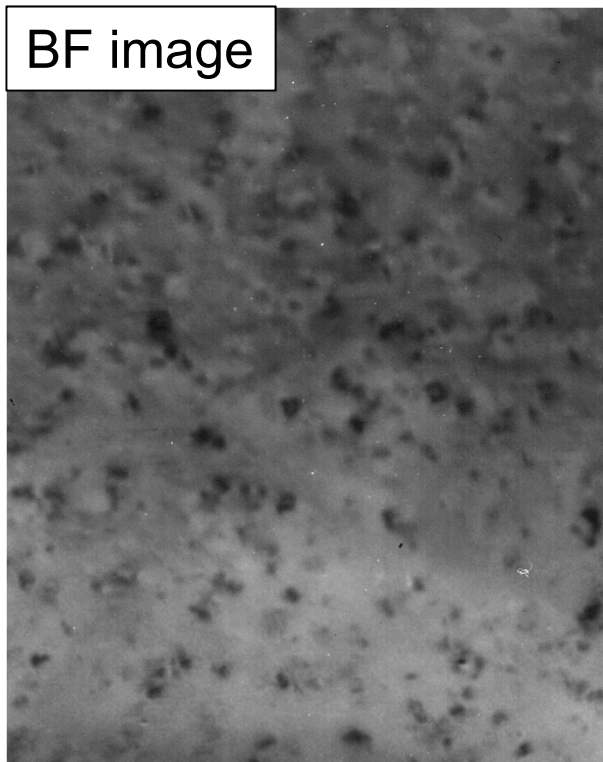
3. PIE results -Microstructure observation (2)-



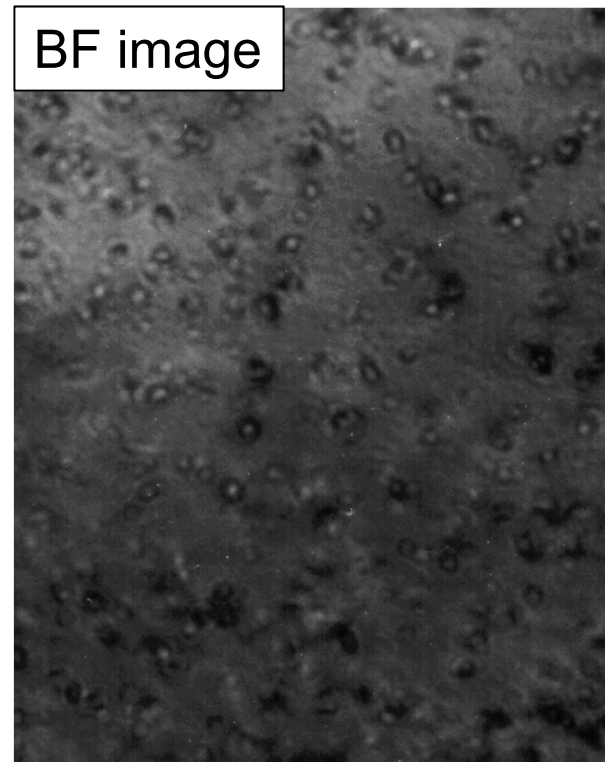
Typical irradiation microstructure

316L SS (ID:SE46) 1.46 dpa, 311°C

Frank loops



Cavities



100nm

- High number density Frank loops and cavities.

4. Summary

Tensile tests

- Irradiation effects on the tensile properties were investigated.

Surface observation by SEM

- BW (T91); corroded surface, large number of pits were observed.
- FGT (SS316L); surface detachment was observed.

Microstructure observation by TEM

- TEM observation for two samples were performed.

Future plan

Tensile tests

- Fracture surface observation on high temp. tested specimens.

Surface observation by SEM

- Cross section observation
- Outer surface

Microstructure observation by TEM

- TEM observation for rest samples.

Bending test and SP test.

- It is necessary to make jigs, specimen setting device, etc.

PIE -Schedule -



Year	2014												2015												2016			
Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
	▼MEGAPIE PCG&PSC(2/10-11)												▼MEGAPIE TRM Agreement (12/31)															
													▼IWSMT-12															
	WASTE, RFEF renewal																											
Transportation													▼On site transportation (RFEF)															
Tensile test																												
Metrographical observation Hardness test																												
TEM (WASTE)																												
Bend-bar																												
SP test																												
OM																												