Radiation Damage Effects within Materials

By

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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AFM	Atomic force microscopy
AGR	Advanced gas-cooled reactor
ANSTO	Australian nuclear science and technology organisation
ASB	Angular selective backscatter
BCC	Body centred cubic
BSECCI	Backscattered electron channelling contrast imaging
BSEI	Backscattered electron imaging
BWR	Boiling water reactor
DEMO	DEMOnstration power plant (relating to ITER)
EBSD	Electron backscatter diffraction
EDS	Energy dispersive spectroscopy
FBR	Fast neutron reactor
FCC	Face centred cubic
FFTF	Fast flux test facility
FIB	Focused ion beam
HFIR	High flux isotope reactor
HFR	High flux reactor
IFMIF	International fusion materials irradiation facility
ITER	International Thermonuclear Experimental Reactor
LWGR	Light water graphite reactor
Magnox	Magnesium non-oxidising
ODS	Oxide dispersed steel
PBR	Pebble-bed reactor
PHWR	Pressurised heavy water reactor
PI^3	Plasma immersion ion implantation
PIPS	Precision ion beam polishing
PKA	Primary knock-on atom
PWR	Pressurised water reactor
RBMK	*reaktor bolshoy moshchnosty kanalny*, high-power channel reactor
RBS	Rutherford backscattering spectrometry
RF	Radio frequency

SCWR	Super critical water cooled reactor
SEM	Scanning electron microscope
SFT	Stacking fault tetrahedra
SRIM	Stopping range of ions in matter
STAR	Small tandem for applied research accelerator
STEM	Scanning transmission electron microscopy
TEM	Transmission electron microscope
TRISO	Tri-isotopic fuels
WDS	Wavelength dispersive spectroscopy
XRD	X-Ray diffraction

ABSTRACT

Radiation damage effects within materials are a key area of research as we strive to build longer lasting, safer and more economical nuclear reactors. Proposed materials must be tested in an appropriate manor to determine their suitability for these applications. The use of neutrons as a means to simulate a reactor environment is extremely slow and costly. Charged particle implantation has been used as a rapid, cost effective method that can be tailored to meet specific experimental requirements. We must, however, understand the fundamental differences between neutron and charged particle radiation damage studies before we can draw conclusions from the results.

Electron microscopy has long been a very important tool for the characterisation of radiation damage; used with complimentary techniques the electron microscope and its associated detectors can give insight into the mechanisms of damage like no other instrument. This research aims to gain an understanding of the radiation damage tolerance of structural reactor materials and ideally fill a gap in the knowledge base of using scanning electron microscopy based techniques to characterise this damage.

A novel use of electron backscatter diffraction has been used to reveal trends in radiation damage studies of stainless steel reactor materials, this application of EBSD has not been seen before in the literature. Results from these studies show a clear difference in the tolerance to radiation damage of FCC and BCC crystal structures within the stainless steels. Significant advances have been made in the development of cross sectional sample preparation methods enabling the findings of these studies using EBSD to be validated by traditional transmission electron microscopy techniques.