Grain boundary damage mechanisms in strained AGR claddings under irradiation

C. Barcellini[1,2*], S. Pimblott[1,3], S. Dumbill[4], M. G. Burke[2], E. Jimenez-Melero[1,2]

[1]DCF, UoM, [2]School of Materials, UoM, [3]School of Chemistry, UoM, [4]NNL

DISTINCTIVE Meeting: Theme 1 - AGR, Magnox and Exotic Spent Fuels
21st October 2015
Bristol

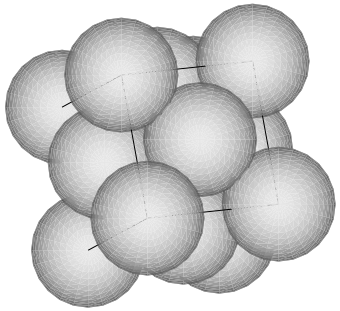
Contents

Introduction

Advanced Gas-cooled Reactor Claddings

20Cr/25Ni Nb-stabilised Stainless Steel

Austenitic Stainless Steel
Fe-Ni-Cr alloy

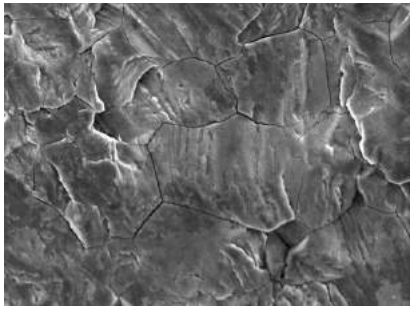


- high corrosion resistance
- no ductile-brittle transition
- high creep resistance

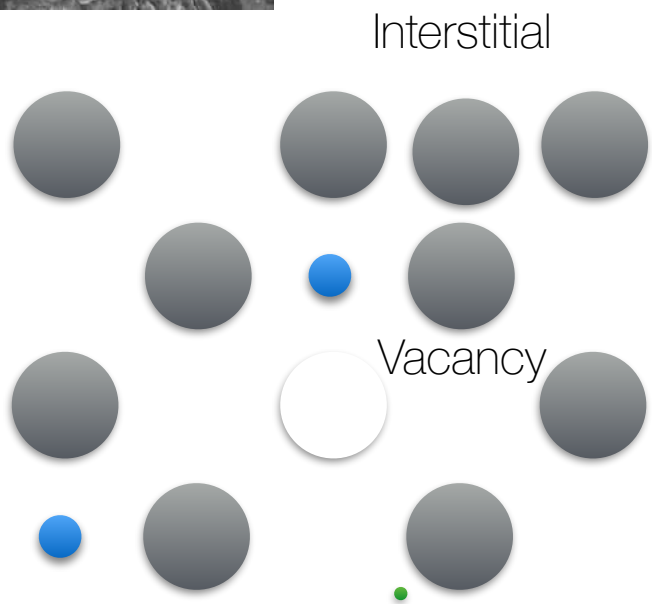
- during service → high-temperature neutron bombardment
- after 3 or 4 years of service → storage into water ponds

Research Councils UK Energy For a Low Carbon Future
10 YEARS DALTON NUCLEAR INSTITUTE
The Queen's Anniversary Prizes 2003 & 2013
MANCHESTER 1824 The University of Manchester Dalton Nuclear Institute
EPSRC Engineering and Physical Sciences Research Council
NATIONAL NUCLEAR LABORATORY
DISTINCTIVE

Sensitisation & Inter-granular Corrosion



Sensitisation can be radiation-induced [1]



Neutron Irradiation

↓

Frenkel Pairs

Radiation Induced Segregation

At the grain boundaries:

- Cr is depleted
- Si is segregated
- Ni is segregated

Intense Ions Beam

- easy variation of irradiation parameters
- shorter irradiation
- little or no residual activation
- money saving

Approach

DAFNE

Dalton **A**ccelerator **f**or **N**uclear **E**xperiments

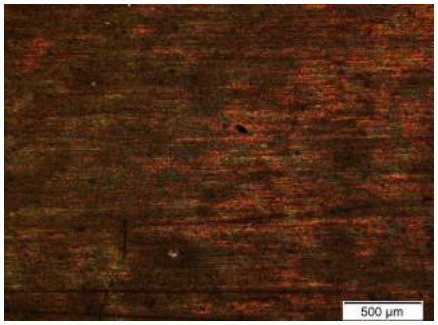
MANCHESTER 1824

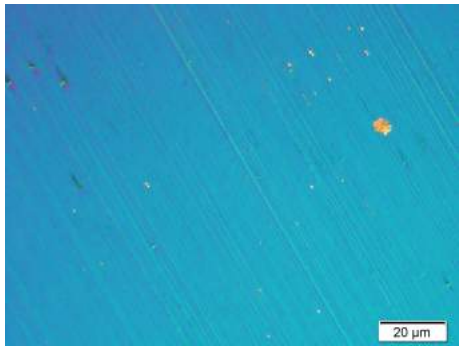
The University of Manchester
Dalton Nuclear Institute

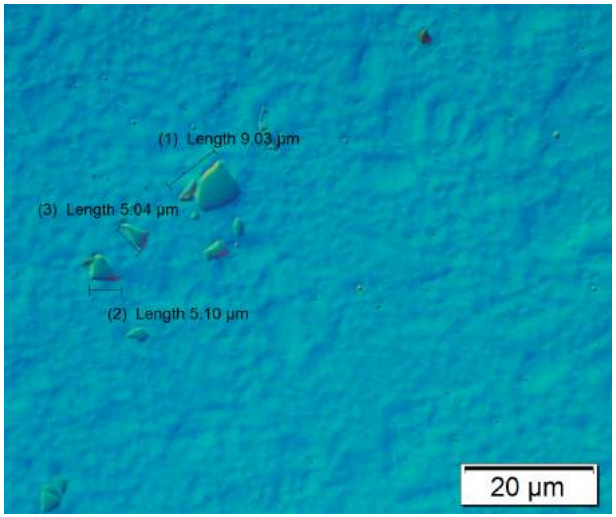
- 5MV Tandem Van der Graaf Accelerator
- 2 ion sources
- 6 beam-lines

Experimental Results

Irradiation







As Received Sample

As received

Mounting

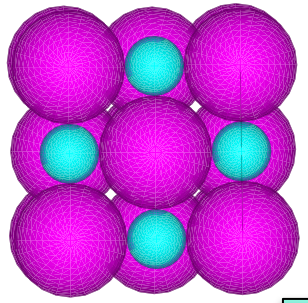
Grinding

Mechanical Polishing

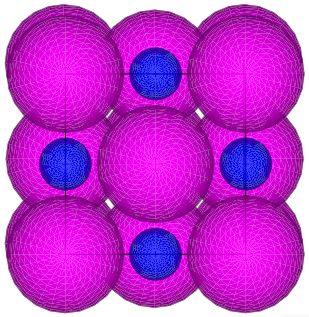
- Water-based diamond suspension (1µm)
- Colloidal silica suspension (0.04µm)

Experimental Results

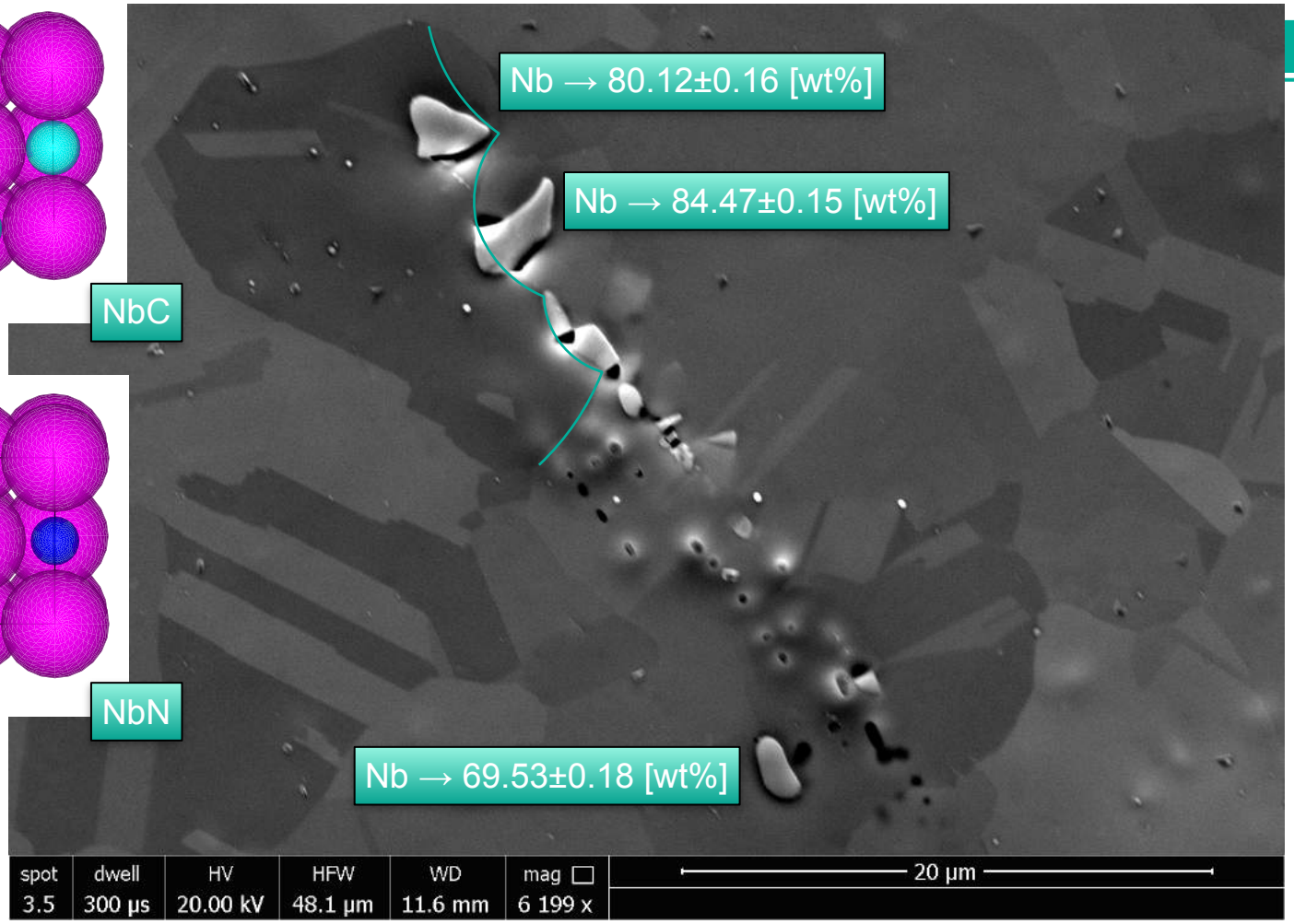
EDS



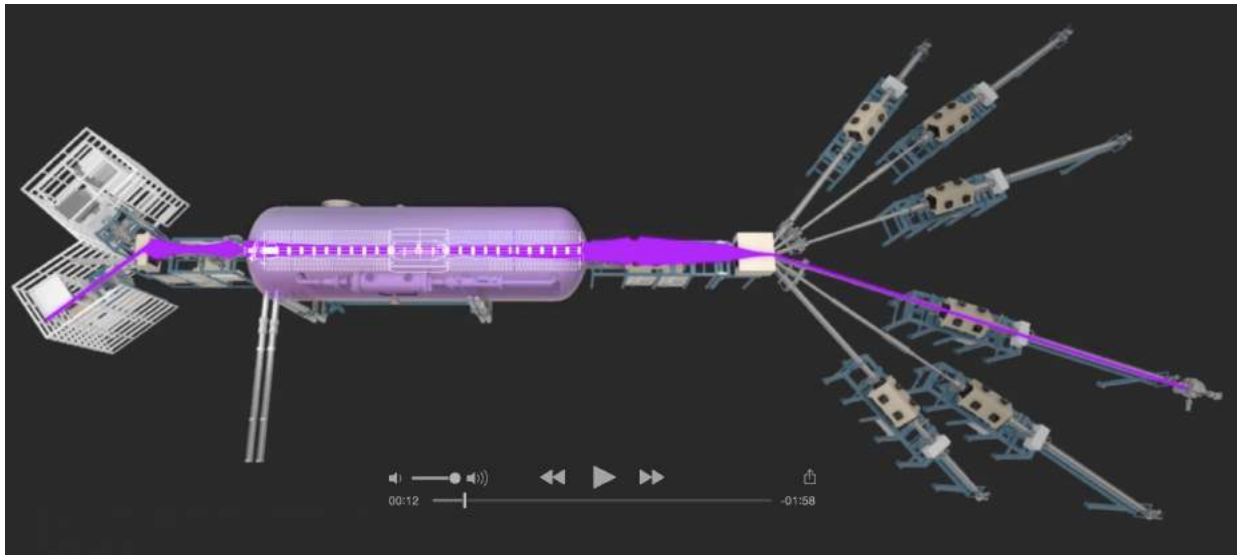
NbC



NbN



Irradiation



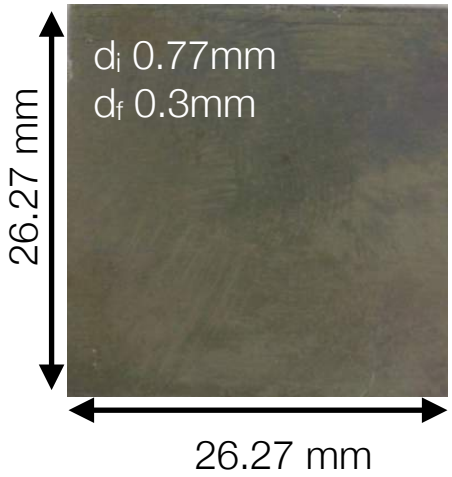
3MeV Proton Irradiation

Beam Average Current → 9.8μA

Duration → 59h

Sample Average temperature → 350ºC

Experimental results

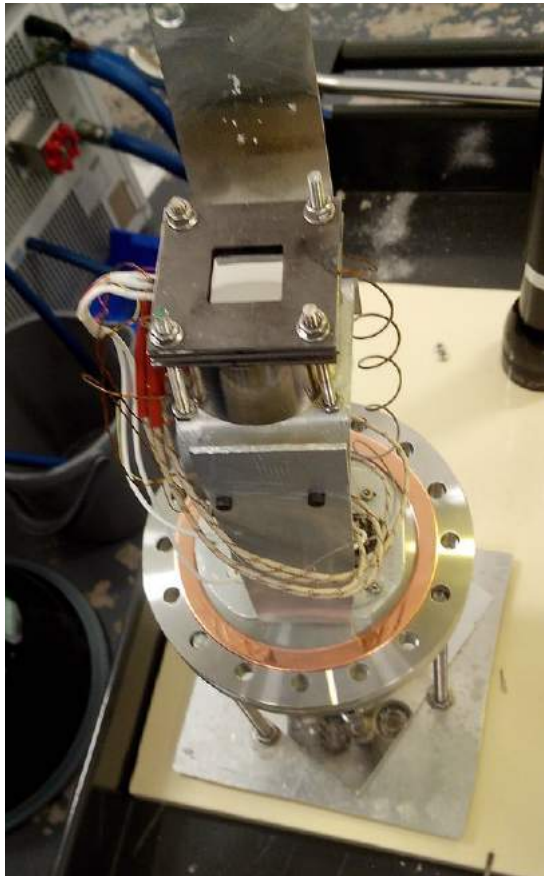


Both sides:
- grinding
- mechanical polishing
  - final step: colloidal silica solution

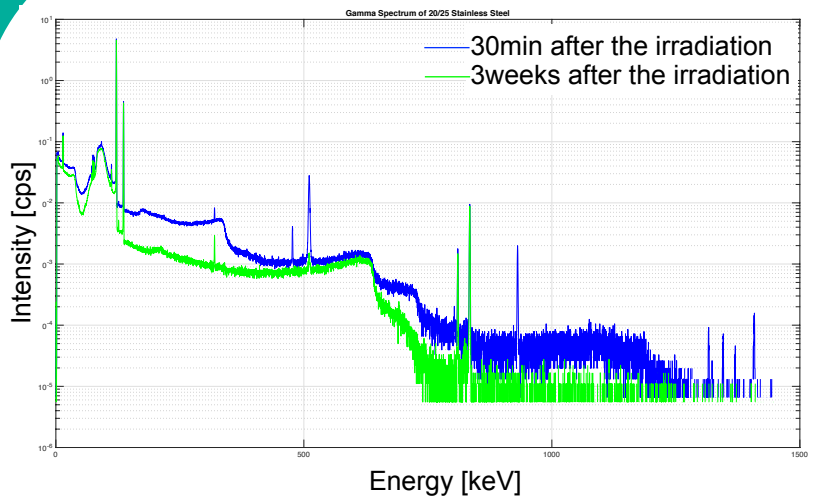
SAMPLE HOLDER

- Blind flange
- Water feedthroughs
- Heater
- Shims (with a 2x2cm^2 windows)
- Auxiliary heater
- SAMPLE
- Ta shim

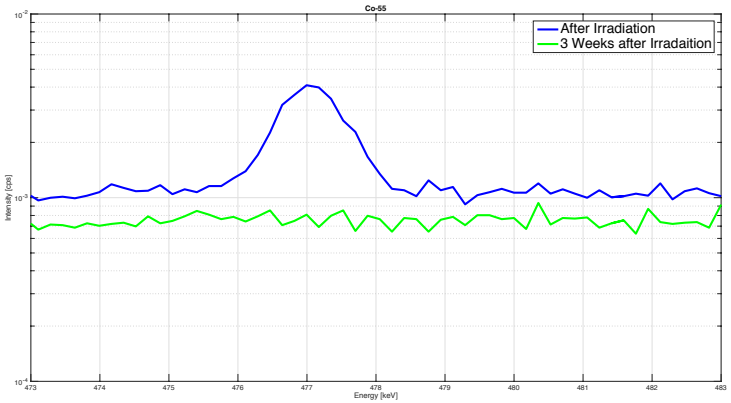
Irradiation

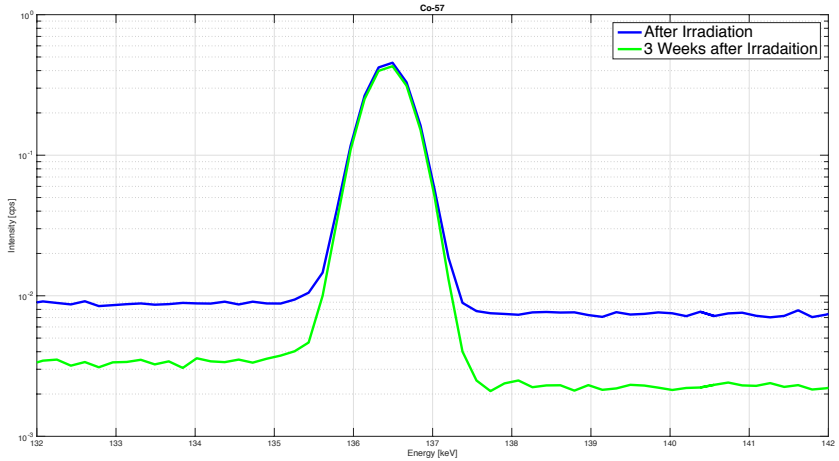


Experimental Results



Irradiation

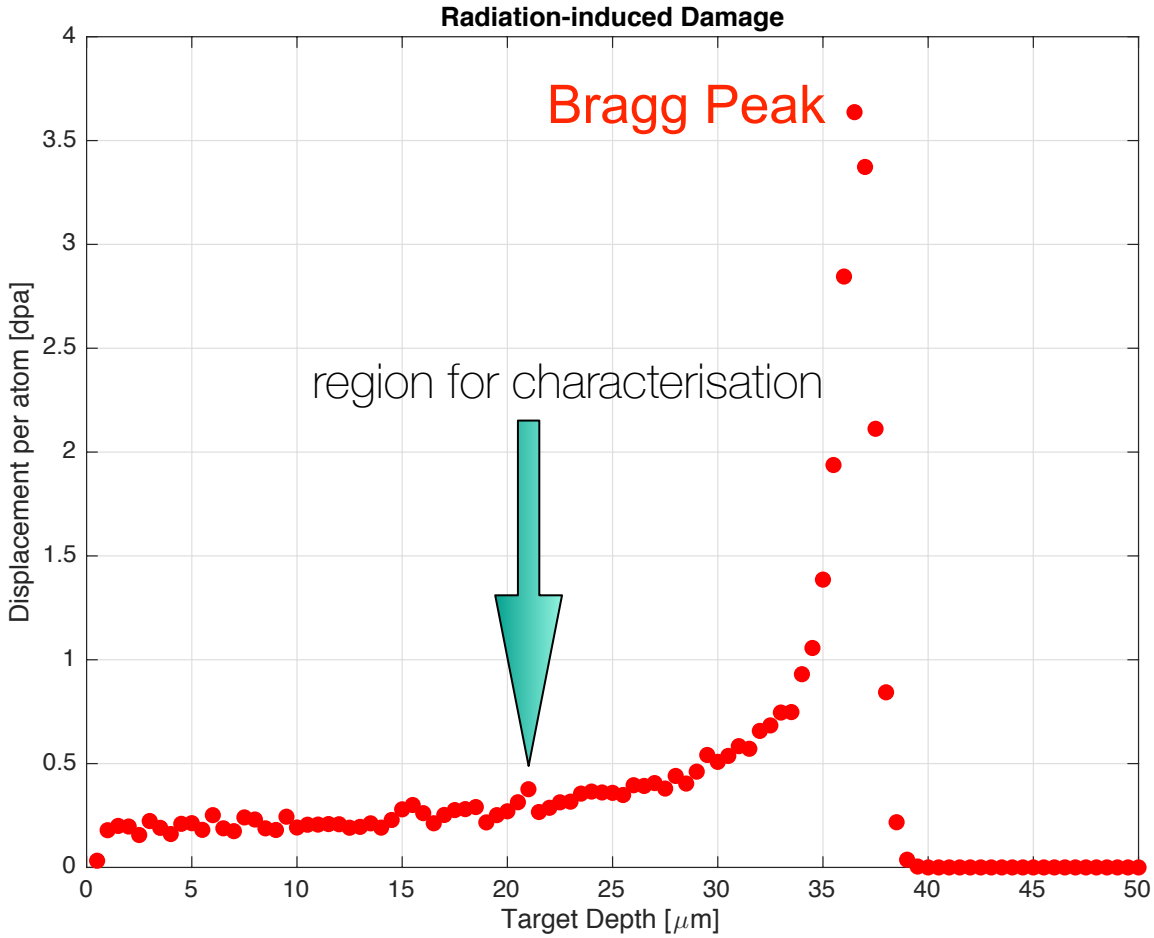




- Co-55 $T_{1/2}$=17.53h
- Co-57 $T_{1/2}$=271.74d

Research Councils UK Energy For a Low Carbon Future
10 YEARS DALTON NUCLEAR INSTITUTE
The Queen's Anniversary Prizes 2011 & 2013
MANCHESTER 1824 The University of Manchester Dalton Nuclear Institute
EPSRC Engineering and Physical Sciences Research Council
NATIONAL NUCLEAR LABORATORY
DISTINCTIVE

Experimental Results



Irradiation

- Bragg Peak
  - 36μm
  - 3.6dpa
- Flat Region
  - 22μm
  - 0.3dpa

Summary

Summary

- Developed sample preparation techniques
  - mechanical polishing
  - electropolishing
- Started the characterisation of the sample
  - Image
  - EDS - matrix composition and precipitates
- Prepared an irradiated sample (0.3dpa)

Future Work

Future work

- TEM
- Irradiated sample
  - preparation for EM
  - characterisation
- Segregation of alloying elements close to g.b.
- Radiation-induced phases

Thank you for your attention

Bibliography

[1] C. Taylor, Radiation-induced sensitisation of stainless steel, Berkeley Nuclear Laboratories, 1986.