19TH INTERNATIONAL SYMPOSIUM ON ZIRCONIUM IN THE NUCLEAR INDUSTRY
Sponsored by ASTM Committee B10 on Reactive and Refractory Metals and Alloys

May 20-23, 2019
The Midland Hotel
Manchester, UK

Symposium Chairman: Dr. Arthur T. Motta
The Pennsylvania State University
University Park, PA USA

Symposium Editorial Chairman: Dr. Suresh K. Yagnik
Electric Power Research Institute
Palo Alto, CA USA

ABOUT THE SYMPOSIUM:
The purpose of the symposium is to provide a forum for exchanging new information on the fabrication, testing, development, irradiation performance and characterization of both traditional and new zirconium-based materials used in the nuclear industry, including materials performance during normal, transient, and accident conditions as well as materials behavior during intermediate and long-term storage conditions.
MONDAY, MAY 20, 2019

8:00 AM
Opening Remarks
A. Garde, ASTM B10 Symposium Committee Chairman
A. Motta, Symposium Chairman
S. Yagnik, Symposium Editorial Chairman

8:20 AM
Presentation of the John Schemel Award for the Best Paper from the 18th International Symposium
A. Motta, Symposium Chairman
S. Yagnik, Symposium Editorial Chairman

SESSION 1: FABRICATION AND ALLOY DEVELOPMENT

Session Chairs:  P. Barbéris  
Framatome  
France

J. Desquines  
Institut de Radioprotection et Sureté Nucléaire  
France

8:30 AM
Quantifying processing map uncertainties by modelling the hot compression behavior of a Zr-2.5Nb alloy
C. Daniel¹, C. Peyton¹, J. Quinta da Fonseca¹, P. Jedrasiak², H. Shercliff², P. Honniball³, L. Bradley³
¹The University of Manchester, Manchester, UK  
²University of Cambridge, Cambridge, UK  
³Rolls-Royce plc, Derby, UK

9:00 AM
Fabrication of E110 alloy fuel rod claddings on electrolytic zirconium base with removing fluorine impurity for providing resistance to breakaway oxidation in high-temperature steam
V. Markelov¹, A. Malgin¹, N. Filatova¹, V. Novikov¹, A. Shevyakov¹, A. Gusev¹, I. Shelepov, A.V. Golovin¹, A. Ugryumov², A. Dolgov², and A. Ziganshin³, V. Donnikov⁴, and V. Latynin⁴
¹VNIINM, Russia  
²TVEL, Russia  
³JSC “ChMP”, Russia  
⁴JSC “VTI”, Russia
9:30 AM

Ceramic coatings for nuclear fuel cladding to enhance accident tolerance
E. Alat¹, J. Hu², D.E. Wolfe¹, and A.T. Motta¹
¹ The Pennsylvania State University, University Park, PA, USA
² Argonne National Laboratory, IL, USA

10:00 AM BREAK

10:30 AM

Coating technology on the zirconium alloy cladding for enhanced accident tolerant fuel
H-G Kim¹, I-H Kim¹, Y-I Jung¹, D-J Park¹, J-H Park¹, Y-H Lee¹, and B-K Choi¹
¹ Korea Atomic Energy Research Institute, Daejeon, Republic of Korea

11:00 AM

The behavior of Cr-coated zirconium alloy cladding tubes at high temperatures
N. Chaari¹, J. Bischoff¹, C. Delafoy¹, P. Barbéris², and K. Nimishakavi³
¹ Framatome, Lyon, France
² Framatome, UGINE, France
³ Framatome, Lynchburg, VA, USA

11:30 AM

Effects of cold spray chromium coatings on the properties of zirconium alloys
J. Romero¹, J. Walters¹, S. Kachur², A. Mueller², J. Partezana², W. Byers², and G. Wang²
¹ Westinghouse Electric Company, Hopkins, SC, USA
² Westinghouse Electric Company, Churchill, PA, USA

12:00 PM

Session Summary
P. Barbéris, Symposium Session Co-chair
J. Desquines, Symposium Session Co-chair

12:20 PM

ASTM B10 Committee Overview
M. Lynyak¹
¹ ASTM International, West Conshohocken, PA, USA

12:30 PM LUNCH
SESSION 2: MECHANICAL BEHAVIOR

Session Chairs:  
R. Montgomery  
Pacific Northwest National Lab  
USA  
F. Onimus  
Commissariat à L'Énergie Atomique - Saclay  
France

2:00 PM  
The effect of loading direction on slip and twinning in an irradiated zirconium alloy  
R. Thomas¹, D. Lunt¹, M. Atkinson¹, J. Quinta da Fonseca¹, M. Preuss¹, F. Barton², J. O’Hanlon²  
and P. Frankel¹  
¹ University of Manchester, Manchester, UK  
² Rolls-Royce plc, Derby, UK

2:30 PM  
Full scale fracture toughness behavior of Zr-2.5Nb pressure tubes with high hydrogen concentrations and different hydride morphologies  
J. Cui¹ and G. Shek¹  
¹ Kinectrics Inc., Toronto, Ontario, Canada

3:00 PM  
Back-calculated true stress-true strain curves from small scale testing and verification using finite element models: application to nanoindentation and micropillar compression study of a heavy ion irradiated Zr-2.5Nb alloy  
Q. Wang¹ and M. Daymond¹  
¹ Queen's University, Kingston, Ontario, Canada

3:30 PM  
BREAK

4:00 PM  
Deformation mechanisms of zirconium alloys after irradiation studied by in situ straining experiments in TEM, molecular and dislocation dynamics simulations  
F. Onimus¹, L. Dupuy¹, M. Gaumé¹, W. Kassem¹, and F. Mompiou²  
¹ Université Paris-Saclay, Gif-sur-Yvette, Cedex, France  
² CEMES CNRS and Université de Toulouse, Toulouse Cedex, France

4:30 PM  
Test-reactor study of the effect of zirconia coating of inconel spacer cells on shadow corrosion  
C. Anghel¹, M. Limbäck¹, G. Westin², T. Tverberg³, B. Andersson¹, M. Leideborg², and J. Wright¹  
¹ Fuel Materials Center of Excellence, Westinghouse, Västerås, Sweden  
² Department of Chemistry - Ångström Laboratory, Uppsala University, Uppsala, Sweden  
³ Institute for Energy Technology, Halden, Norway
5:00 PM
Influence of hydrides upon the fatigue initiation behavior of irradiated Zircaloy-2
P. Honniball ¹, L. Cogez ², and C. Gee ¹.
¹ Rolls-Royce plc, UK
² Canadian Nuclear Laboratories, Chalk River, Ontario, Canada

5:30 PM
Session Summary
R. Montgomery, Symposium Session Co-chair
F. Onimus, Symposium Session Co-chair

5:50 PM
Closing Remarks
Symposium Chairman

6:00 PM SYMPOSIUM ADJOURNS FOR THE DAY
8:10 AM
Opening Remarks
Symposium Chairman

SESSION 3: IN REACTOR BEHAVIOR AND IRRADIATION EFFECTS

Session Chairs:  
T. Darby  
Rolls-Royce plc  
UK
A. Couet  
University of Wisconsin  
Madison, WI  
USA

8:20 AM
Measurement of in-reactor stress relaxation in pre-irradiated zirconium alloys by four-point bend technique  
S. Yagnik¹, I. Arimescu², R. Adamson³, G. Kobylyansky⁴, S. Seryodkin⁴, and A. Obukhov⁴  
¹ Electric Power Research Institute, Palo Alto, CA, USA  
² Framatome, Richland, WA, USA  
³ Zircology Plus, Fremont, CA, USA  
⁴ SC “SSC RIAR”, Russia

8:50 AM
Ex-situ and in-situ studies of radiation damage mechanisms in Zr-Nb alloys  
J. Liu¹, G. He¹, A. Callow¹, K. Li¹, S. Lozano-Perez¹, A. Wilkinson¹, M. Moody¹, C. Grovenor¹,  
J. Hu², M. Kirk², M. Li², A. Mir³, J. Hinks³, S. Donnelly³, J. Partezana⁴, and H. Nordin⁵  
¹ Oxford University, Oxford, UK  
² Argonne National Laboratory, Argonne, IL, USA  
³ University of Huddersfield, Huddersfield, UK  
⁴ Westinghouse Electric Company, Pittsburgh, PA, USA  
⁵ Atomic Energy of Canada Limited, Chalk River, Ontario, Canada

9:20 AM
Towards an improved understanding of the mechanisms involved in the increased hydrogen uptake and corrosion at high burnups in zirconium-based claddings  
S. Abolhassani¹, A. Baris¹, R. Vanta¹, J. Hawes¹, R. Grabherr¹, A. Colldeweih¹, R. Restani¹, A. Hermann¹, J. Bertsch¹, M. Chollet¹, G. Kuri¹, M. Martin¹, S. Portier¹, H. Wiese¹, H. Schweikert¹,  
G. Bart¹, K. Ammon², G. Ledergerber², and M. Limbäck³  
¹ Laboratory for Nuclear Materials, Nuclear Fuels Group, NES, and AHL, NES, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland  
² Kernkraftwerk Leibstadt AG, CH-5325 Leibstadt, Switzerland  
³ Westinghouse Electric Sweden AB, Västerås, Sweden
9:50 AM  BREAK

10:20 AM  
**Evaluation of neutron irradiated additively-manufactured Zircaloy-2**  
J. Partezana¹, P. Xu², and W. Cleary²  
¹ Westinghouse Electric Company LLC, Pittsburgh, PA, USA  
² Westinghouse Electric Company LLC, Columbia, SC, USA

10:50 PM  
**Corrosion and deuterium pickup in Zr-2.5Nb: twenty years of in-reactor testing at the OECD Halden Boiling Water Reactor**  
H. Nordin¹ and R. Szőke²  
¹ Canadian Nuclear Laboratories, Chalk River, Ontario, Canada  
² Institute for Energy Technology, Halden, Norway

11:20 AM  
**Session Summary**  
T. Darby, Symposium Session Co-chair  
A. Couet, Symposium Session Co-chair

11:50 AM  LUNCH

**SESSION 4: CORROSION**

Session Chairs:  
M. Limbäck  
Westinghouse Electric Sweden  
Sweden

C. Grovenor  
Oxford University  
UK

1:20 PM  
**New methodologies for high resolution mapping of light elements in zirconium oxide with SIMS**  
C. Jones¹, K. Li¹,², J. Liu², T. Aarholt²,³, M. Gass⁴, K. Moore¹,⁵, M. Preuss¹, C. Grovenor²  
¹ University of Manchester, Manchester, UK  
² University of Oxford, Oxford, UK  
³ University of Oslo, Oslo, NO  
⁴ Wood plc, Warrington, UK  
⁵ Photon Science Institute, University of Manchester, Manchester, UK
1:50 PM
Investigating the corrosion behavior of Zircaloy-4 in LiOH under a thermal gradient and two-phase flow regime
A. Panteli¹, F. Baxter¹, H. Hulme¹, M. Gass¹, A. Cole-Baker¹, P. Binks¹, J. Smith², C. Miszkowska²
¹Wood plc, Warrington, UK
²Rolls-Royce plc, Derby, UK

2:20 PM
Effect of ion irradiation of the metal matrix on the oxidation rate of M5Framatome alloy
M. Tupin¹, R. Verlet¹, K. Colas¹, M. Jublot¹, G. Baldacchino¹, K. Wolski², I. Idarraga³, and D. Kaczorowski⁴
¹CEA Saclay, Gif-sur-Yvette, Cedex, France
²Ecole des Mines de Saint Etienne, Cedex, France
³EDF SEPTEN, Lyon, France
⁴Framatome ANP, Lyon, France

2:50 PM BREAK

3:20 PM
The effect of photon irradiation on the corrosion of zirconium alloys
A. Couet¹, Y. He¹, K. Terrani², S. Armson³, S. Frankel³, M. Preuss³, T. Kim¹, M. Elbakhshwan¹, L. He¹
¹University of Wisconsin, Madison, WI, USA
²Oak Ridge National Laboratory, Oak Ridge, TN, USA
³The University of Manchester, Manchester, UK

3:50 PM
Characterization of long-term, in-reactor Zircaloy-4 corrosion coupons and the impact of flux, fluence, and temperature on oxide growth, stress development, phase formation, and grain size
B. M. Ensor¹,², G. Lucadam³, J. R. Seidensticker³, R Bajaj³, Z. Cai⁴, A.T. Motta¹
¹The Pennsylvania State University, University Park, PA, USA
²Naval Nuclear Laboratory, Knolls Site, Schenectady, NY, USA
³Naval Nuclear Laboratory, Bettis Site, West Mifflin, PA, USA
⁴Advanced Photon Source, Argonne National Laboratory, Argonne, IL, USA

4:20 PM
Session Summary
M. Limbäck, Symposium Session Co-chair
C. Grovenor, Symposium Session Co-chair

4:50 PM
Closing Remarks
Symposium Chairman

5:00 PM SYMPOSIUM ADJOURNS FOR THE DAY
8:20 AM
**Opening Remarks**
Symposium Chairman

**SESSION 5: HYDROGEN EFFECTS**

Session Chairs: J. Bertsch  
Paul Scherrer Institute  
Switzerland

P. Rudling  
Advanced Nuclear Technology International  
Sweden

8:30 AM
**Enhanced hydrogen uptake and reaction kinetics during oxidation of Zircaloy-4 in nitrogen containing steam atmospheres**  
M. Grosse¹, M. Steinbrück¹, S. Pulvermacher¹, and B. Schillinger²  
¹ Karlsruhe Institute of Technology, Institute for Applied Materials, Karlsruhe, Germany  
² Technische Universität München, München, Germany

9:00 AM
**Zirconium hydride precipitation and dissolution kinetics in zirconium alloys**  
E. Lacroix¹, P.-C. Simon¹, A.T. Motta¹, J.D. Almer²  
¹ The Pennsylvania State University, University Park, PA, USA  
² Argonne National Laboratory, Lemont, IL, USA

9:30 AM
**Zirconium-applied anisotropic cluster dynamics for irradiation induced defect modeling in presence of hydrogen**  
N. Chaari¹, F. Bourlier¹, D. Brimbal², P. Barberis³  
¹ Framatome, Lyon, France  
² Framatome, La Defense, France  
³ Framatome, Ugine, France

10:00 AM BREAK
10:30 AM
Understanding the hydrogen pickup mechanisms under irradiation: effect of ion irradiation of the oxide and the metal on the hydrogen pickup rate of M5®
B. Queylat¹, M. Jublot¹, M. Tupin¹, F. Martin²
¹CEA-DEN, Service d’Études des Matériaux Irradiés, CEA, Université Paris-Saclay, F-91191, Gif-sur-Yvette Cedex, France
²Den-Service de la Corrosion et du Comportement des Matériaux dans leur Environnement (SCCME), CEA, Université Paris-Saclay, F-91191, Gif-sur-Yvette, France

11:00 AM
Micro-mechanical characterization of hydrides in Zr-2.5 wt% Nb pressure tube material
V. Bhakhri¹, W. Li¹, C. Howard¹, S. Hanlon¹, C. Dixon¹, C. Mayhew¹, C. Judge¹, and S. St. Lawrence¹
¹Canadian Nuclear Laboratories, Chalk River, Ontario, Canada

11:30 PM
Fundamental understanding of Nb effect on corrosion mechanisms of ZrNb alloys in and out of reactor
Z. Yu¹, M. Moorehead¹, L. Borrel¹, A. Couet¹, J. Hu², M. Bacchav³
¹University of Wisconsin, Madison, WI, USA
²Argonne National Laboratory, Argonne, IL, USA
³Idaho National Laboratory, Idaho Falls, ID, USA

12:00 PM
Session Summary
J. Bertsch, Symposium Session Co-chair
P. Rudling, Symposium Session Co-chair

12:30 PM  KROLL AWARD LUNCHEON

POSTER SESSION

Session Chairs:  M. Preuss
University of Manchester
UK

I. Arimescu
Framatome
USA

3:00 PM – 5:30 PM  POSTER SESSION
THURSDAY, MAY 23, 2019

8:00 AM
Opening Remarks
Symposium Chairman

SESSION 6: HYDRIDES IN ZIRCONIUM ALLOYS

Session Chairs: A. Ambard
Electricité de France
France

H. Nordin
Canadian Nuclear Laboratories
Canada

8:10 AM
A fast efficient multi-scale approach to modeling the development of hydride microstructures at the component level in zirconium alloys
M. Patel¹, L. Reali¹, A. Sutton¹, D. Balint¹, and M. Wenman¹
¹ Imperial College London, London, UK

8:40 AM
Influence of thermal-mechanical cycling on pre-hydrogenated Zircaloy-4 embrittlement by radial hydrides
J. Desquines¹, M. Puls², S. Charbaut¹, and M. Philippe³
¹ IRSN, Saint-Paul-Lez-Durance, France
² MPP Consulting, Oakville, Ontario, Canada
³ IRSN, Fontenay-aux-Roses, France

9:10 AM
Characterization of crystal structure and stress state of hydride platelets in low hydrogen concentration Zircaloy-2 with synchrotron X-ray diffraction, TEM, and EELS
N. N. Badr¹, F. Long¹, O. V. Shiman¹, C. Cochrane¹, and M. R. Daymond¹
¹ Queen’s University, Kingston, Ontario, Canada

9:40 AM BREAK

10:10 AM
Fracture of gamma and delta hydrides during delayed hydride cracking
S. Hanlon¹, G. McRae², C. Coleman¹, and A. Buyers¹
¹ Canadian Nuclear Laboratories, Chalk River, Ontario, Canada
² Carleton University, Ottawa, Ontario, Canada
On the Nature of the Breakaway Corrosion Phenomenon during Zr and Zr Alloy Oxide Growth
B. M. Ensor¹, A. T. Motta², J. Partezana³, A. Lucente¹, J. Seidensticker¹, and Z. Cai⁴
¹ Naval Nuclear Laboratory, Knolls Site, Schenectady, NY, USA
² The Pennsylvania State University, University Park, PA, USA
³ Westinghouse Electric Company LLC, Pittsburgh, PA, USA
⁴ Argonne National Laboratory, Lemont, IL, USA

Characterization of hydrides precipitated in the α-Zr matrix of zirconium alloys: effects of stress, microstructure and neutron irradiation on hydride texture, terminal solid solubility and dislocation structure
P. Vizcaíno¹, A. Flores¹, M. Vicente², J. Santisteban², G. Domizzi³, A. Tolley², A. Condó², and J. Almer⁴
¹ Centro Atómico Ezeiza, CNEA, Buenos Aires, Argentina
² Centro Atómico Bariloche, CNEA, Bariloche, Argentina
³ Centro Atómico Constituyentes, CNEA, Buenos Aires, Argentina
⁴ Advanced Photon Source, Argonne National Laboratory, Argonne, IL, USA

Session Summary
A. Ambard, Symposium Session Co-chair
H. Nordin, Symposium Session Co-chair

SESSION 7: HIGH TEMPERATURE TRANSIENTS AND MODELING OF PROCESS OR PHENOMENON

Session Chairs: M. Steinbruck
Karlsruhe Institute of Technology
Germany

B. Kammenzind
Bettis Naval Nuclear Laboratory
USA

Experimental simulation of the behavior of E110 claddings under accident conditions using electrically heated bundles
Z. Hózer¹, I. Nagy¹, R. Farkas¹, N. Vér¹, M. Horváth¹, Z. Kis¹, B. Maróti¹, L. Szentmiklósi¹, P. Holecz², G. Auguszt² and G. Gémes²
¹ Hungarian Academy of Sciences Centre for Energy Research, Budapest, Hungary
² TÜV Rheinland InterCert Ltd., Budapest, Hungary
2:00 PM

**Development of thermokinetic tools for phase transformation studies of Zr alloys in service and LOCA conditions**

C. Toffolon-Masclet¹, L. Martinelli¹, C. Desgranges², P. Lafaye³, J. C. Brachet¹, F. Legendre¹, J-C Crivello⁴, J-M Joubert⁴, D. Monceau⁴

¹ DEN-Service de Recherches Métallurgiques Appliquées, CEA, Université Paris-Saclay, Gif-sur-Yvette, France
² DEN-Service de la Corrosion et du Comportement des Matériaux dans leur Environnement, CEA, Université Paris-Saclay, Gif-sur-Yvette, France
³ Safran-Tech, rue des jeunes bois, Châteaufort, Magny les hameaux, France
⁴ Centre for Research in Computational Thermochemistry (CRCT), Department of Chemical Engineering, Polytechnique Montréal, Montréal, Québec, Canada
⁵ Université Paris Est, ICMPE, CNRS, UPEC, Thiais, France
⁶ CIRIMAT, CNRS, INPT, UPS, ENSIACET, Université de Toulouse, Toulouse Cedex 4, France

2:30 PM

**Analysis of the corrosion behavior of vapor-deposited CrN-coated zirconium under normal operation and accident scenarios**

C. Dever¹, K. Daub², H. Nordin¹

¹ Canadian Nuclear Laboratories, Chalk River, Ontario, Canada
² Queen’s University, Kingston, Ontario, Canada

3:00 PM

**BREAK**

3:20 PM

**Furthering the mechanistic understanding of the corrosion of Zr alloys via microstructural analysis: a combination of multiscale advanced experimental techniques and DFT modelling**

S. Armson¹, A. Garner¹, M. Yankova¹, F. Baxter¹,², J. Smith², C. Race¹, M. Preuss¹, and P. Frankel¹

¹ The University of Manchester, Manchester, UK
² Rolls-Royce plc, Derby, UK
³ Wood. PLC, Birchwood, UK

3:50 PM

**Results of the QUENCH-LOCA experimental program at KIT**

J. Stuckert¹, M. Große¹, M. Steinbrück¹, M. Walter¹, and A. Wensauer²

¹ Karlsruhe Institute of Technology, Karlsruhe, Germany
² PreussenElektra GmbH, Hannover, Germany
Towards a mechanistic understanding of pellet cladding interaction using advanced 3D characterization and atomistic simulation
P. Frankel¹, A. Garner¹, A. Plowman¹, S. Hanlon², C. Gillen¹, A. Phillion², C. Race¹, J. Donoghue¹, C. Anghel⁴, A. Ambarde⁵, M. Daymond³
¹ The University of Manchester, Manchester, UK
² Canadian Nuclear Laboratories, Chalk River, ON, Canada
³ Queen’s University, Kingston, ON, Canada
⁴ Westinghouse Electric Sweden AB, Västerås, Sweden
⁵ EDF Research and Development, Materials and Mechanics of Components, Ecuelles, Moret-sur-Loing, France

Session Summary
M. Steinbruck, Symposium Session Co-chair
B. Kammenzind, Symposium Session Co-chair

Presentation of Best Poster Award
Symposium Chairman

Announcement of 20th International Symposium on Zirconium in the Nuclear Industry
A. Garde, ASTM B10 Symposium Committee Chairman

SYMPOSIUM ADJOURNS

OPTIONAL MEETING (Not part of Symposium)

ASTM B10.02 Subcommittee Meeting
J. Pierce, ASTM B10.02 Sub Chairman
POSTERS

The sensitivity in the crack growth resistance of irradiated Zr-2.5Nb to small changes in the orientation of hydrides
S. St. Lawrence
1Canadian Nuclear Laboratories, Chalk River, Ontario, Canada

Characterizing fatigue damage in Zr-2.5Nb
H. Nordin, A. Phillion, T. Karlsen
1Canadian Nuclear Laboratories, Chalk River, Canada

Diffusion path comparison of the hydrogenated species in the oxide layers formed on Zircaloy-4 and M5 in PWR conditions
M. Jublot, K. Colas, M. Tupin, C. Bisor
1CEA-DEN, Université Paris-Saclay, Gif-sur-Yvette Cedex, France

The cause of transition in fuel cladding oxidation rates
S. Ortner, M. Blackmur, M. Fenwick, H. Weekes, H. Swan, M. Gass
1National Nuclear Laboratory, Abingdon OX14 3DB, UK
2Wood plc, Birchwood Park, Warrington, UK

Oxide stresses and tetragonal phase distributions in oxidised Zircaloy-4
H Swan, M. Blackmur, P. Styman, H. Wilcox, S. Sherry, F. Baxter, J. Smith, S. Ortner
1National Nuclear Laboratory, Abingdon, UK
2Wood plc, Birchwood Park, Warrington, UK
3previously Rolls-Royce plc, Raynesway, Derby, UK

Shadow corrosion: experiments and modeling
P. Barbéris, M. Skocic, D. Kaczorowski, D. Perche, Y. Wouters, K. Nowotka
1Framatome, Ugine, France
2Framatome, Le Creusot, France
3Framatome, Lyon, France
4SIMaP / Université Grenoble Alpes, Saint-Martin-d’Hères Cedex, France
5Framatome GmbH, Erlangen, Germany

Linking radiation damage to solute segregation, inter-diffusion and solubility in the Zr-Nb-Cr system
V. Tuli, A. Jain, D. Trinkle, M. Wenman, L. Messina, P. Burr
1The University of New South Wales, Sydney, Australia
2University of Illinois at Urbana-Champaign, Urbana, IL, USA
3Imperial College London, London, UK
4KTH Royal Institute of Technology, Stockholm, Sweden
Modeling of hydrogen pickup in zirconium alloys and correlation to oxide nano-porosity development
A. Couet¹, L. Borrel¹, J. Liu², and C. Grovenor²
¹ University of Wisconsin - Madison, WI, USA
² University of Oxford, Oxford, UK

Optimized manufacture of nuclear fuel cladding tubes by numerical modeling of processes and microstructure evolution analysis
A. Gaillac¹, P. Barbéris¹, I. Crassous¹, and F. Lyonnet²
¹ Framatome Ugine, Ugine Cedex, France
² Framatome Paimboeuf, Paimboeuf, France

Texture development of the α and β phases during hot-rolling of a dual-phase Zr-2.5Nb alloy
C. Daniel¹, M Preuss¹, J. Fonseca¹, P. Honniball², L. Bradley²
¹ The University of Manchester, Manchester, UK
² Rolls-Royce plc, Derby, UK

Phase characterization of Zr-Nb-Fe ternary system at the Zr-Nb rich side
F. Long, M. Griffiths, Z. Yao, and M. Daymond
Queen’s University, Kingston, Ontario, Canada

The nature of dislocation loops in proton irradiated zirconium alloys
H. Xu¹, R. Jones⁴, M. Topping², A. Garner¹, S. Irukuvarghula¹, G. Zilahi³, P. Kenesei⁴, R. Hulse¹, G. Ribárik³, T. Ungár¹,³, C. Riley⁵, P. Honniball⁵, P. Frankel¹, and M. Preuss¹
¹ University of Manchester, Manchester, UK
² Queen’s University, Kingston, Ontario, Canada
³ Eötvös Loránd University, Budapest, Hungary
⁴ Advanced Photon Source, Argonne National Laboratory, Argonne, IL, USA
⁵ Rolls-Royce plc, Derby, UK

Low elongation rate Zr-2.5Nb pressure tubes – A case study
R.A. Holt¹, R.G. Fleck², G.A. Bickel³, and L. Micuda⁴
¹ Queen’s University, Kingston, Ontario, Canada
² CANDU Owners Group Inc., Toronto, Ontario, Canada
³ Canadian Nuclear Laboratories, Chalk River, Ontario, Canada
⁴ Bruce Power Inc., Toronto, Ontario, Canada

Microstructure length-scale mapping of dislocation density
T. Skippon¹, L. Balogh¹, Z. Wang¹, Q. Wang¹, C. Cochrane¹, and M. Daymond¹
¹ Queen’s University, Kingston, Ontario, Canada

Physically based model and experimental validation of zirconium alloy corrosion for LOCA scenario
L. Borrel¹, K. Shirvan², J. Fournelle¹, and A Couet¹
¹ University of Wisconsin-Madison, Madison, WI, USA
² Massachusetts Institute of Technology, Cambridge, MA, USA
Effect of the addition of Cu on irradiation induced microstructures and hardening in Zr-Nb alloys
Q. Dong¹, Z. Yao¹, and M. Daymond¹
¹ Queen's University, Kingston, ON, Canada

Effect of hydrogen concentration and temperature on the DHC crack growth threshold stress of irradiated electron beam welded Zircaloy
R. Bentley¹, C. Gee¹, and H. Chaput²
¹ Rolls-Royce plc, Derby, UK
² Canadian Nuclear laboratories, Chalk River, Ontario, Canada

Effect of Ni coolant content on hydrogen pickup in PWR fuel rods
F. Garzarolli¹, P. Rudling¹, and E. Mader²
¹ Advanced Nuclear Technology International
² Electric Power Research Institute

Structure-property correlations in Zr-2.5% Nb alloy
P. Devi Y¹, N Keskar¹, K. Mani Krishna¹, D Srivastava², G. Dey¹, and M Krishnan¹
¹ Bhabha Atomic Research Centre, Trombay, India
² Nuclear Fuel Complex, Hyderabad, India

The role of thermomechanical processing on precipitates in Zircaloy-2 and HiFi™
Z. Shah¹, A. Harte¹, J. Robson¹, M. Limbäck², M. Alm³, and M. Preuss¹
¹ School of Materials, University of Manchester, Manchester, UK
² Westinghouse Electric Company, Västerås, Sweden
³ AB Sandvik Materials Technology, Sandviken, Sweden

M5 and Zy2 breakaway during simulated LOCA test
P. Barberis¹, C. Ly, C. Linardon¹, and R. Zino²
¹ Framatome, Ugine, France
² Framatome, Lyon, Saint-Etienne, France

Using modeling to improve understanding of corrosion and hydrogen pick-up of zirconium alloys
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On the mechanisms of hydrogen pickup during the oxidation of zirconium alloys in an aqueous environment
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Nuclear fuel claddings after high-temperature oxidation: Electron microscopy methods and nano-indentation for pseudo-binary phase diagram Zr1Nb – O calculations and hydrogen effect studies
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Prediction of the zirconium hydride precipitation barrier with an anisotropic 3D phase-field model incorporating bulk thermodynamics and elasticity
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