FeCrAlY and TiN coatings on T91 steel after irradiation with 72 MeV protons in flowing LBE

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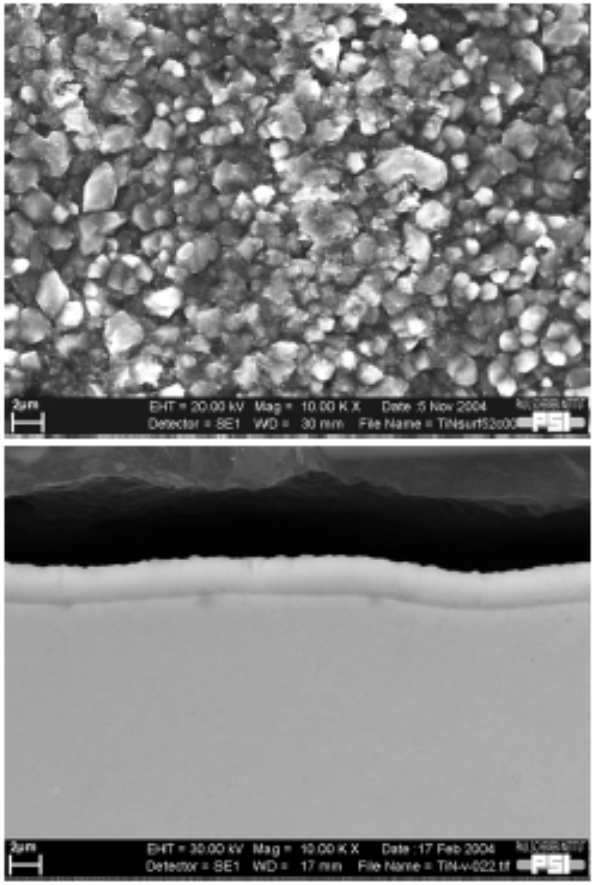
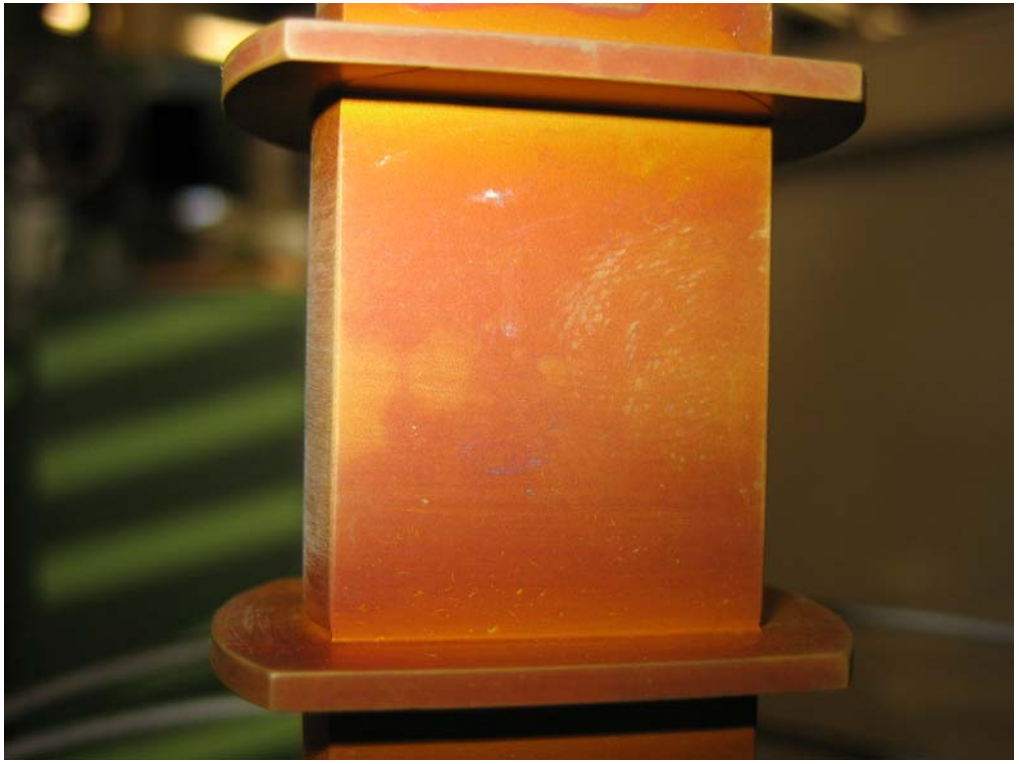
T91/TiN – Tube preparation

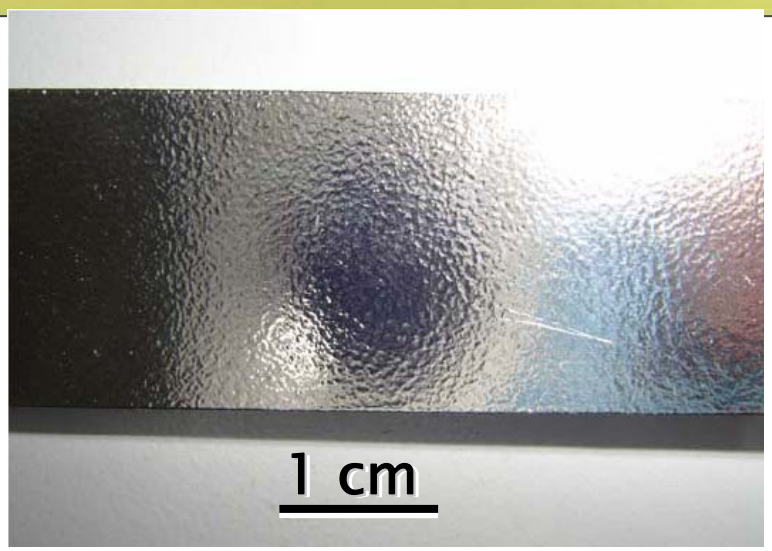




Glasbrenner, JNM 356 (2006) 213.

T91/FeCrAlY Sample preparation

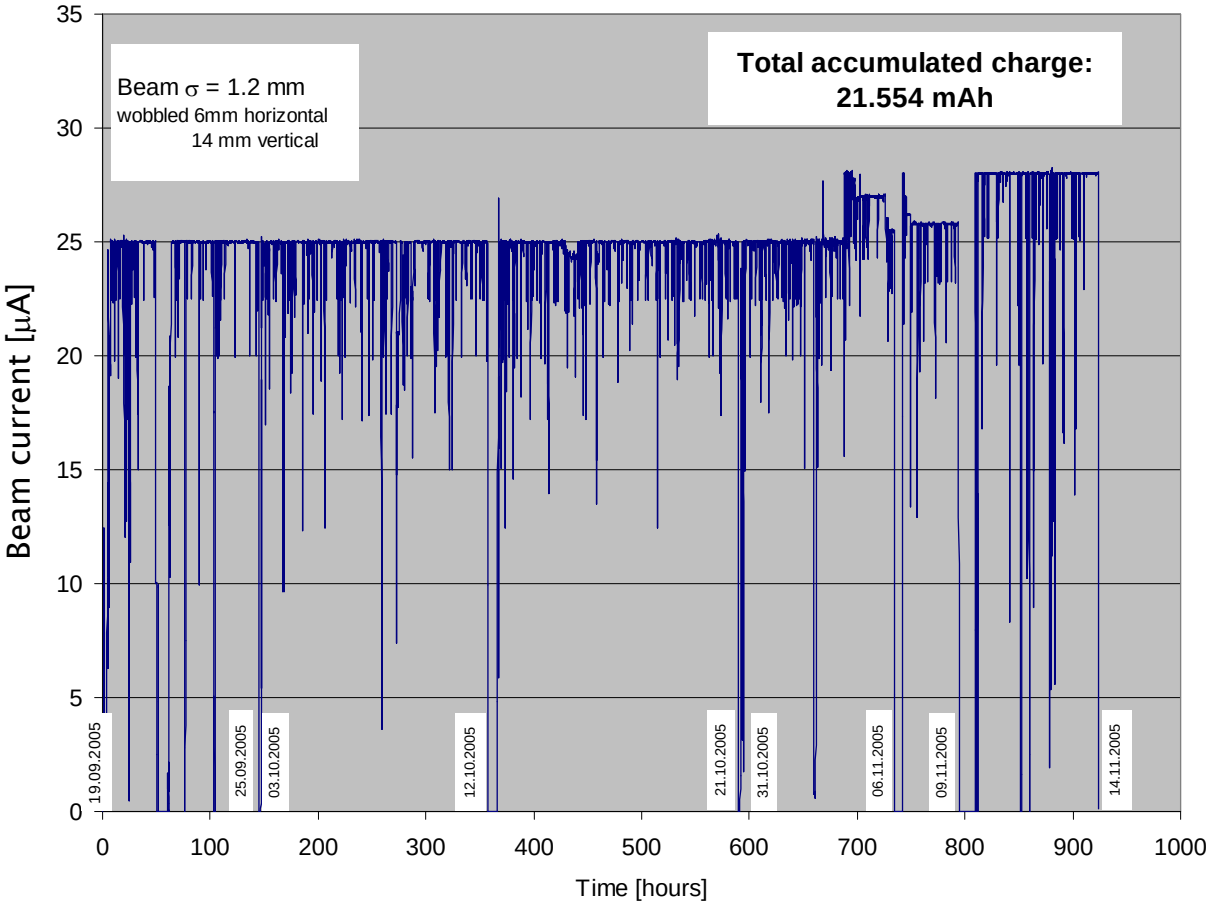
	Fe [wt%]	Cr [wt%]	Al [wt%]	Y [wt%]	Ni, Co [wt%]
powder	76.7	15.5	7.4	0.37	<0.03
coating	76.6	15.82	6.39	0.44	NN
+ GESA	80.5	15.2	3-4	NN	NN



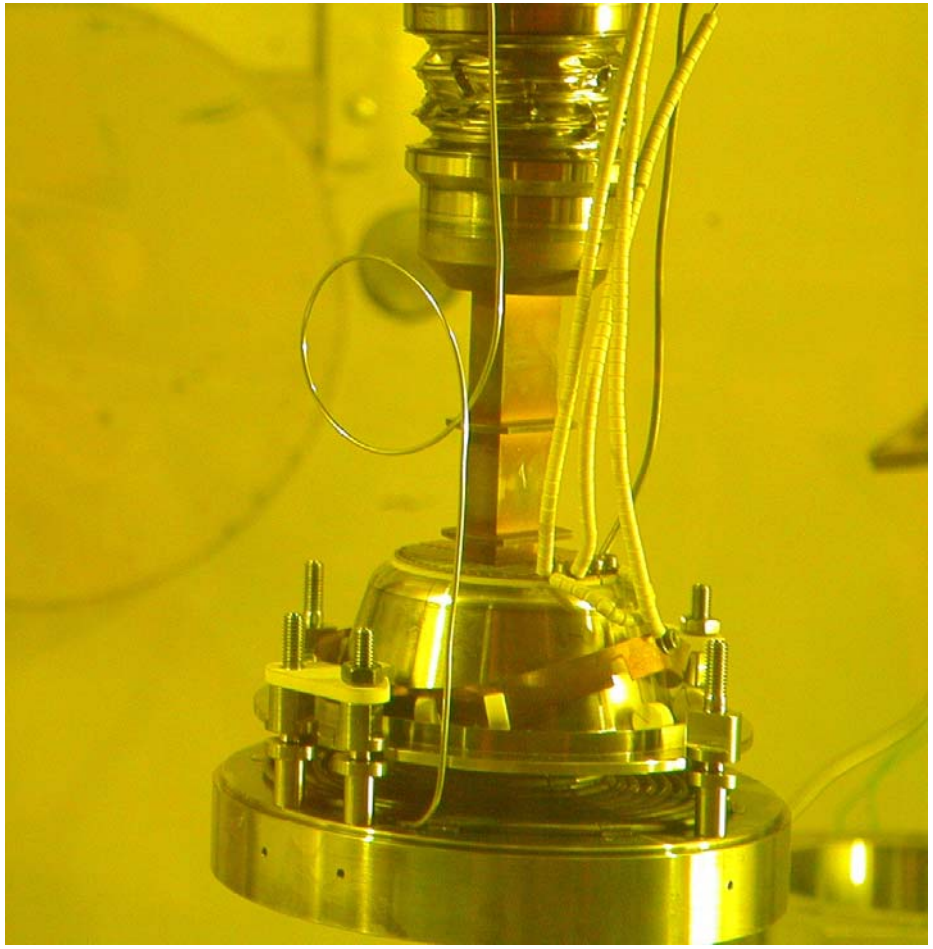
FeCrAlY-coating & GESA:
Front face only

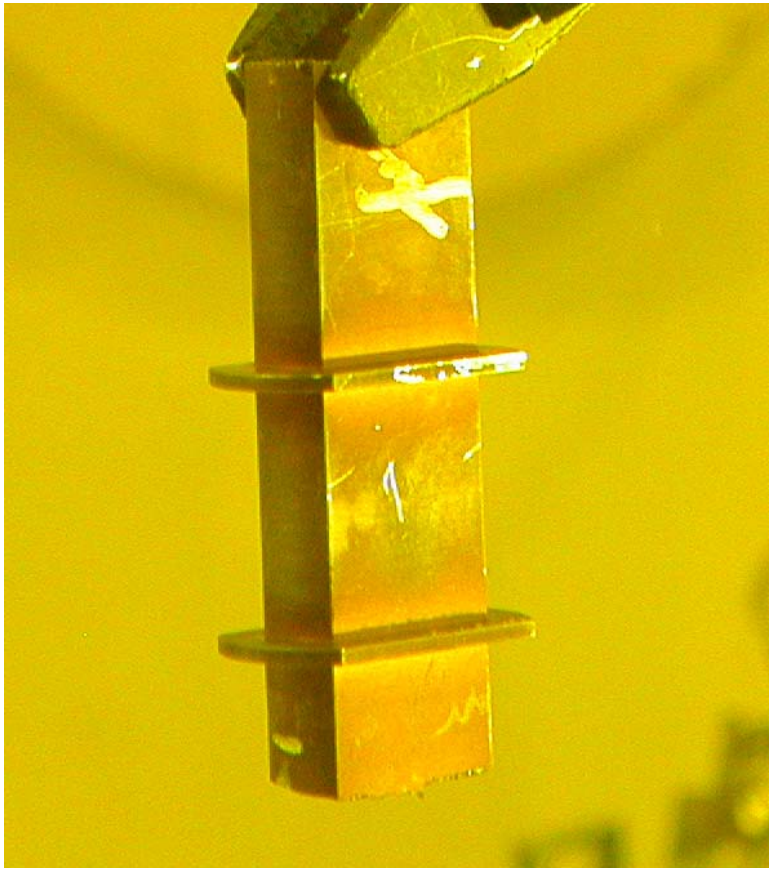
Irradiation experiment

Irradiation period: September 19 – November 14, 2005



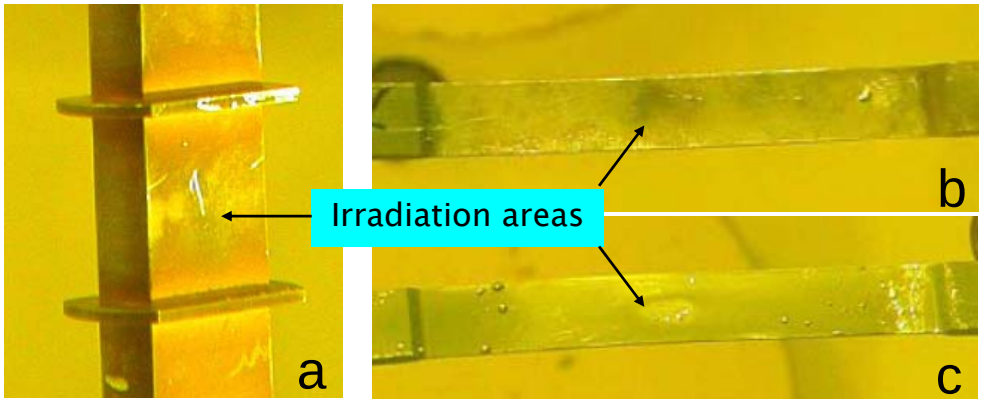
Lisor6 – Test Section Tube

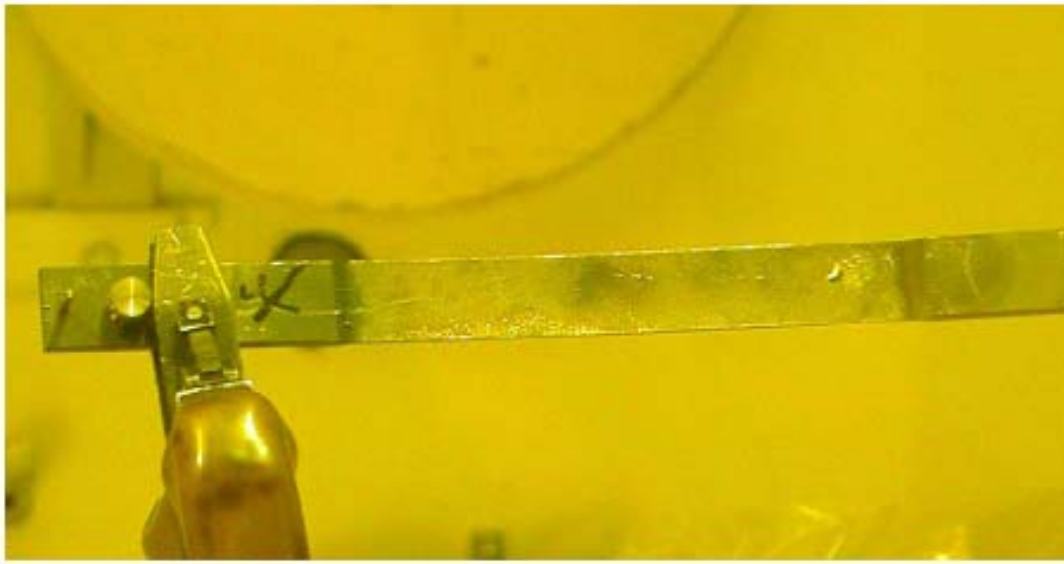


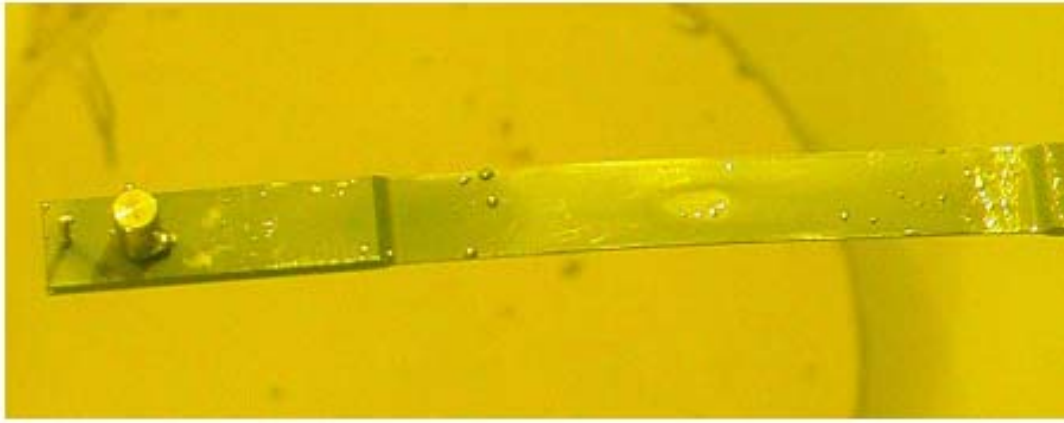


Beam entrance window

Lisor6 – Stressed Specimen

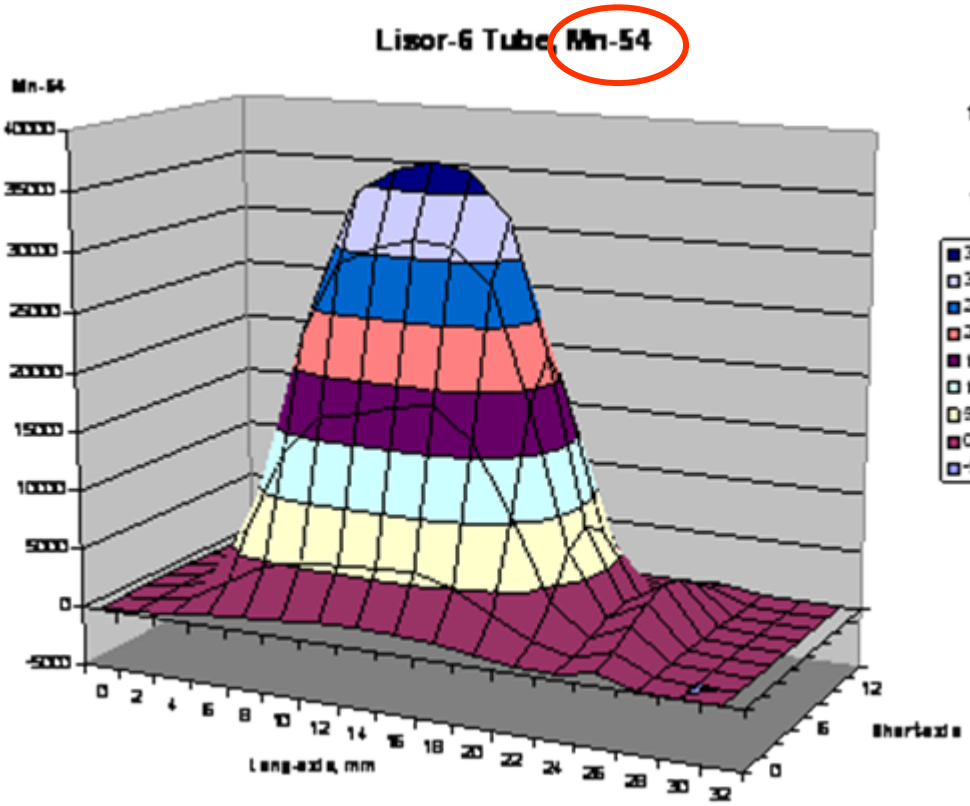




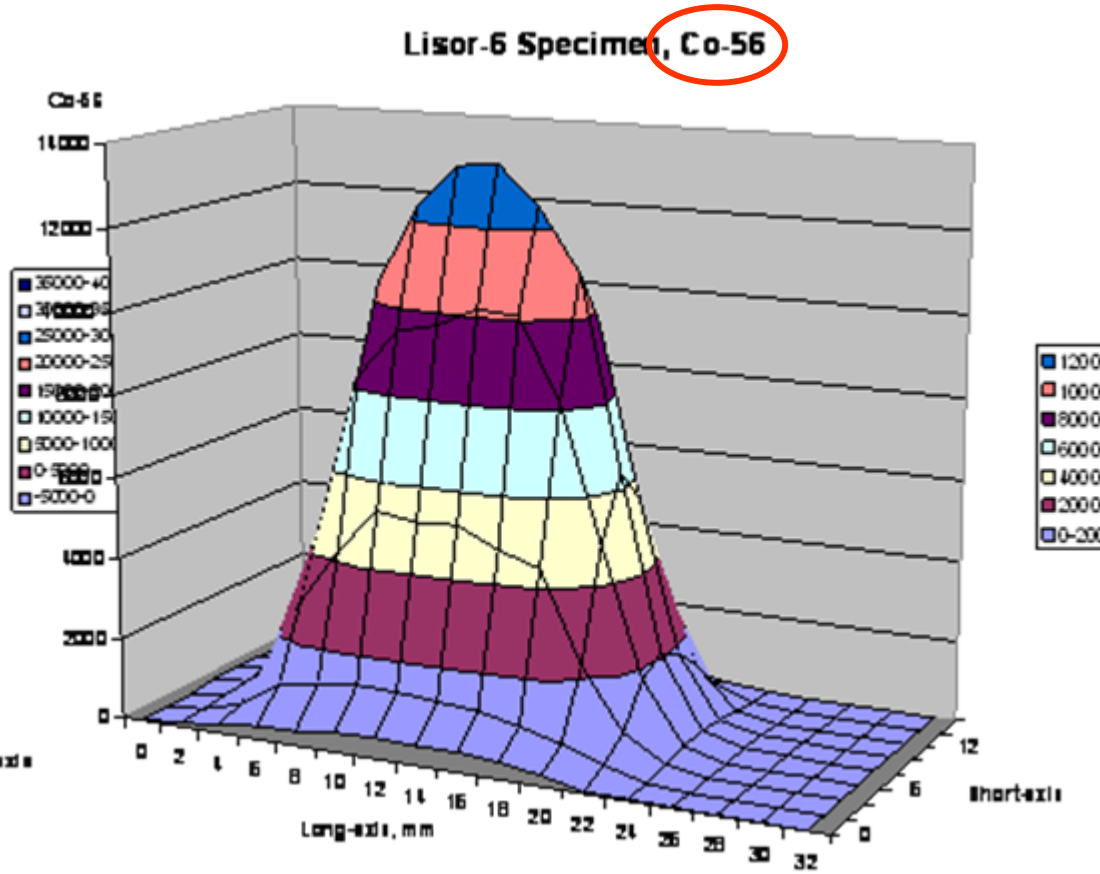


Sample bent during irradiation:
⇒ non-centric position in the test section tube
⇒ dpa-correction

Lisor6 – Gamma Mapping

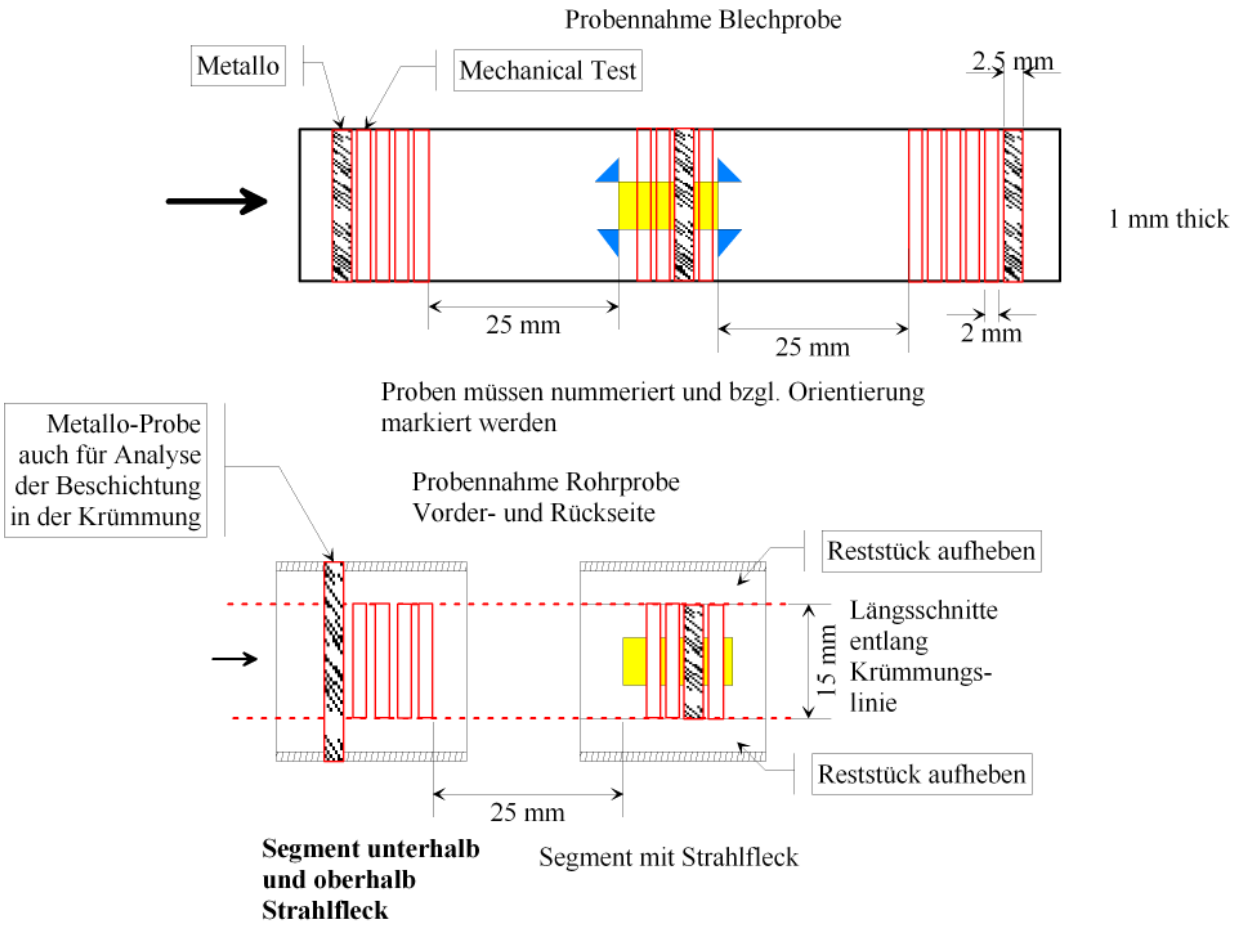


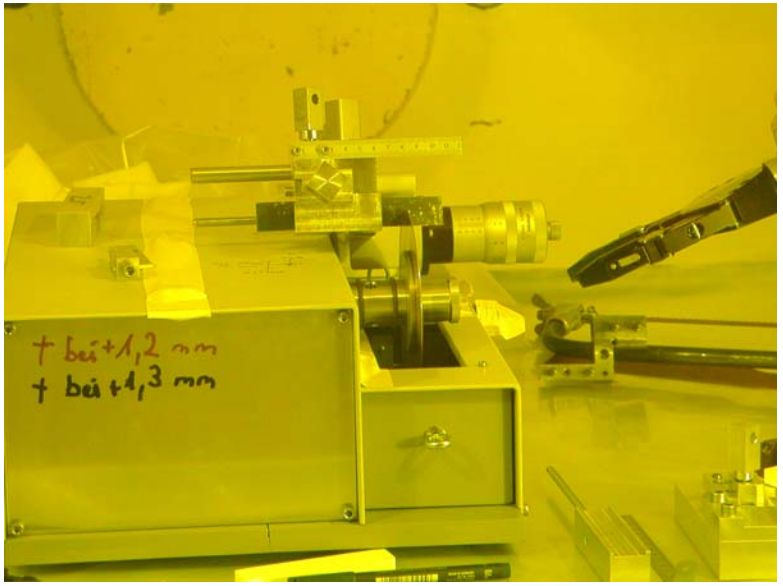
From the tube

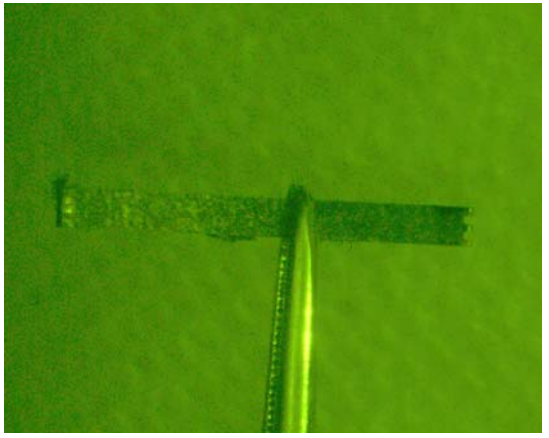


From the specimen

Lisor-6 Cutting plan





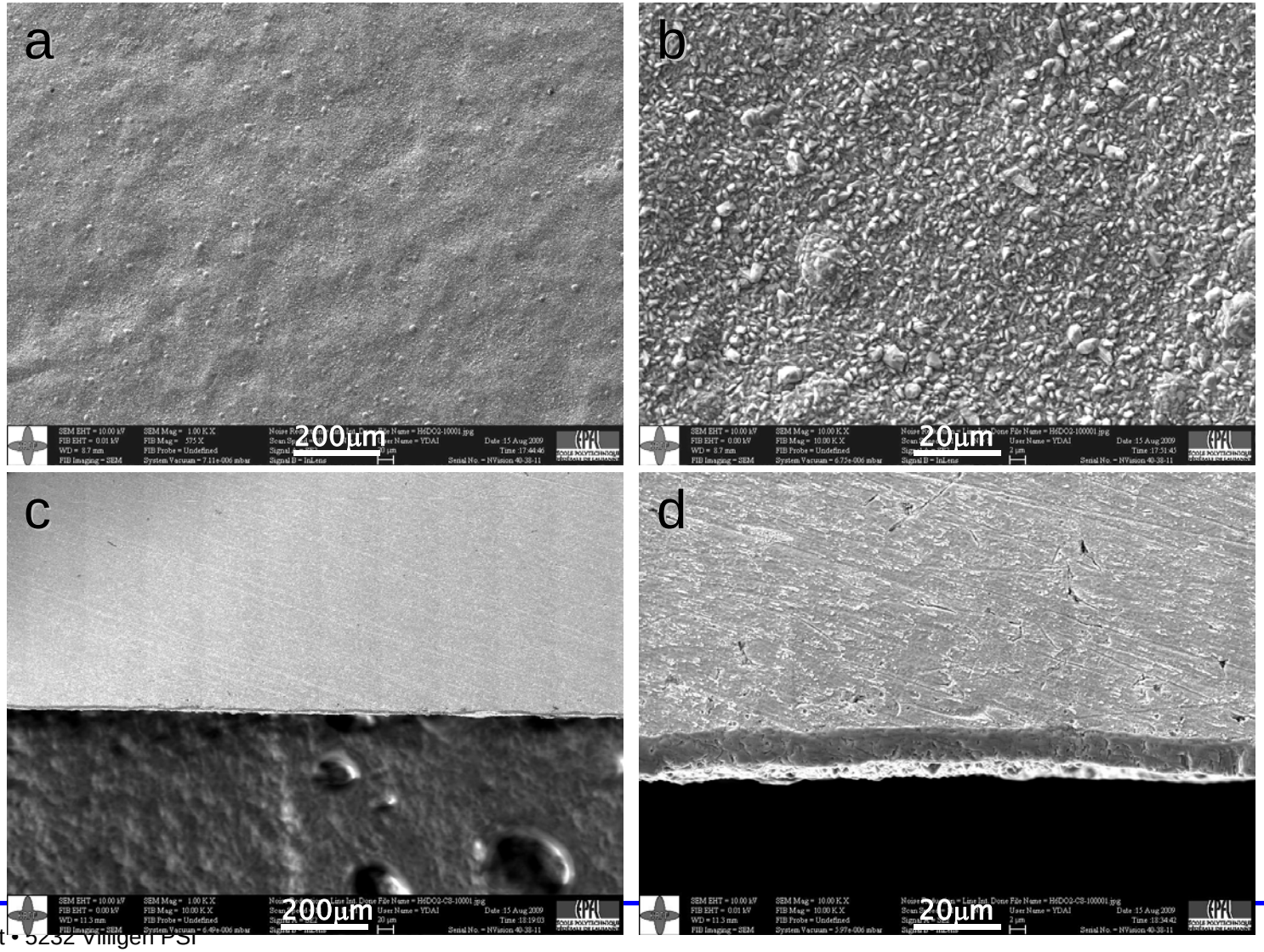


Lisor-6 Post Irradiation Examinations (PIE)

- EPMA/SEM inspection of the irradiated, TiN coated tube, and FeCrAlY/GESA coated specimen, comparison to unirradiated references
- Nano-indentation on FeCrAlY/GESA coating
- Bending tests of reference samples: Behavior of the coatings under mechanical loading

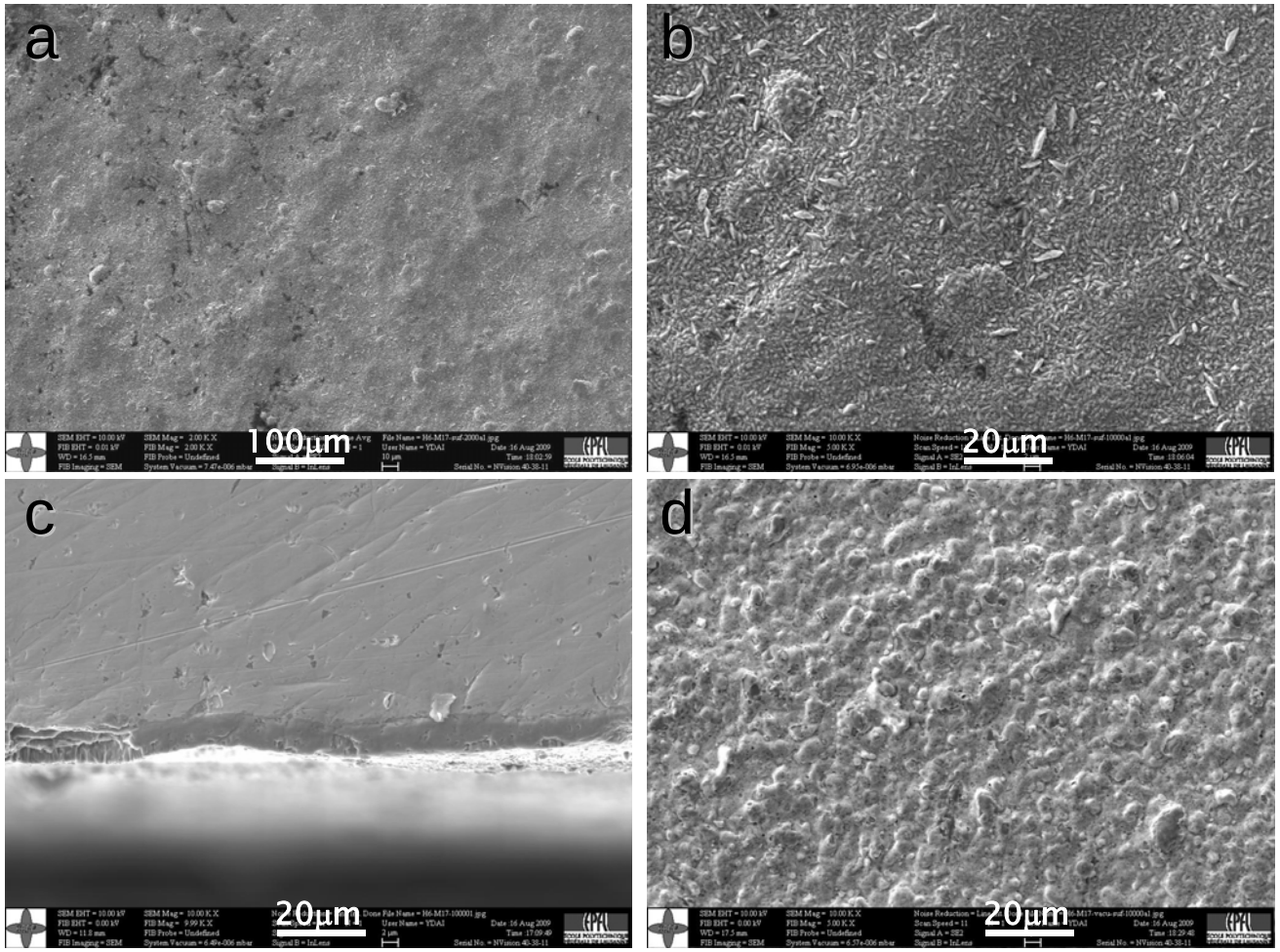
SEM Inspection

TiN coating, unirradiated



SEM Inspection

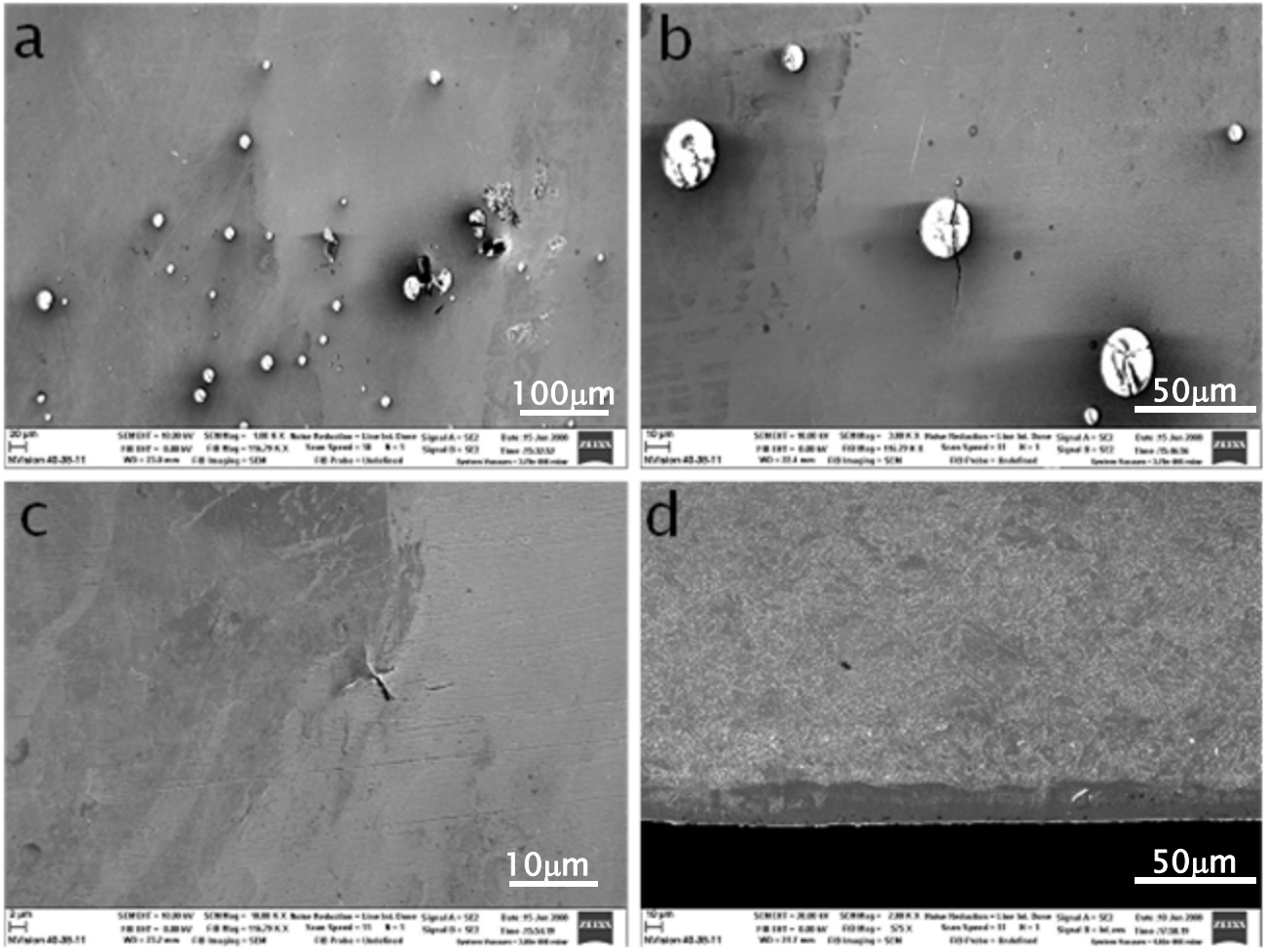
TiN coating, irradiated to 1.8 dpa



c: surface facing to flowing LBE; d: surface facing to vacuum. No evident damage.

SEM Inspection

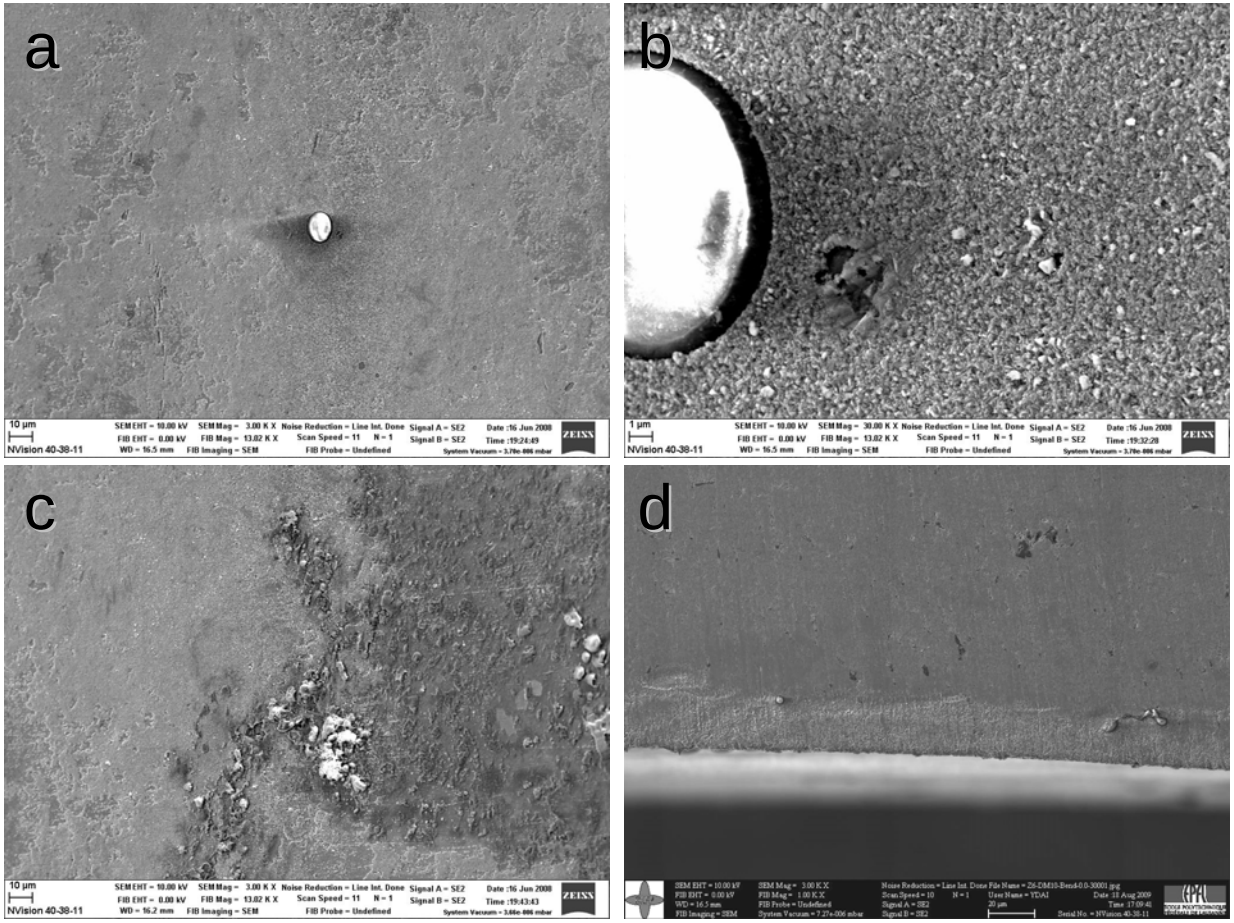
FeCrAlY/GESA coating, unirradiated



With some micro-cracks and Al/Y oxides on surface

SEM Inspection

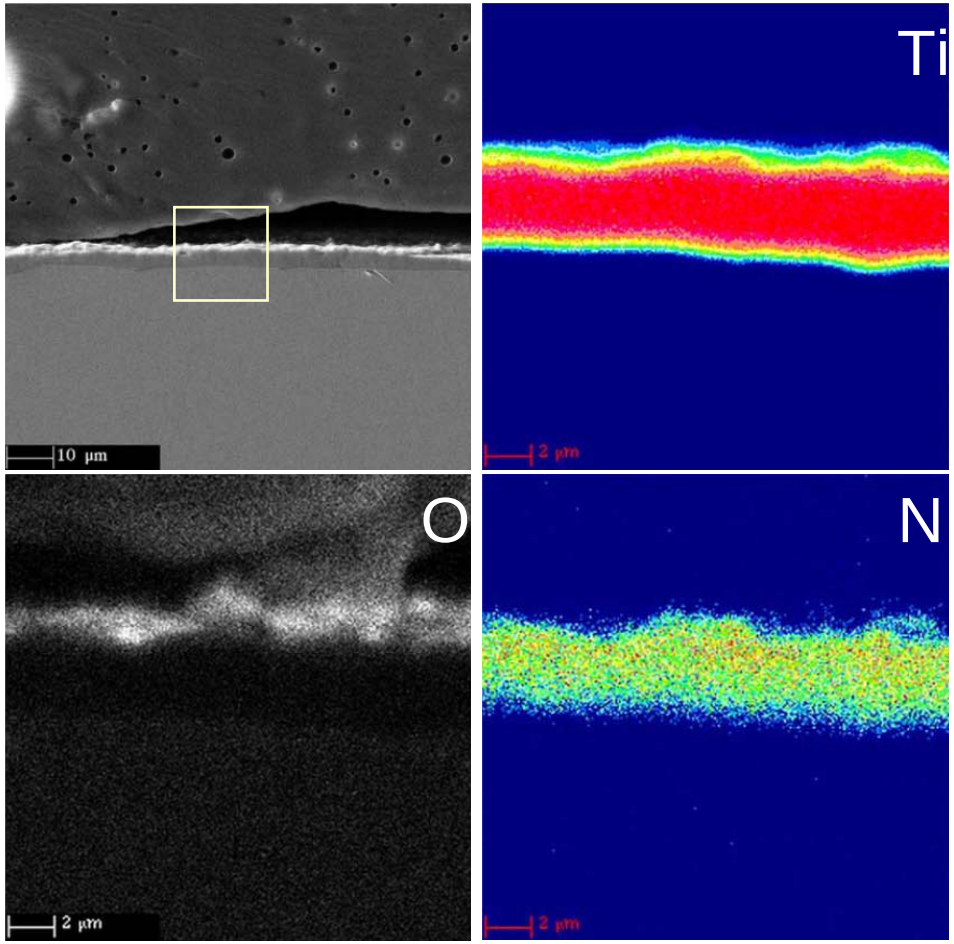
FeCrAlY/GESA coating, irradiated to 2.5 dpa



surface facing to flowing LBE: slightly oxidized, no evident damage

EPMA Inspection

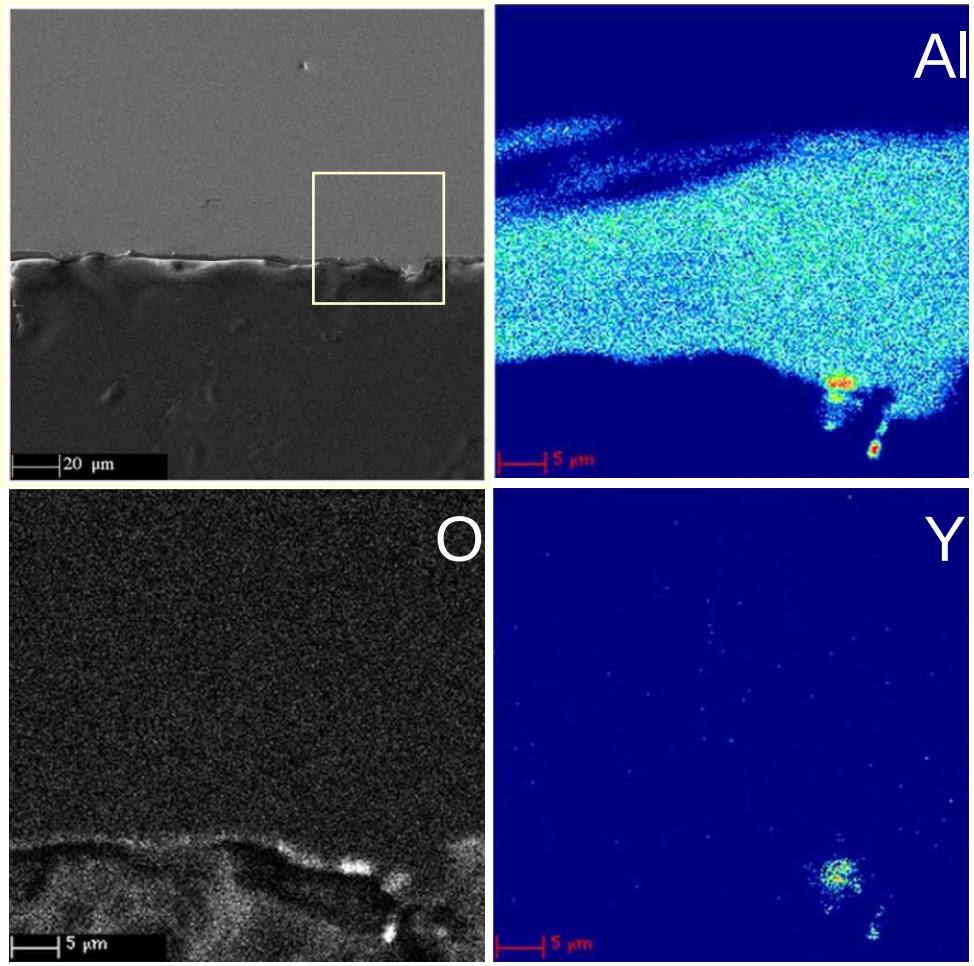
TiN coating, irradiated to 1.8 dpa



Confirm SEM observations: no evident damage

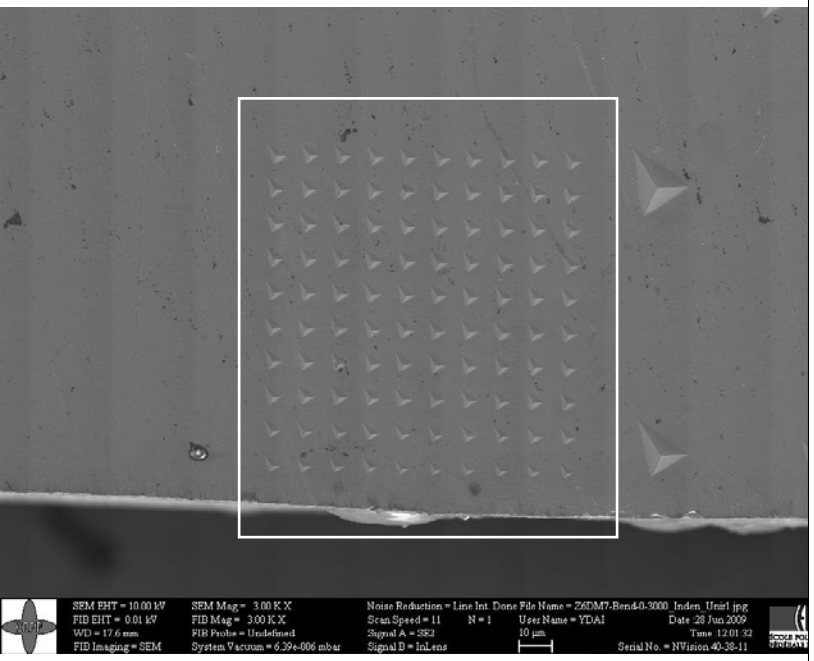
EPMA Inspection

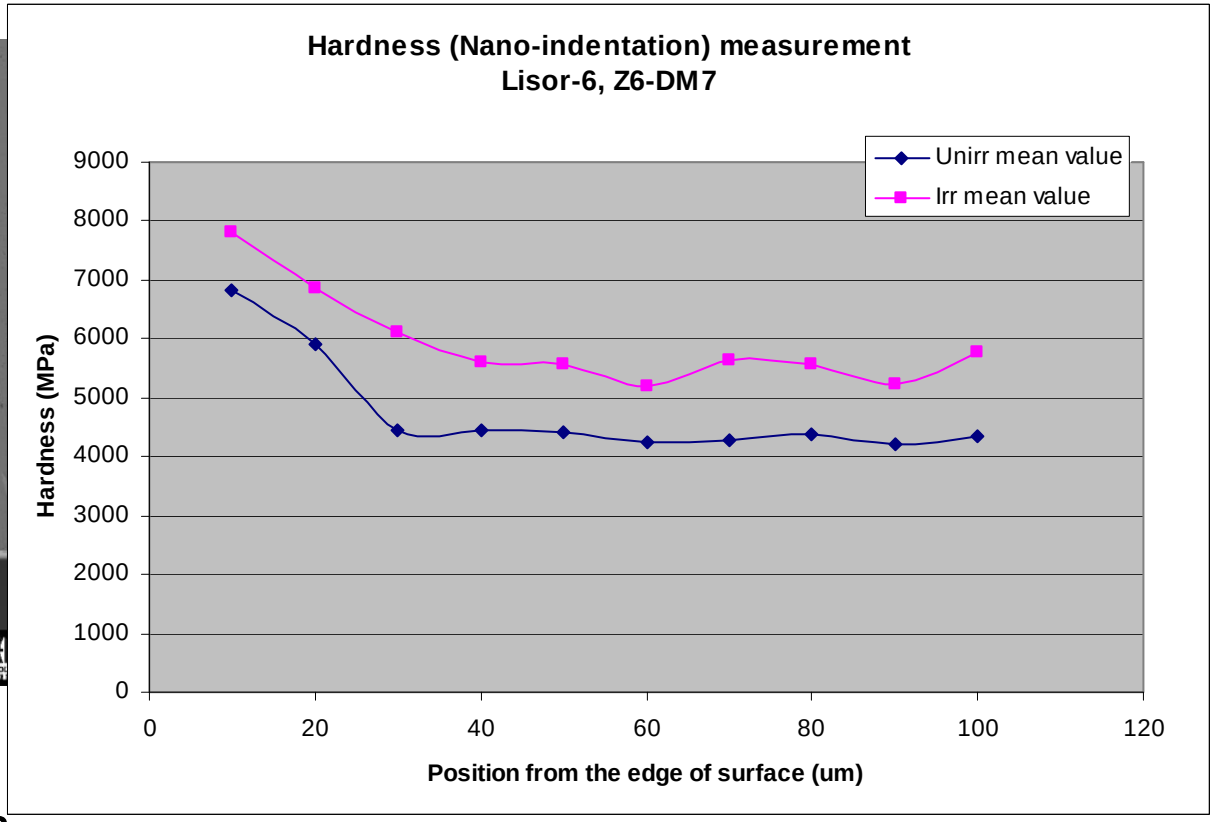
FeCrAlY/GESA coating, irradiated to 2.5 dpa



Confirm SEM observations: no evident damage, Al/Y oxides on surface

Nano-indentation on FeCrAlY coatings



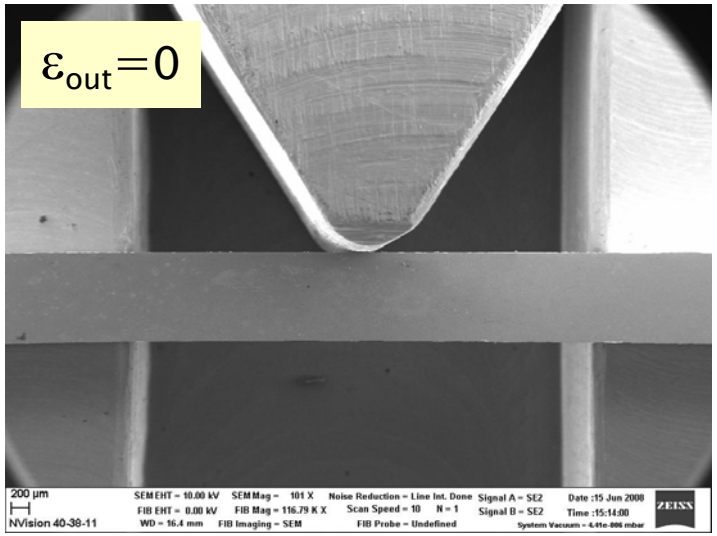


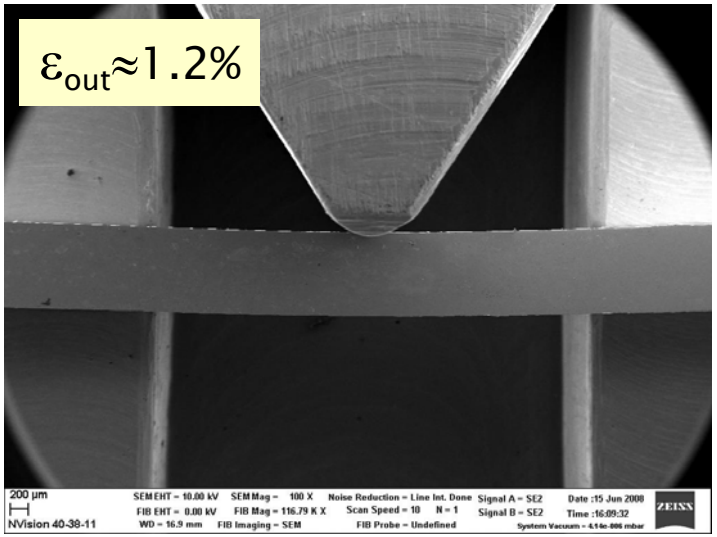
Cross section,
Coating at bottom, 30 micron
10 micron distance indents

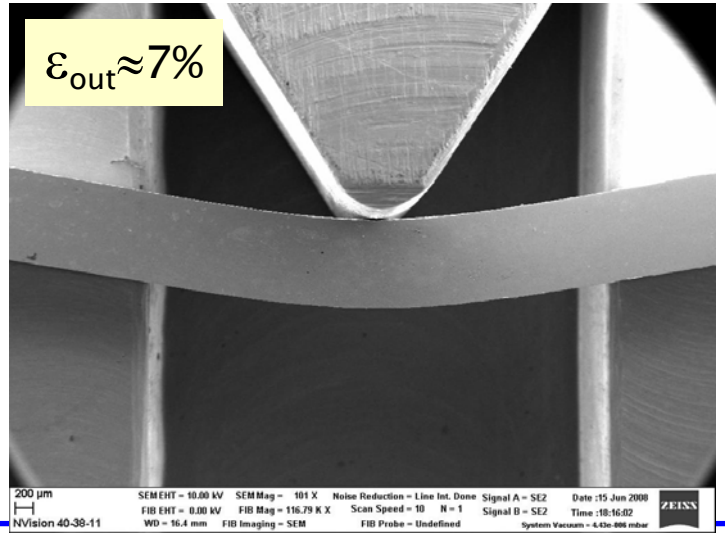
Sample of ~0.4 dpa shows irradiation-induced hardening in both matrix and coating materials.

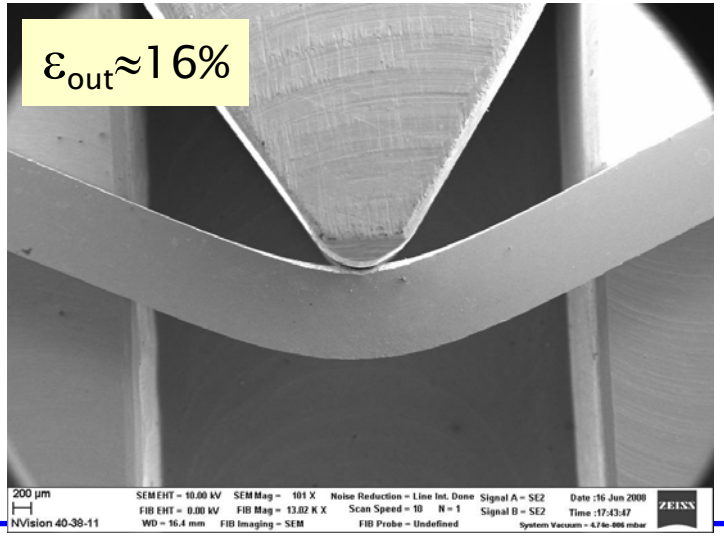
FeCrAlY-coated specimen: “In-situ” Bending test

Reference sample





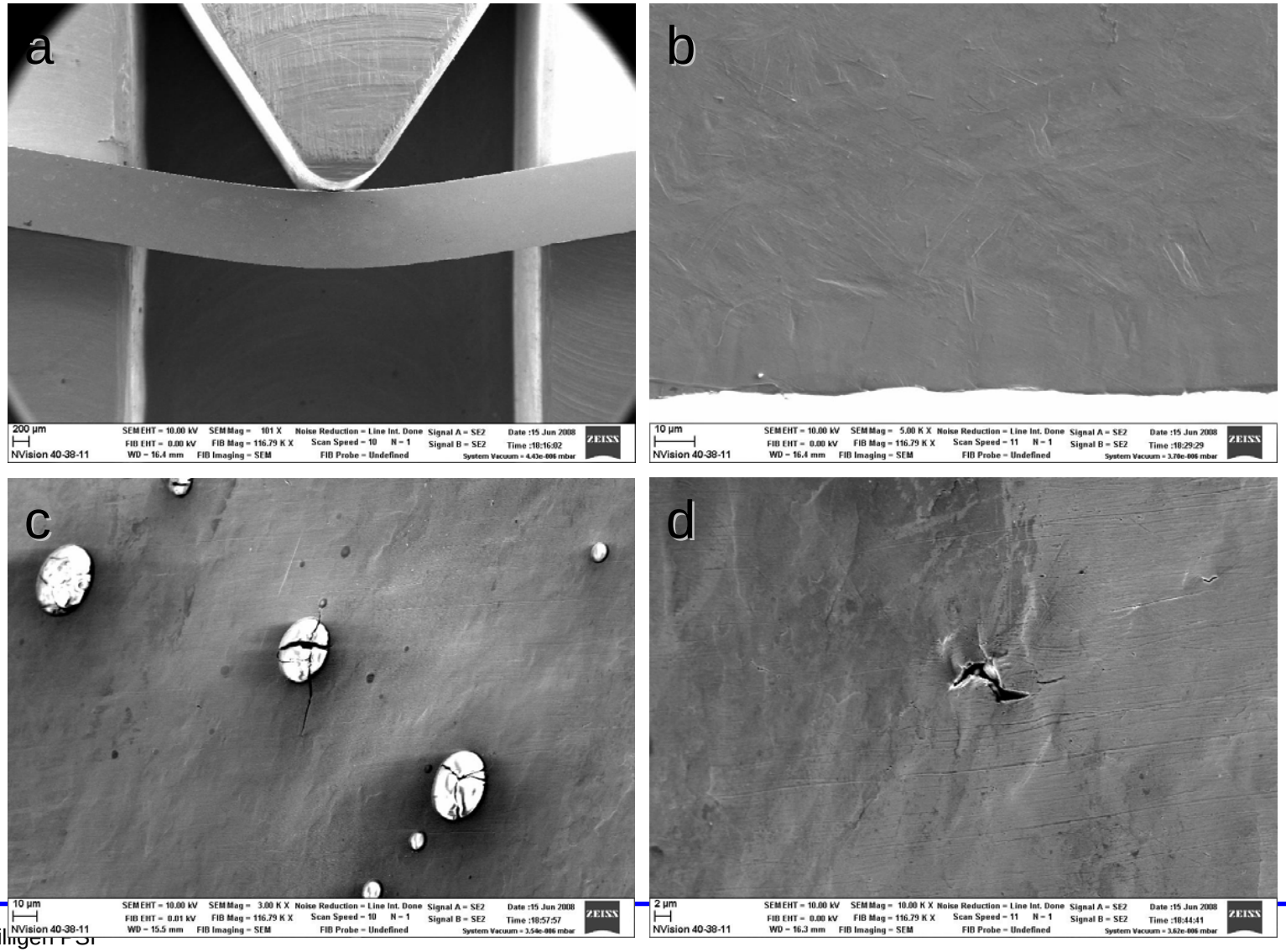




"In-situ" Bending test

FeCrAlY/GESA coated specimen, unirradiated

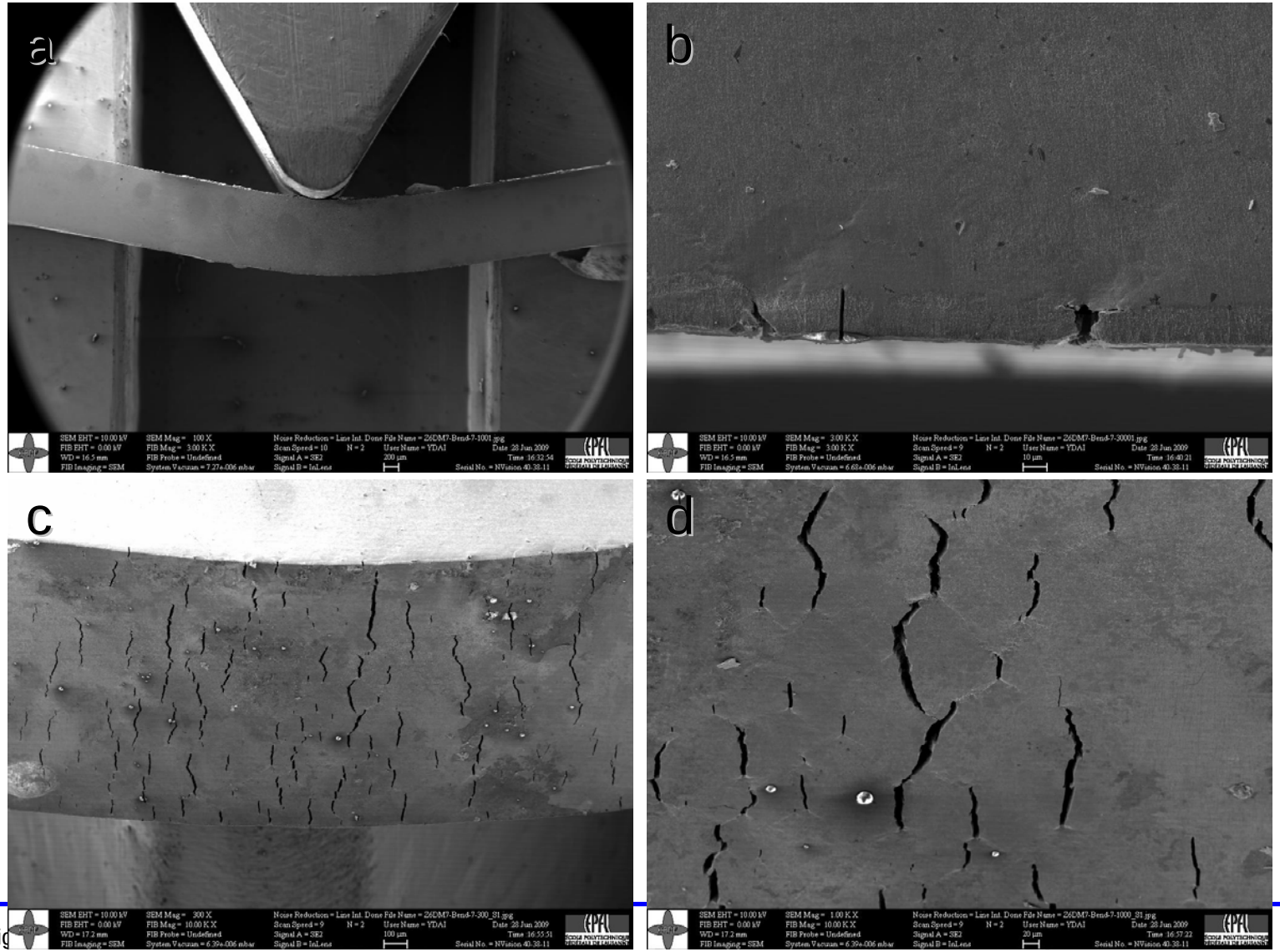
$\varepsilon_{out} \approx 7\%$



"In-situ" Bending test

FeCrAlY/GESA coated specimen, irradiated to 0.48 dpa

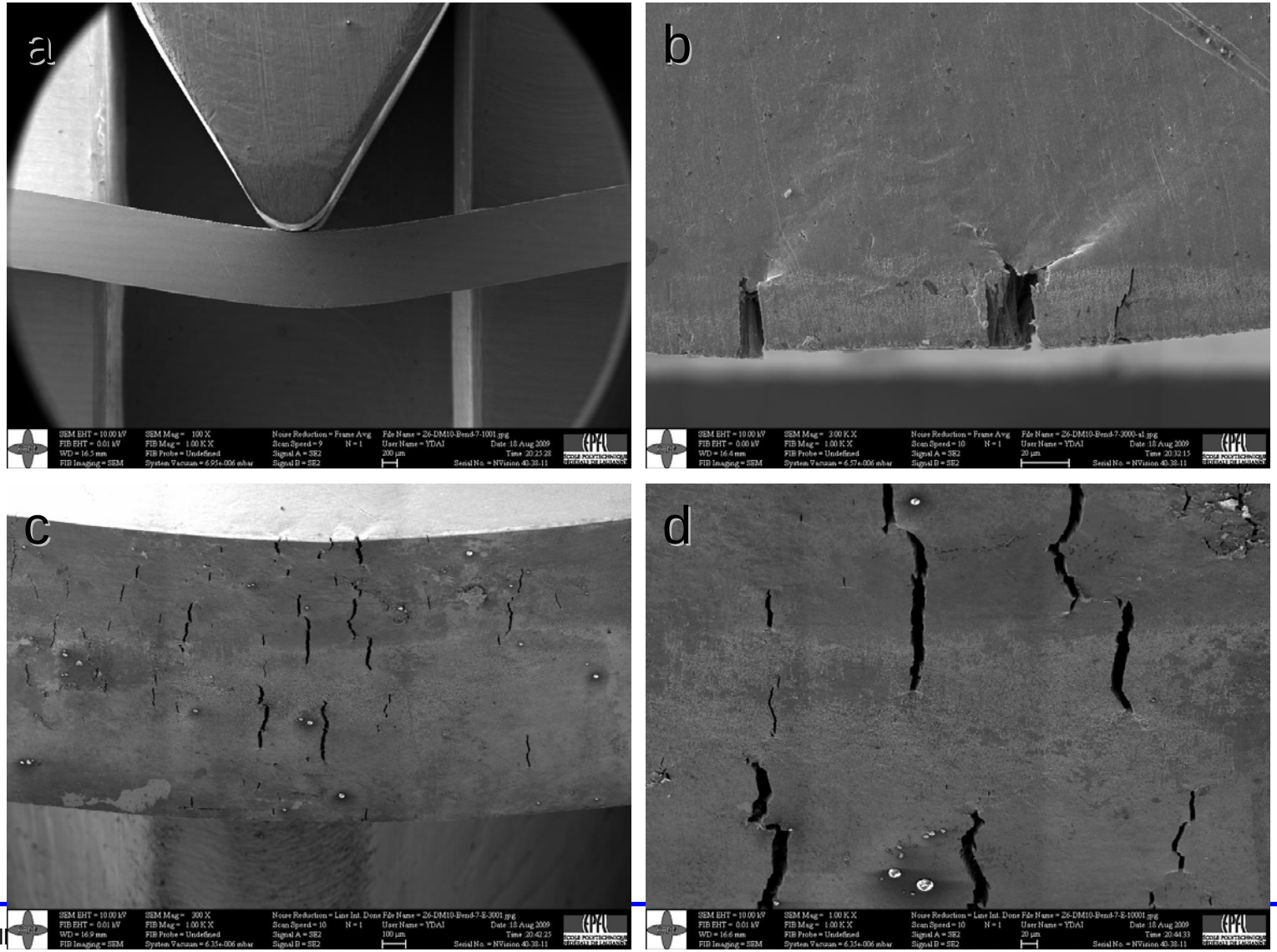
$\varepsilon_{out} \approx 8.7\%$



“In-situ” Bending test

FeCrAlY/GESA coated specimen, irradiated to 2.5 dpa

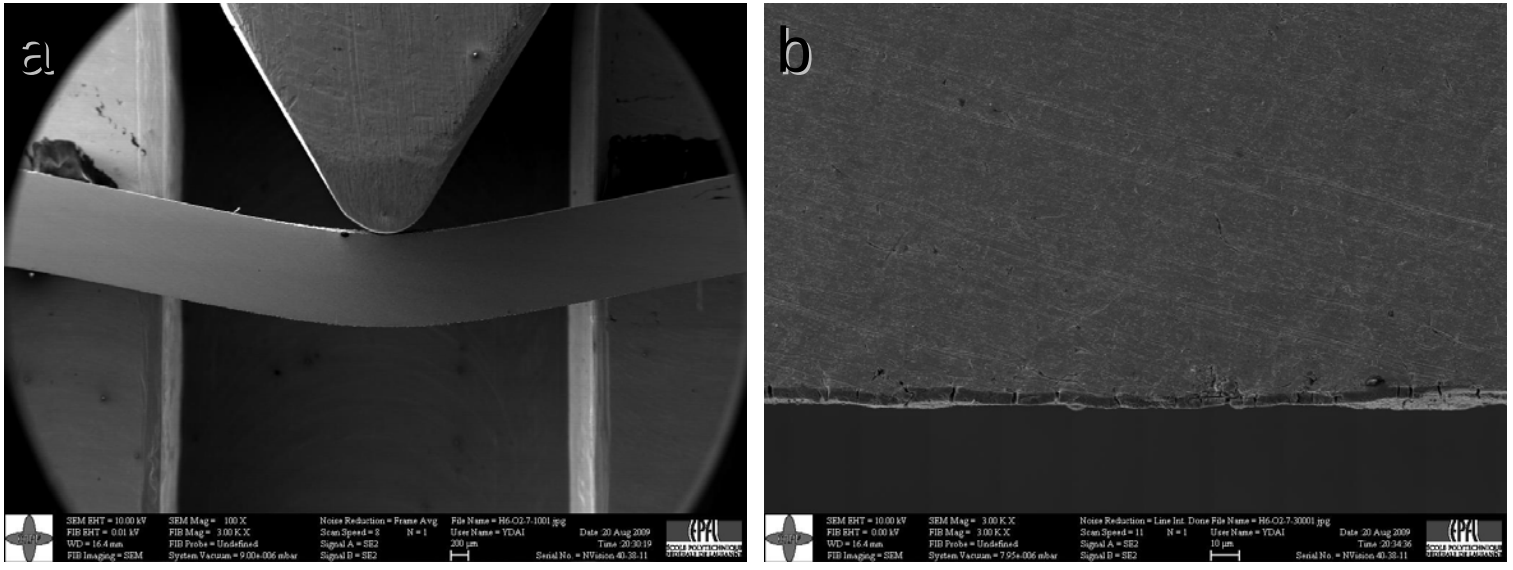
$\varepsilon_{out} \approx 8.8\%$

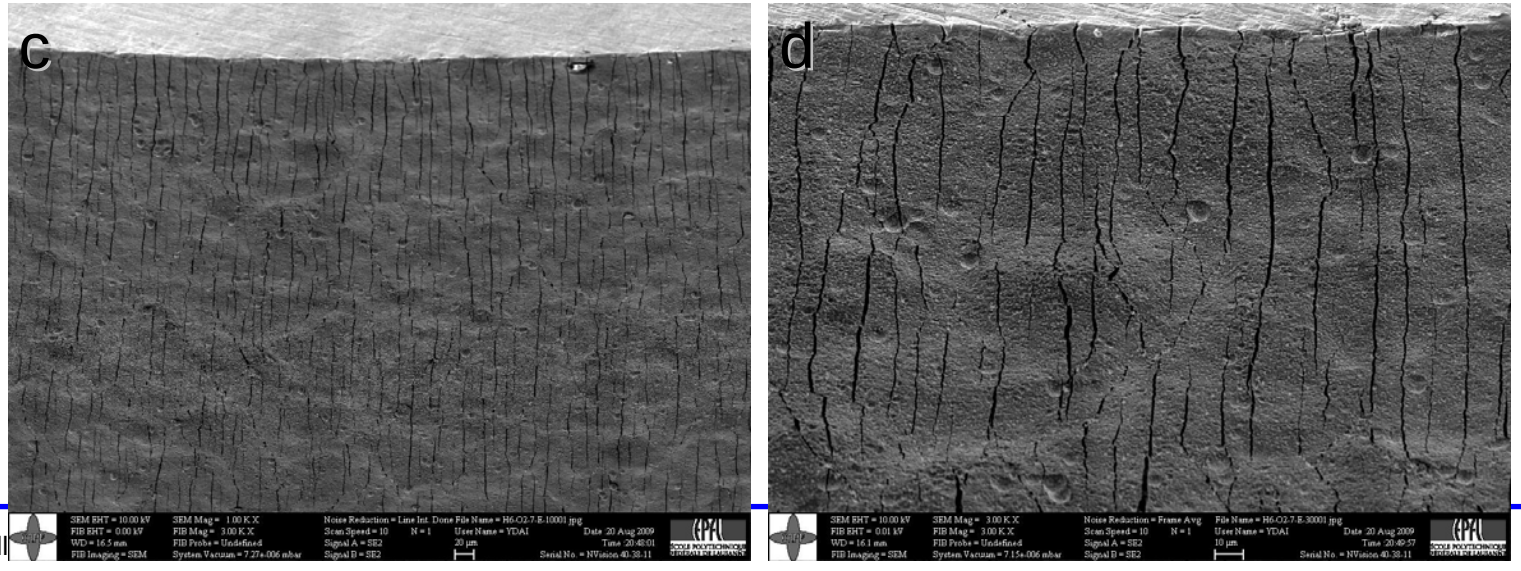


"In-situ" Bending test

TiN coated specimen, unirradiated

$\varepsilon_{out} \approx 8.8\%$

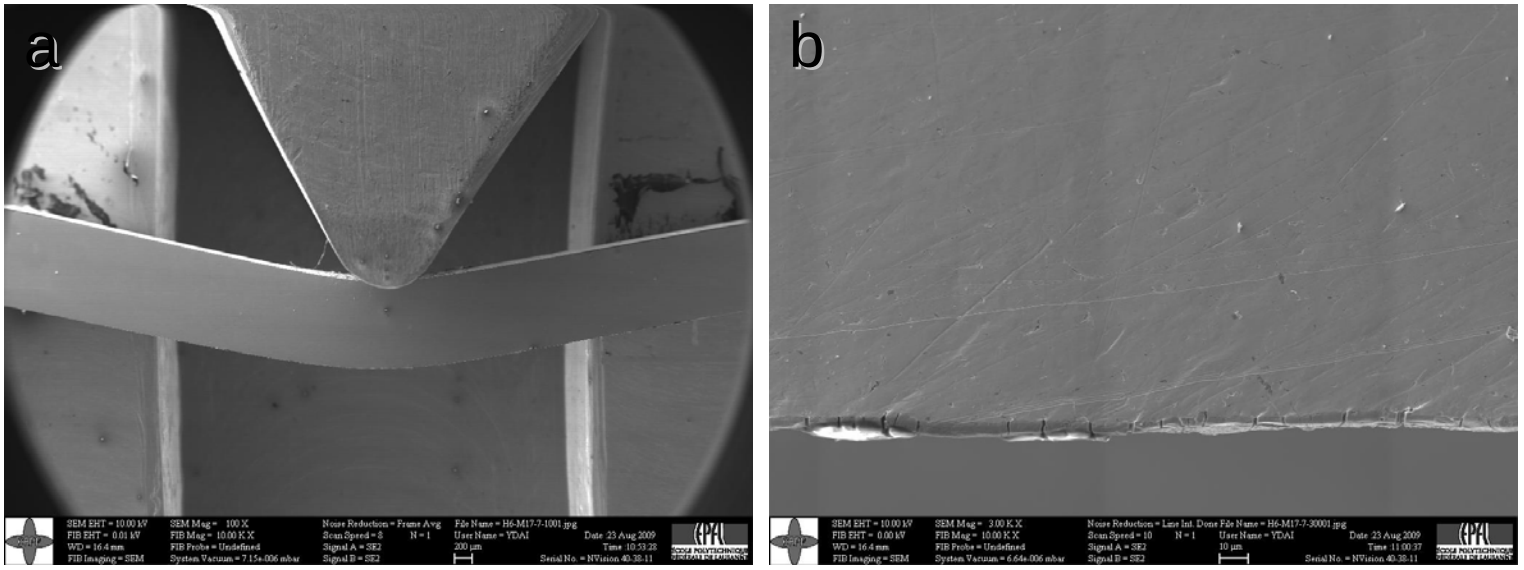


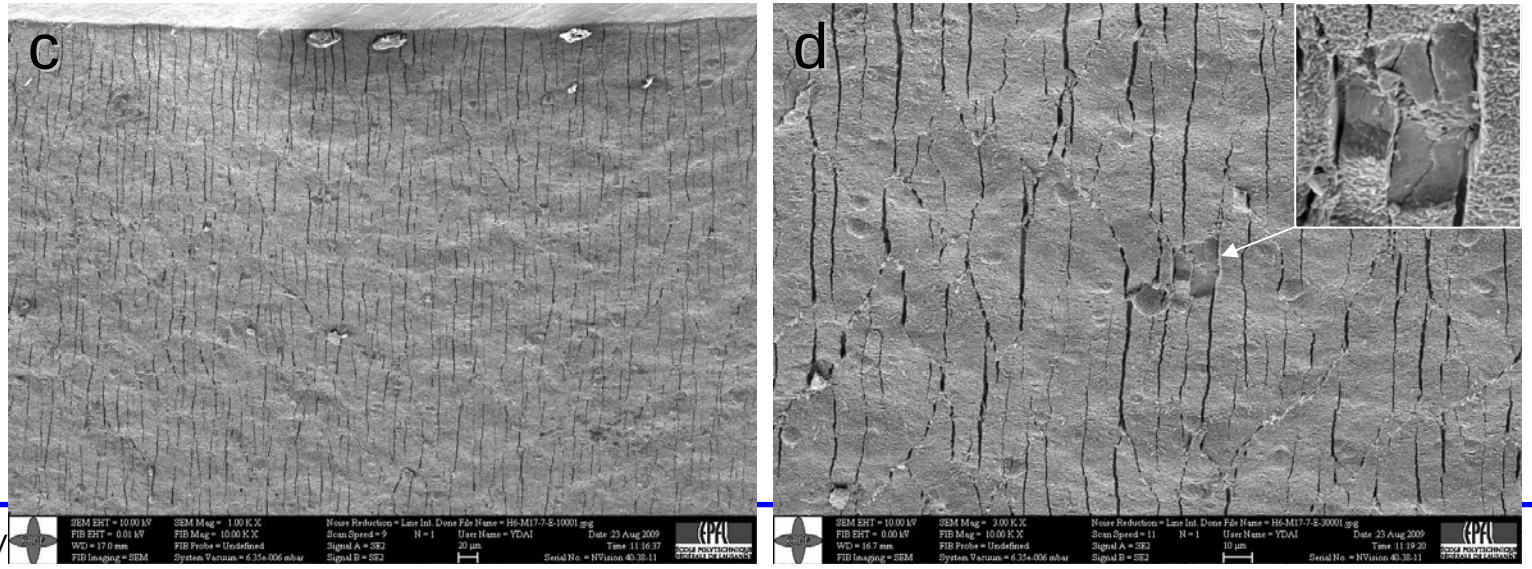


"In-situ" Bending test

TiN coated specimen, irradiated to 1.8 dpa

$\varepsilon_{out} \approx 9.1\%$





Conclusions

1) In the present experimental condition, no evident damage induced by either irradiation or LBE corrosion on both coatings, which suggests good compatibility of both coatings with LBE under irradiation.

2) The mechanical stability, or in other word the bounding of the coating layer with the steel matrix, looks good under the present irradiation condition, even at a rather high deformation level, e.g. 3-4% strain after irradiation.

3) The thickness of coating layer should be carefully selected to avoid large cracks which may result in LME.