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Performance and Reliability Of Metallic Materials for Nuclear Fission Power Generation

PROMINENT

Summary and update

September 2012

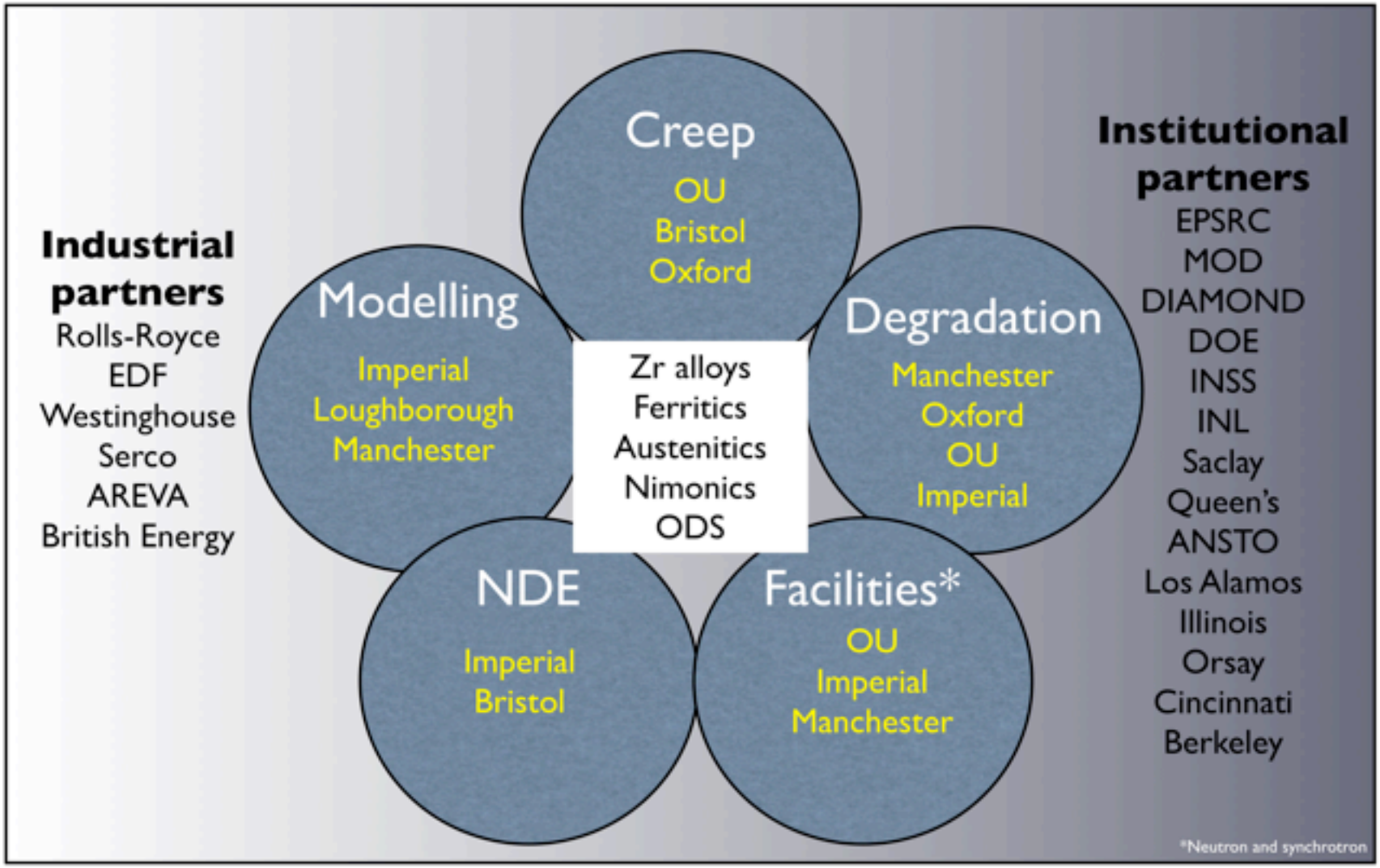
Imperial College London

Loughborough University

OxfordMaterials

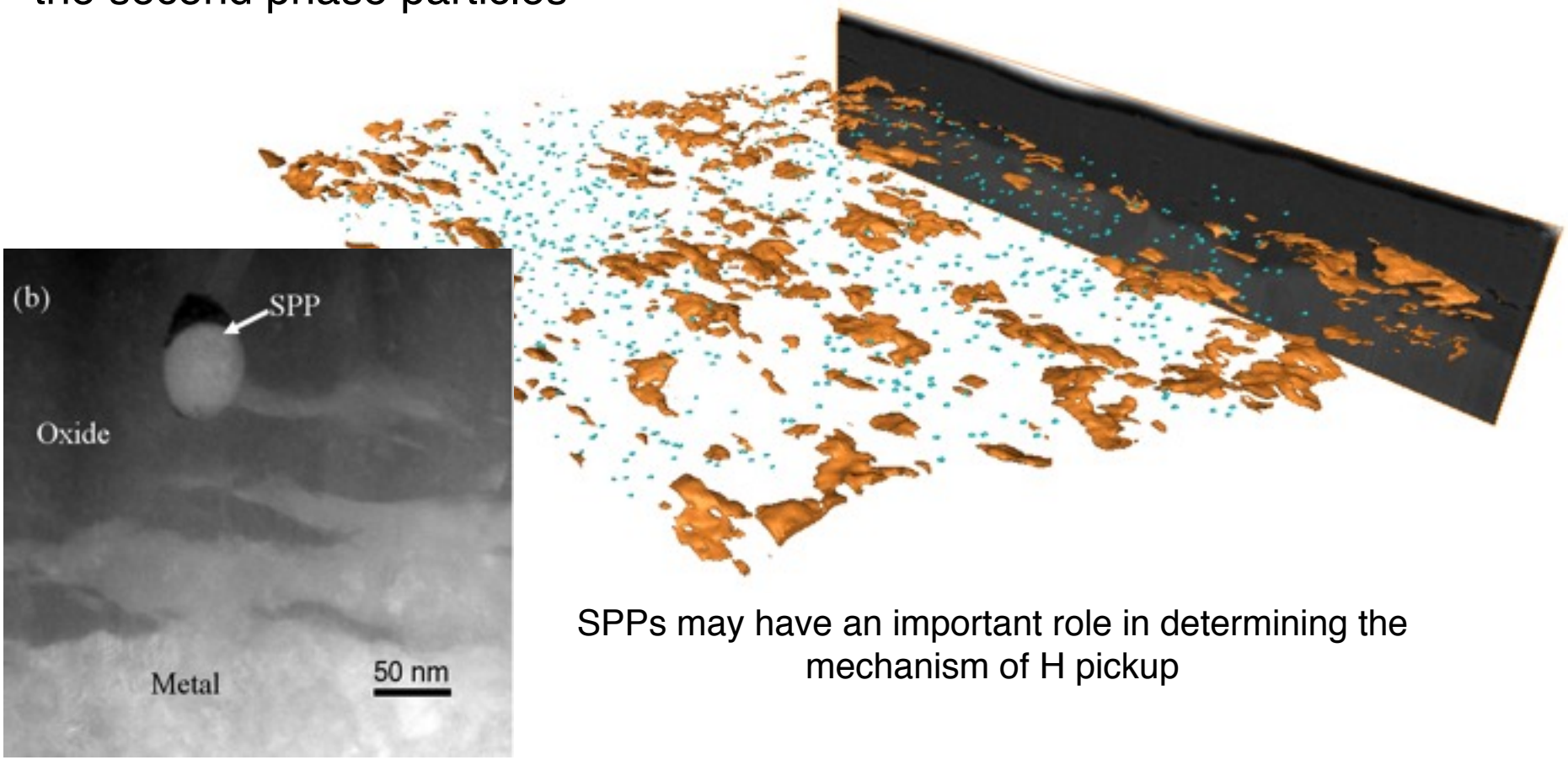
Our research challenges

- Challenge 1: Materials stability and degradation under in-service environmental exposure
  - 1.1 Radiation damage 3 projects
  - 1.2 IASCC 1 project
  - 1.2 Creep 2 projects
  - 2 Stability of zirconium 3 projects
- Challenge 2: State Monitoring of Materials
  - Linear and non-linear ultrasonic monitoring techniques
    - 2 projects
  - Links to Challenge 1, theme 1.2.
- **Crosscutting theme for all the projects:**
  - Advanced analytical and modelling techniques


Creep
OU
Bristol
Oxford
Modelling
Imperial
Loughborough
Manchester
Degradation
Manchester
Oxford
OU
Imperial
Zr alloys
Ferritics
Austenitics
Nimonics
ODS
NDE
Imperial
Bristol
Facilities*
OU
Imperial
Manchester
Industrial partners
Rolls-Royce
EDF
Westinghouse
Serco
AREVA
British Energy
Institutional partners
EPSRC
MOD
DIAMOND
DOE
INSS
INL
Saclay
Queen's
ANSTO
Los Alamos
Illinois
Orsay
Cincinnati
Berkeley
*Neutron and synchrotron

FIB slicing (Paper presented at Fall MRS 2011)

Sean Yardley, DPhil student, has worked on identifying and positioning the second phase particles



SPPs may have an important role in determining the mechanism of H pickup

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Where does the ^{18}O end up at different stages of the oxidation process?

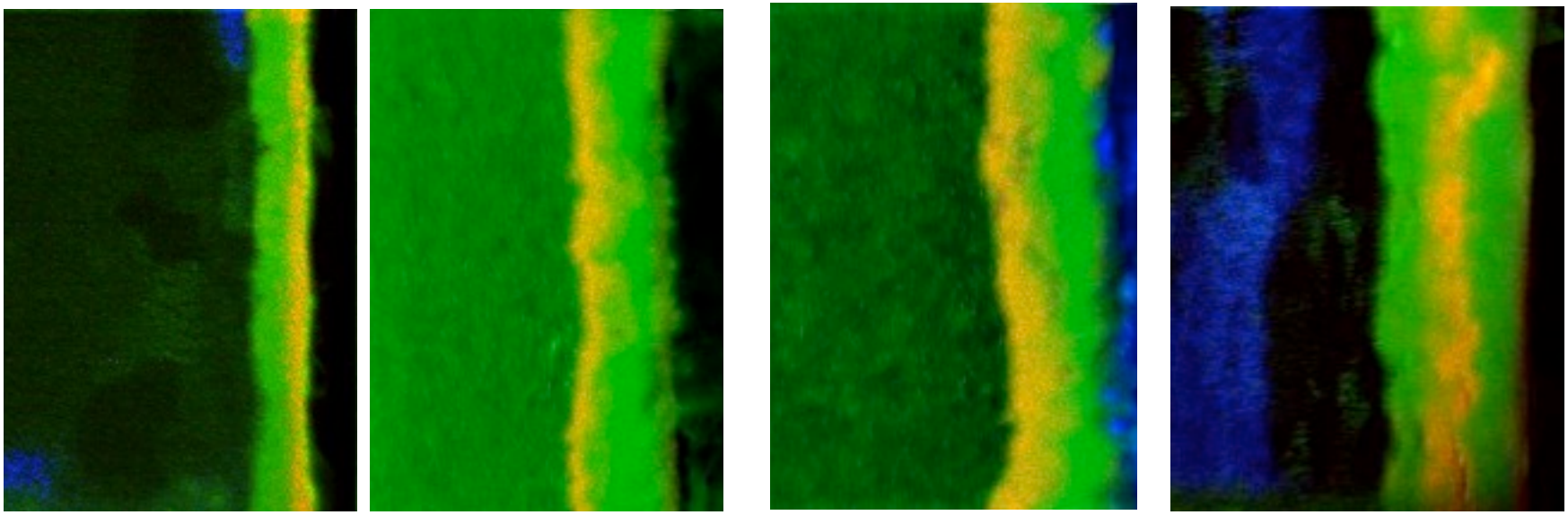
Colour coding
R= ^{18}O, G=^{16}O, B=2H

Sample SZLRX17
34 Days

Sample SZLSR17
80 Days

Sample SZLRX1
114 Days

Sample SZLSR1,
160 Days



Top surface

Metal/oxide interface

Middle of oxide

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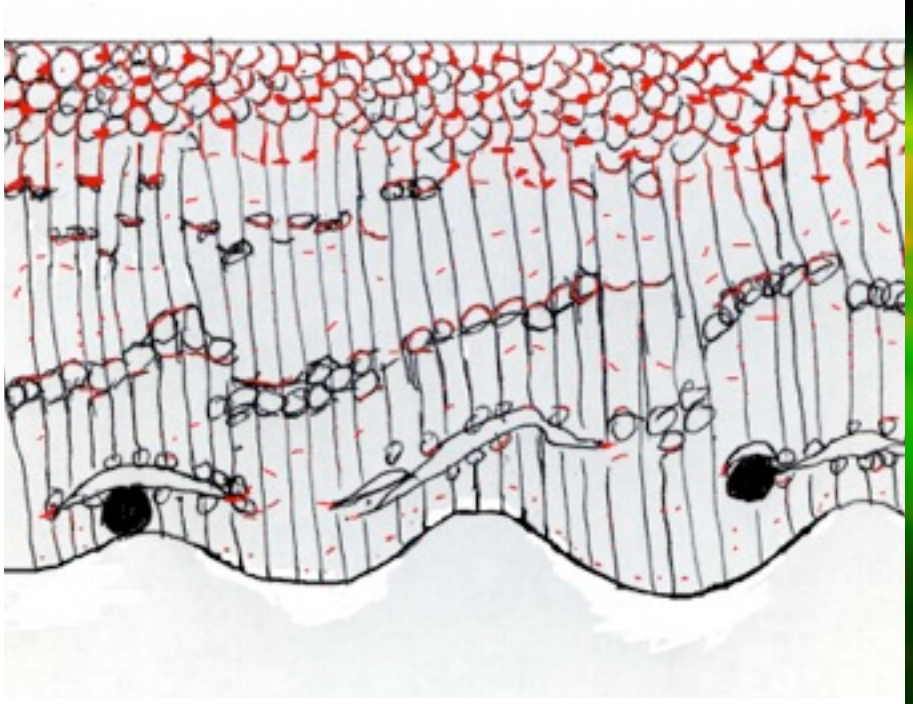
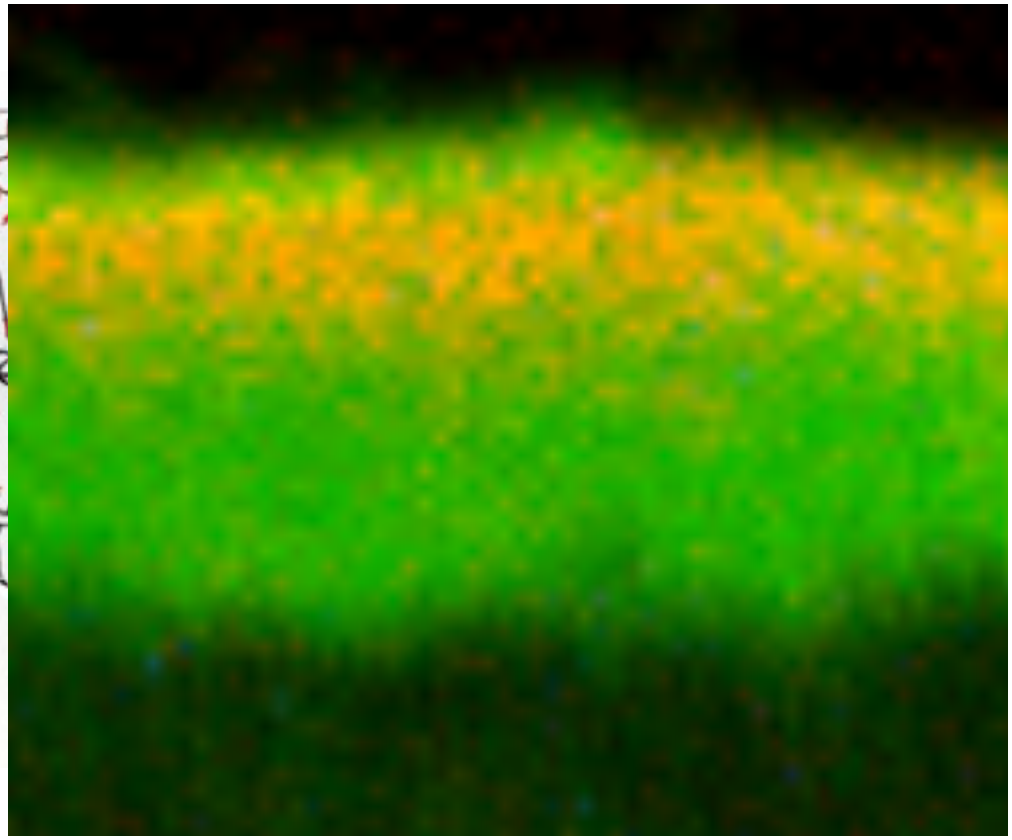
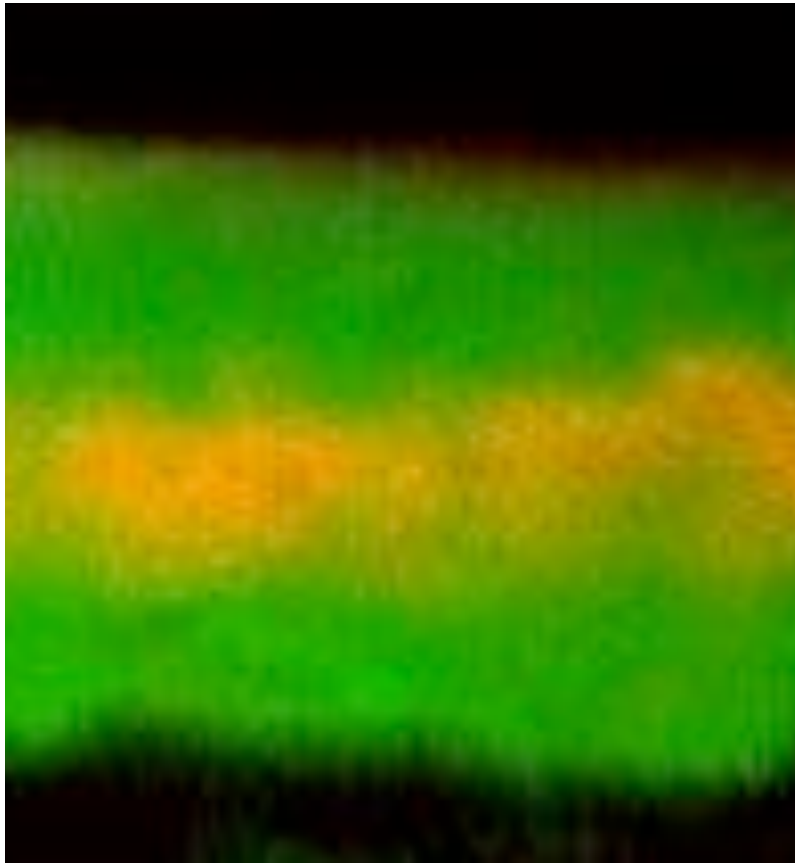
Pre-transition: dense inner oxide





^{18}O can only diffuse into oxide along monoclinic ZrO_2 grain boundaries

Post-transition: porous outer oxide but new dense inner oxide



Deuterium concentrations

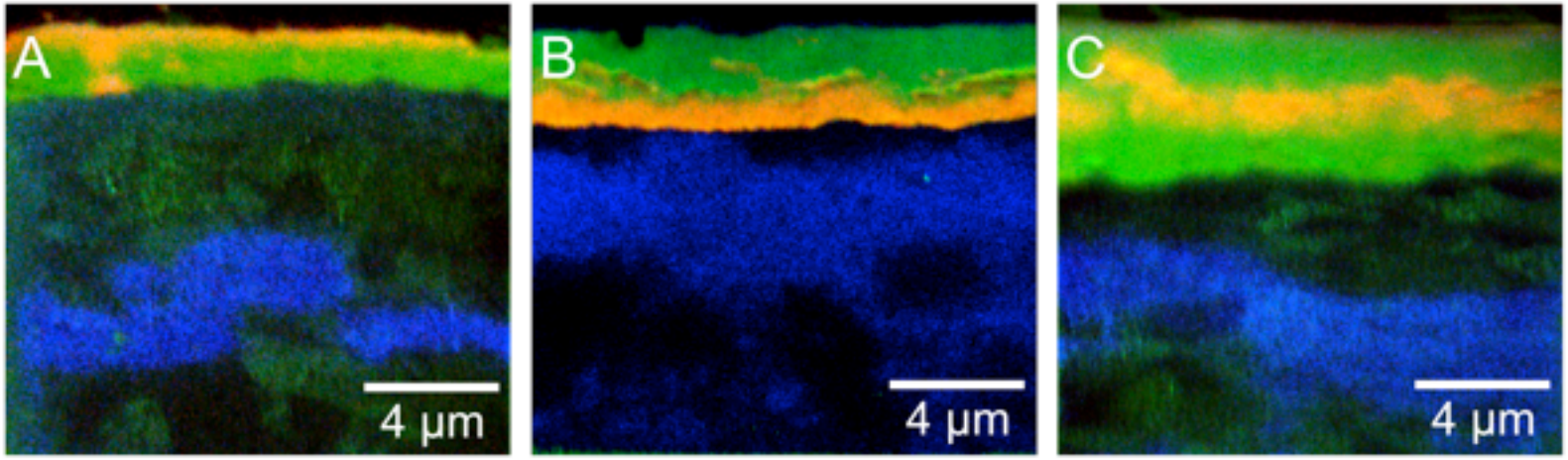
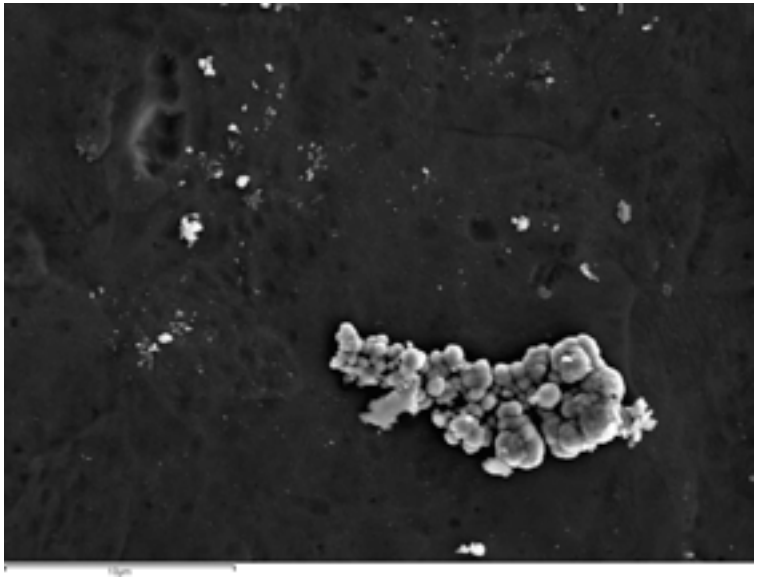


Figure 6: Colour merge images showing the relative locations of the $^{18}O^-$ (red), $^{16}O^-$ (blue) and $^{2}H^-$ (green) signals. Hydrides are found below the metal/oxide interface but no deuterium was detected in the oxide layer. A: 34 + 20 day sample, B: 80 + 20 day sample, C: 160 + 20 day sample.

Copper Decoration Experiments

- Used by Cox on zirconium oxides in 90s.
- New techniques (3D FIB Sectioning, In-Situ TEM liftout) allow more detailed analysis
- Capable of identifying current paths in oxide scale



• Most samples show no Cu deposition even after long periods

• If the surface is damaged mechanically then Cu deposition is very rapid

•Even then, no obvious site of local conduction

PROMINENT ODS work

Effects of irradiation

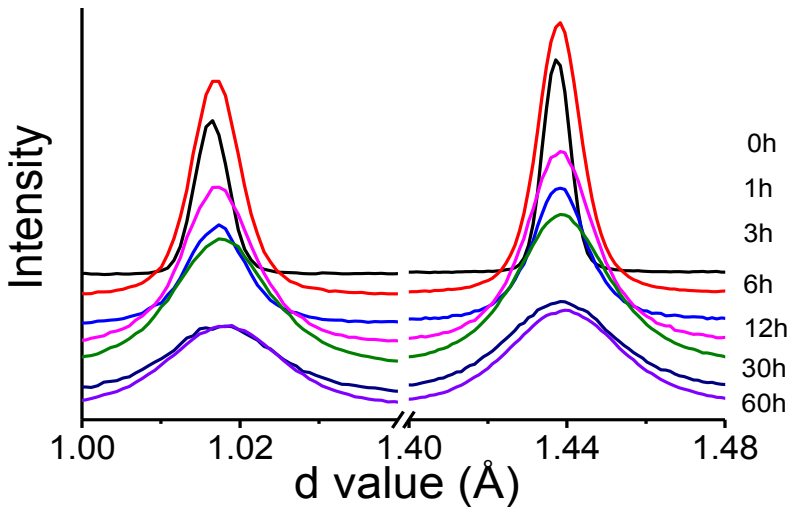
- Micro-mechanical properties of advanced fission materials, including ODS (Oxford)
- Modelling Gaseous Solute Accumulation in Fission Reactor Materials (Loughborough); starting with Fe base for ODS

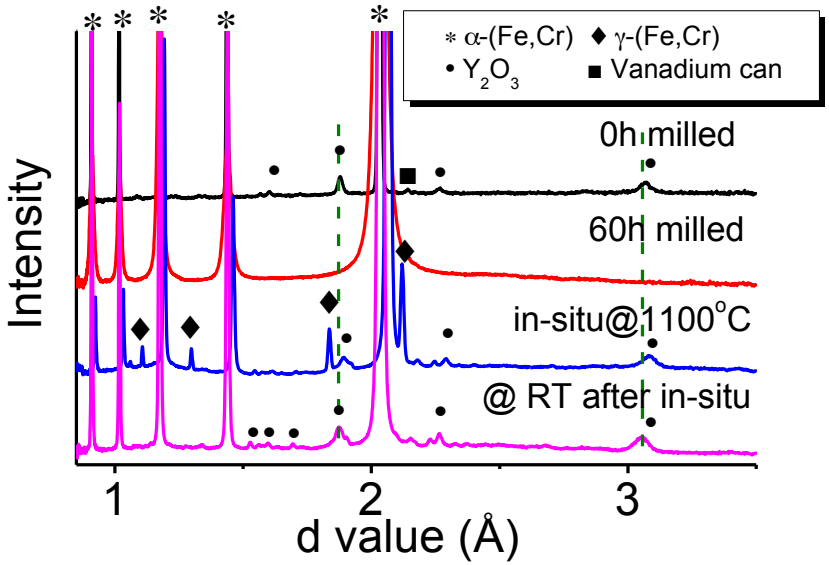
Damage behaviour

- Effect of Precipitates on Creep in ODS steels and Zirconium alloys (Imperial)

Fabrication analysis

- Milling time is critical to the dissolution of the yttria particles
- Insufficient milling leads to formation of particle clusters with intermetallics rather than yttria dissolution





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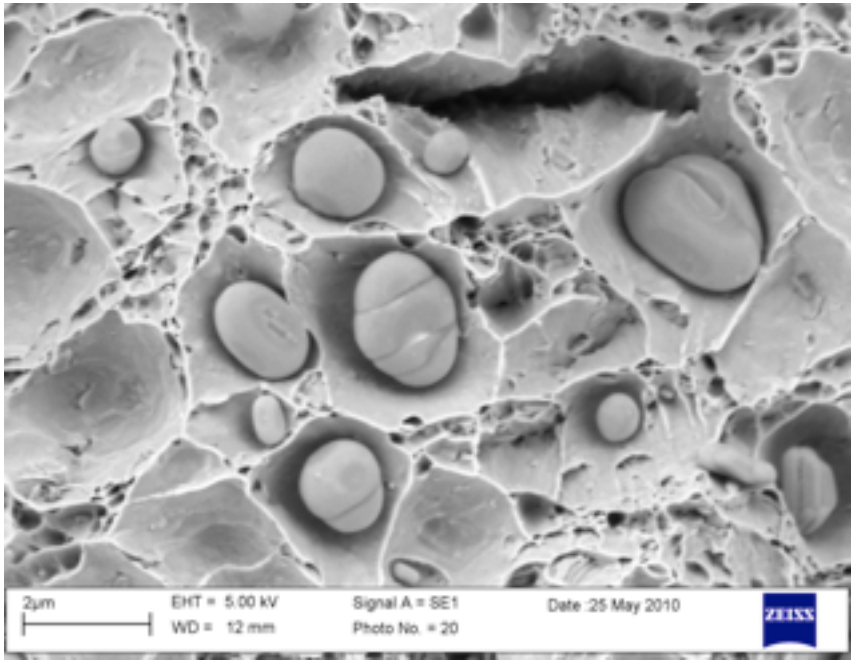
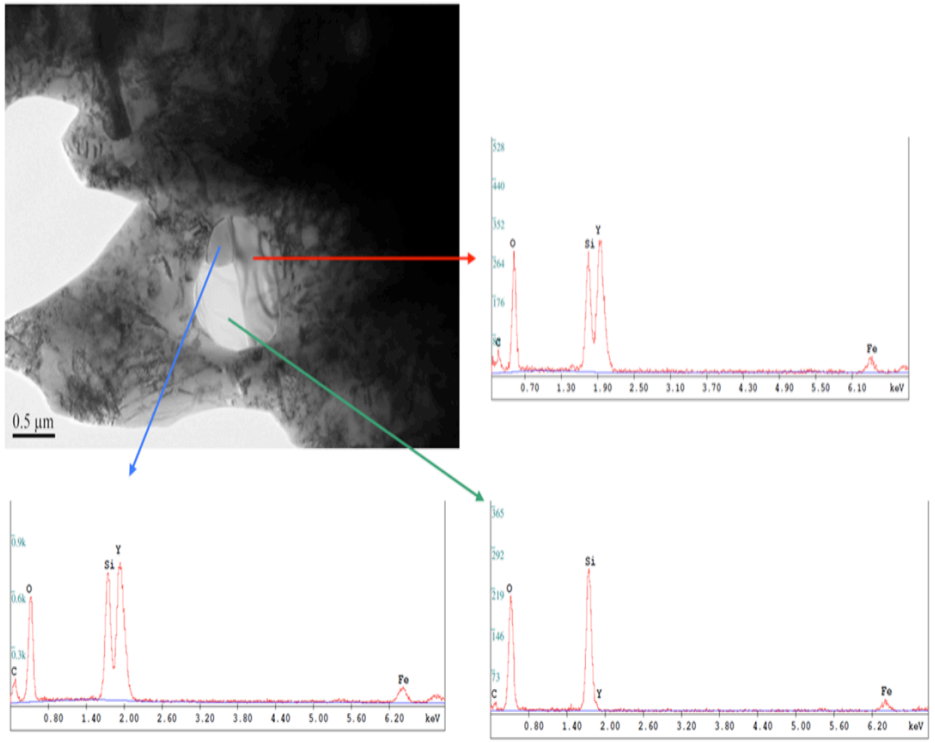
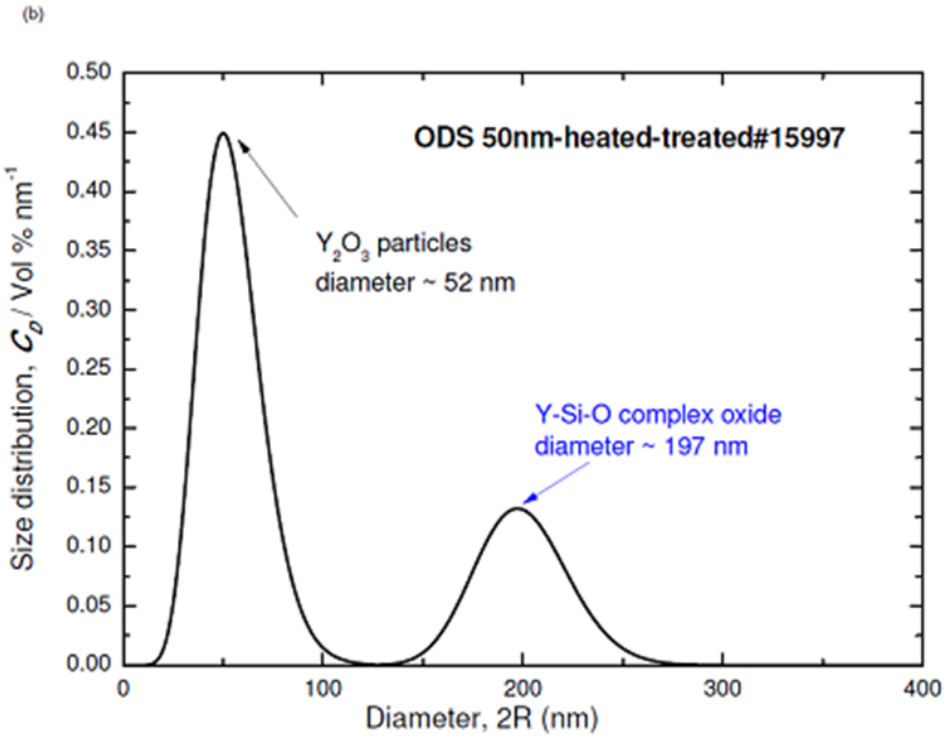




Small-angle neutron scattering

- Small-angle neutron scattering measurements show the reaction of the yttria to form a complex Y-Si-O oxide



OU ODS work

Material chemical composition (wt%).

Material	Cr	W	V	Ta	C	ND
ODS-9v1	9	2.5	0.25	0.25	<0.01	0.3 YTiO*
9CrTa - HT	9	2.5	0.25	0.34	<0.01	-
ODS-14v1	14	3.0	-	-	<0.01	0.3 YTiO*

RAFM - Nb ~ 10^{-3} Al ~ 10^{-3} Mo ~ 10^{-3} Cu ~ 10^{-2} Co ~ 10^{-2}

* stabilised stoichiometric amount Industrial

- Start point of base alloyed material given on table above.
- Atomised by Argon gas and sealed in containers with inert atmosphere.
- Sieved in three particle sizes of >150, 38-75 and >38 µm.
- chemical analysis performed at each step production from received billets to final sample to avoid and/or identify contamination during process.
- Analysis of C, N and O content by XPS.

THEME 3: State/NDE monitoring of materials in nuclear systems

Bristol: **S. Best, A. Croxford**

Evaluation of nonlinear ultrasonic parameters, very sensitive to damage precursors

→Conventional Inspection finding defects with advanced techniques that are more sensitive to damage

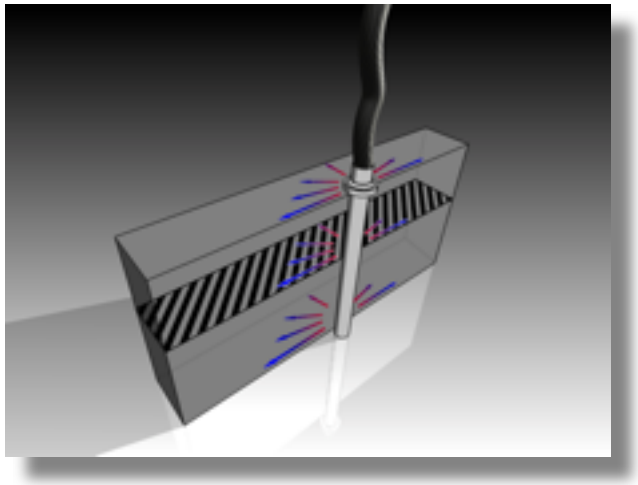
Imperial: **A. Gajdacsi, F. B. Cegla**

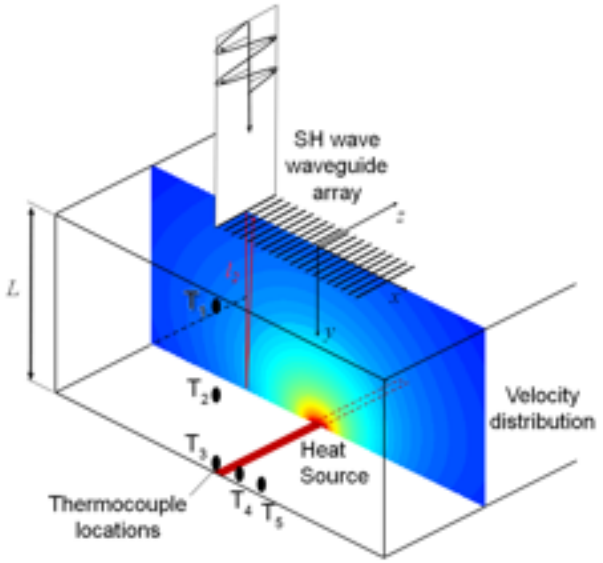
Monitoring of linear ultrasonic parameters

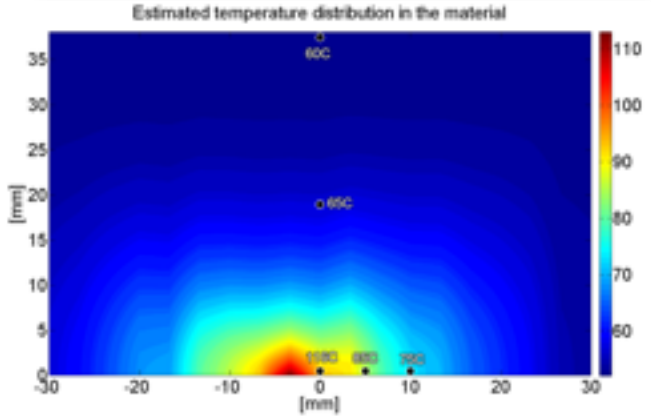
→ Monitoring much smaller changes than with conventional techniques in areas of concern

Imperial- Preliminary results

Successful simulation of damage by non-uniform heating test rig → Test rig construction for introducing real damage and sensitivity analysis in progress

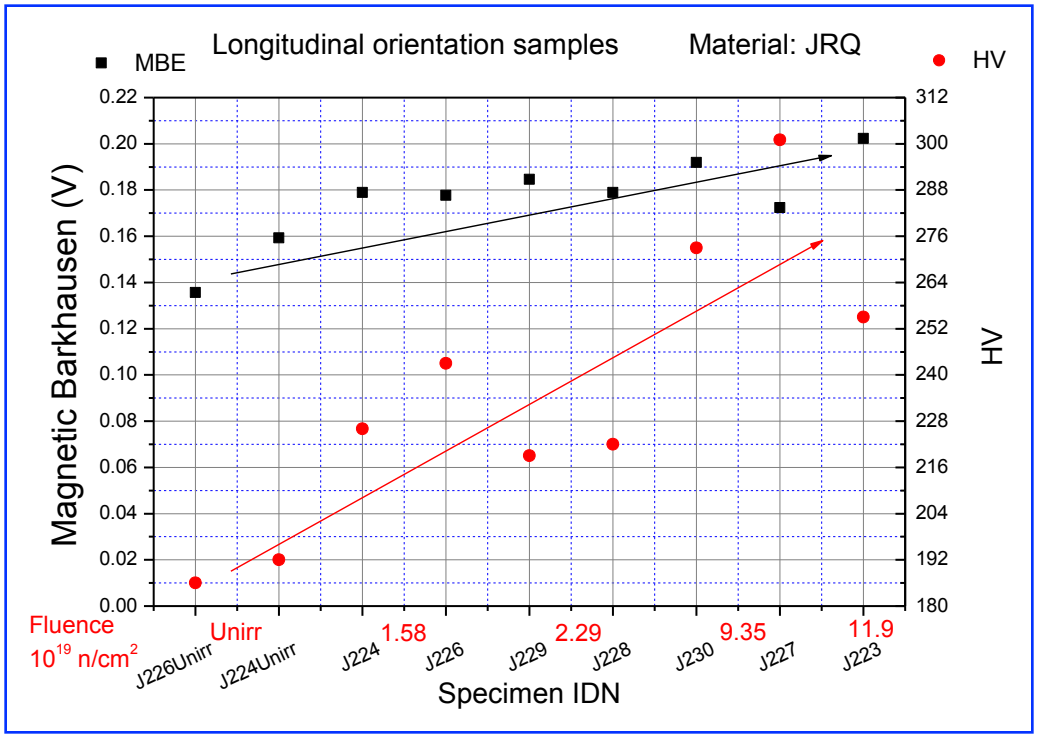






Magnetic technique development

- Correlation between Barkhausen noise and hardness increase from irradiation



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Programme links

- Other RCUK and industry-funded research programmes
- Platform grant at Oxford
- Various UK-India projects
- EDF High Temperature Centre
- International collaborations

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Questions?

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