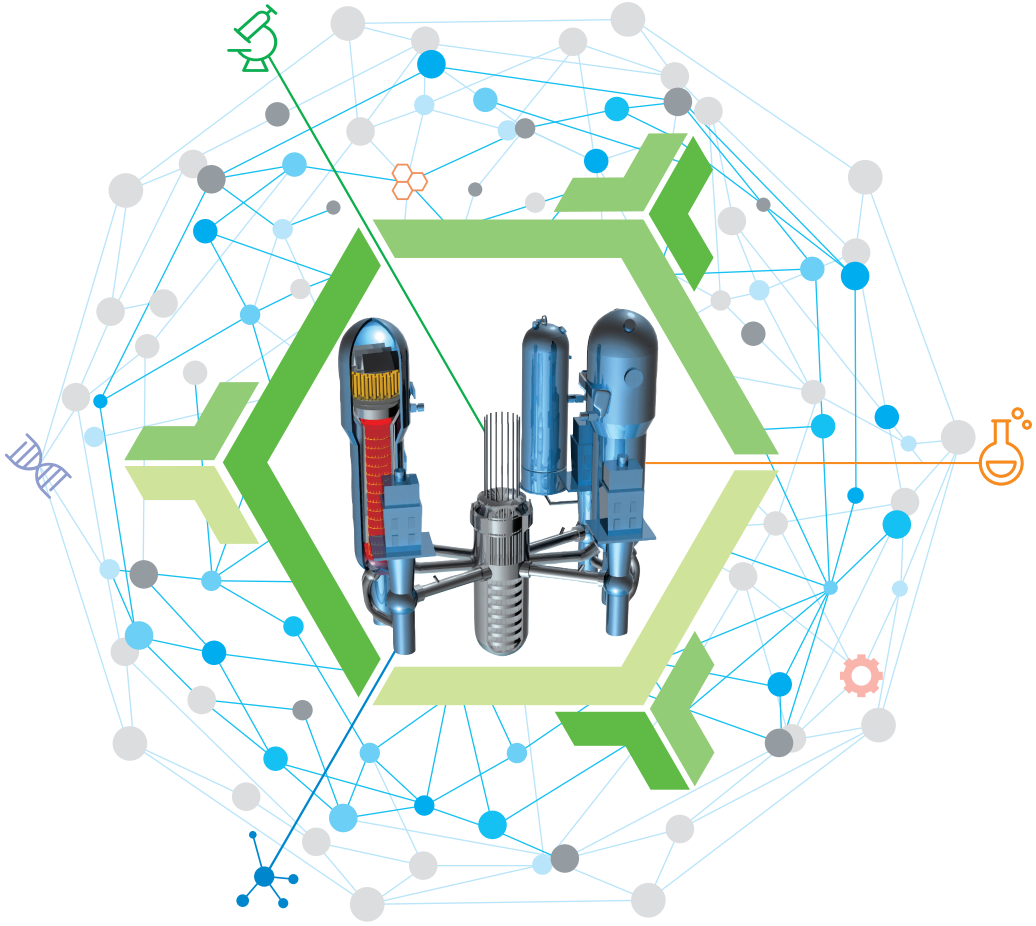
http://mdportal.kaeri.re.kr

KAERI Korea Atomic Energy Research Institute

Materials Safety Technology Research Division in Korea Atomic Energy Research Institute



한국원자력연구원 | 재료안전기술연구부

01

Materials Safety Technology Development

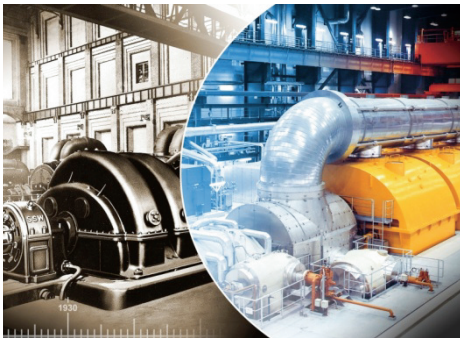
재료안전기술개발
CONTACT : 김동진 Dong-Jin Kim / Director
Tel : +82-42-868-8387
E-mail : djink@kaeri.re.kr

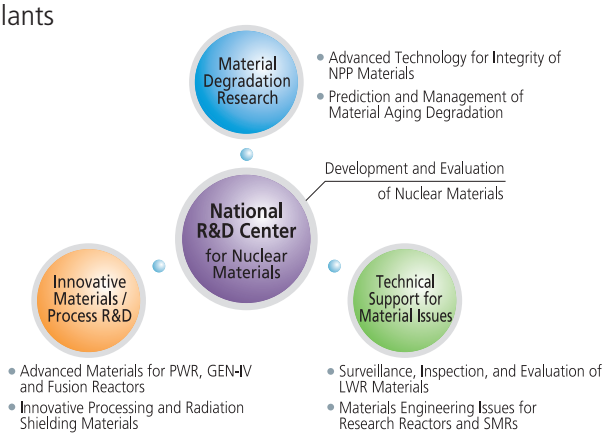
Materials Safety Research

- Material research is inevitable to achieve the safe and economic operation of nuclear power plants since the component materials are degraded by aging under reactor conditions, such as radiation, high temperature, water chemistry, stress, etc.
- Development of advanced nuclear energy systems can only be realized by breaking through the limitation of the materials performance under extremely harsh conditions.
- About 70 research staffs (50 permanent staffs, 20 post-docs and graduate students) are currently working on R&D projects in Materials Safety Technology Development Division.

Main Research Area

- Evaluation of materials degradation in operating nuclear power plants
- Development of innovative materials & process for various nuclear systems
- Technical support for materials issue of operating plants





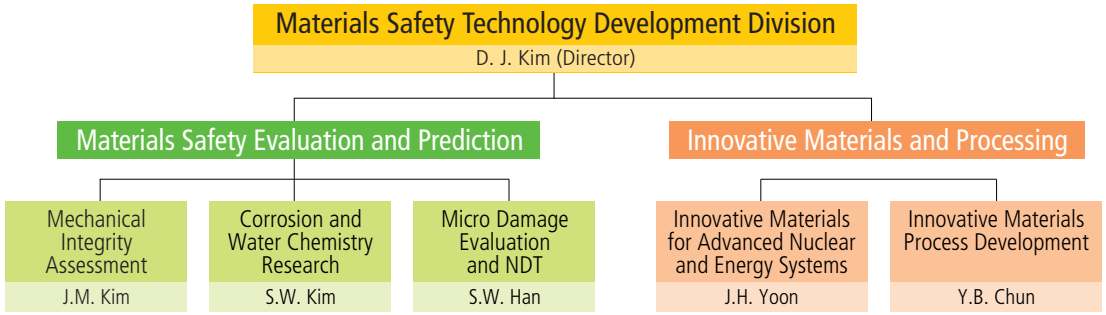
Research Groups and Teams

❖ Materials Safety Evaluation and Prediction

- Mechanical Integrity Assessment
- Corrosion and Water Chemistry Research
- Micro-damage Evaluation and NDT

❖ Innovative Materials and Processing

- Innovative Materials for Advanced Nuclear and Energy Systems
- Innovative Materials Process Development



02

Mechanical Integrity Assessment

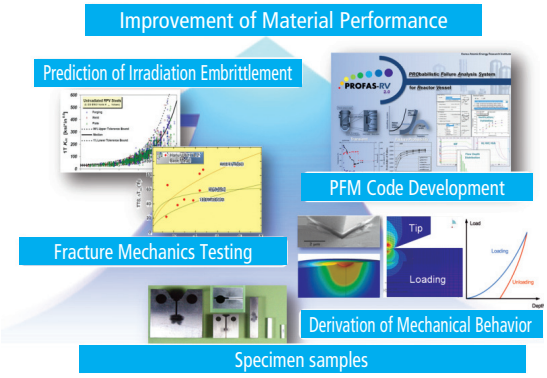
재료건전성평가
CONTACT : 김종민 Jongmin Kim
Tel : +82-42-868-4495
E-mail : jmkim@kaeri.re.kr

Introduction

- Reliability of fracture mechanics technology is indispensable to ensure the integrity of pressurized components in nuclear power plants. Research programs are underway on developing advanced technology for integrity evaluation of reactor materials in nuclear power plants and predictive models for failure behavior of pressure boundary materials.

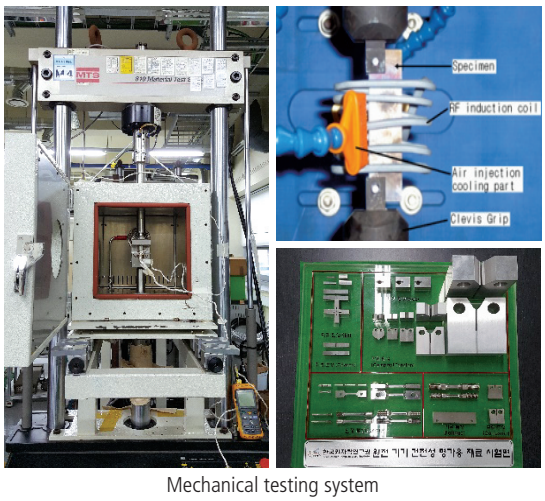
On-going R&D Activities

- Tests and analysis of irradiation embrittlement behaviors of RPV & RVI materials using research reactors
- Improvement of PTS evaluation software (PROFAS-RV) for the fracture mechanics analysis
- Development of computational codes (PROFAS-PIPE) for evaluating pipe failure rate in water cooled reactors.
- Derivation of fracture behavior by using small specimen technique
- Development of predictive model for failure of pressure boundary materials under severe accident conditions
- Microstructure-based modeling of irradiation damage for multi-scale analysis
- Application of statistics and machine learning to integrity assessment of pressure boundary materials



Technology and Facilities

- Fracture & mechanical testing system : servo-hydraulic test machine (25~500kN), environmental / thermal fatigue, fracture tests in vacuum, instrumented charpy
- Semi-hot laboratory, weld reconstitution of charpy specimens, specimen machining system for irradiated material
- Software : Calphad (ThermoCalc / DICTRA), neutron transport (DORT), FEM Code, PROFAS-RV & PROFAS-PIPE (PFM analysis code for RPV & Pipe)



Mechanical testing system

Specimen machining system for irradiated materials

03

Corrosion and Water Chemistry Research

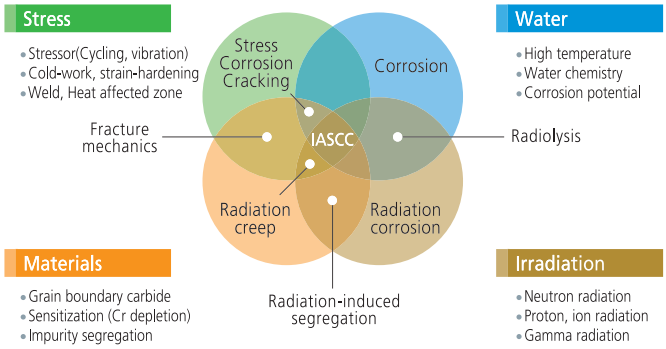
내환경소재연구
CONTACT : 김성우 Sung-Woo Kim
Tel : +82-42-868-4875
E-mail : kimsw@kaeri.re.kr

Introduction

- Various types of localized corrosion (PWSCC, ODSCC, IASCC, FAC) for metallic alloys in structural components such as nozzles, steam generator, reactor internals and coolant piping systems are inevitable in nuclear power plants. The mechanistic understanding for degradation through precise corrosion assessment using novel technologies gives us keys to find counteracting technology and life prediction models for nuclear components.
- In addition, sludge on SG tubing is the major root cause of impurity accumulation, loss of heat transfer, and corrosion degradation of the materials. CRUD on fuel claddings tubing also induces axial offset anomaly, and increases thermal resistance and thus corrosion of cladding. It is also important to develop mitigation technologies for sludge and CRUD deposition, based on boiling phenomena, water chemistry, surface property, and electro-chemical reaction.

On-going R&D Activities

- Technology development of verification of materials aging in primary coolant system
- Development of failure and degradation analysis technologies of reactor internal baffle former bolts from decommissioning NPP
- Prediction model of corrosion resistance of reactor vessel internals in neutron-coolant environment
- Technology of evaluation of CRUD thermal property and CRUD-induced localized corrosion



Technology and Facilities

Corrosion Evaluation → Corrosion Mechanism → Corrosion Model & Prediction → Mitigation & Protection

- **Nuclear materials corrosion evaluation and modeling technology**
  - ✓ SCC initiation and growth in Alloy 600/690 DMW, Alloy 600/Alloy 690 SG tubing
  - ✓ IASCC for stainless steel in PWR reactor internals
  - ✓ FAC assessment for secondary pipes of NPPs
  - ✓ Mechanistic understanding of corrosion and prediction model for life management
- **Water chemistry and corrosion mitigation technology**
  - ✓ Simulation and mitigation of sludge deposition on SG tubing
  - ✓ Reaction mechanism at the interface between materials and sludge
  - ✓ Mitigation of CRUD deposition on fuel claddings
- **Technical support for failure analysis of degraded components from operating NPPs**


FACTS for FAC study


SSRT and HT-HP loop for SCC test


HT-HP loop for CRUD and Sludge studies


Hot-Lab for failure analysis

04

Micro Damage Evaluation and NDT

미세손상분석

CONTACT : 한순우 Soon-Woo Han

Tel : +82-42-868-2881

E-mail : swhan@kaeri.re.kr

Introduction

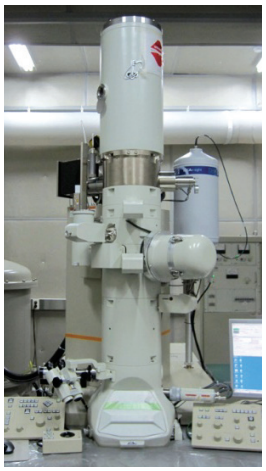
- Enhancement of nondestructive testing and evaluation (NDT) is researched for the early detection of micro-damage of nuclear materials under operation which is important in safety management of nuclear power plants. The current R&D programs include new ultrasonic testing method, enhanced ultrasonic signal processing, simulation on ultrasonic/eddy current signals and AI model for automated damage detection.
- Microstructural characterization techniques for irradiated material (e.g. TEM, PALS, 3D-APT etc) have been developed for understanding radiation damage mechanisms in nuclear reactor materials. Micro-scale material testing techniques (e.g. nano-indentation, micro-pillar compression, etc.) have been applied for the evaluation of radiation effects on the mechanical properties of nuclear reactor materials.

On-going R&D Activities

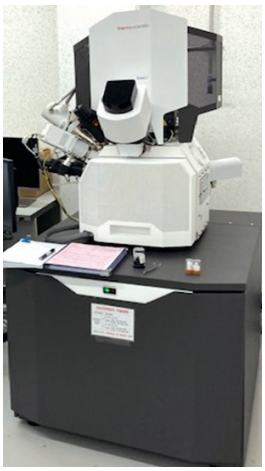
- Material safety evaluation method based on nonlinear ultrasonics
- Damage detection of hydrogen tanks and pressure vessels
- Database construction and AI development for eddy current testing signals for steam generator tubes
- Optimization for phased-array ultrasonic signals for damage detection in dissimilar weld zone
- Micro-scale material characterization for structural nuclear materials
- Development of material database and safety evaluation method for storing spent nuclear fuel in CANDU irradiated fuel bay

Technology and Facilities

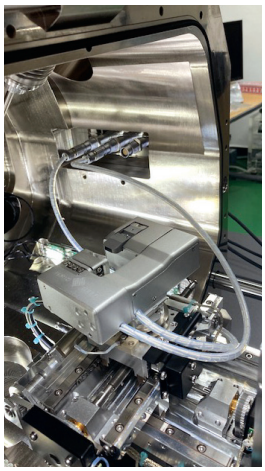
- High-power ultrasonic pulser / receiver
- Laser ultrasonic testing system and laboratory: laser pulser, laser vibrometers, optical fiber laser device and laser ultrasonic scanner
- Eddy current testing system and laboratory
- Microstructure analysis of irradiated materials : Field-emission transmission electron microscope with EDS & EELS, focused ion beam scanning-electron microscope with EDS & EBSD, ion-miller etc.
- Characterization of micro-size specimen: micro- and nano-indentation, in-situ micromechanical testing in SEM
- Software : ABAQUS mechanical module, COMSOL AC / DC module



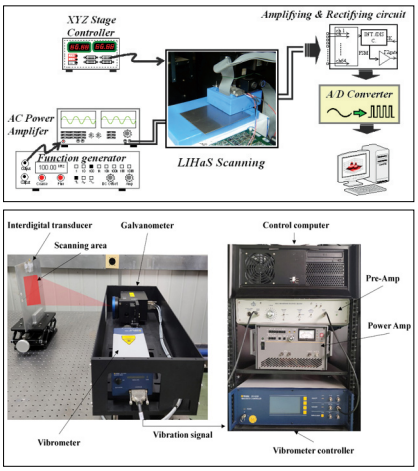
TEM



FIB



In-situ nanoindenter



Ultrasonics based NDT system

05

Innovative Materials for Advanced Nuclear and Energy Systems

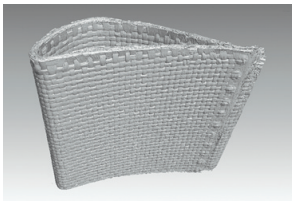
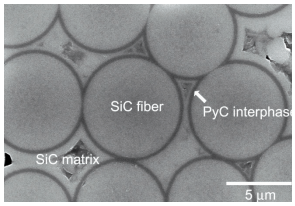
혁신소재연구
CONTACT : 윤지현 Jihyun Yoon
Tel : +82-42-868-8554
E-mail : jhyoon4@kaeri.re.kr

Introduction

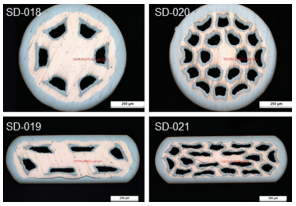
- The innovative materials research team conducts fundamental and applied innovative materials research for advanced nuclear and energy systems, including molten salt reactors, advanced gas turbine, high efficient superconducting systems, hypersonic vehicles, accident-tolerant nuclear power systems. Research programs are focused on compatibility assessment with harsh environments, fabrication technology development of fiber-reinforced ceramic composites, superconductor, ultra-high temperature ceramics, and fully ceramic microencapsulated fuel.

On-going R&D Activities

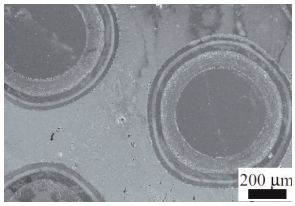
- Compatibility assessment of structural materials with molten salt environment for MSRs
- Development of SiC composites for advanced nuclear energy systems and gas turbine systems
- Development of ultra-high temperature ceramics for hypersonic vehicle applications
- Development of superconductor with high current for large-scale wind energy using irradiation

SiC Composite



Superconductor



FCM fuel

Technology and Facilities

- Compatibility test facilities of structural materials with molten salt environment
- Fabrication facilities of fiber-reinforced ceramic composites
- Accident-tolerant test facilities (thermal shock, hot steam corrosion, LWR primary coolant loop)
- CVD system for fabrication of ultra-high temperature ceramics
- Fabrication facilities of MgB_2 / REBCO superconductors, thin films and functional materials
- Powder metallurgy, tube & box furnaces, measurement system for electronic characteristics


Fabrication and test facilities of UHTC and SiC composites


Fabrication facilities of superconductors

Innovative Materials Process Development

혁신제조공정개발

CONTACT : 천영범 Young-Bum Chun

Tel : +82-42-868-4571

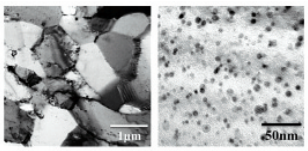
E-mail : youngbumchun@kaeri.re.kr

Introduction

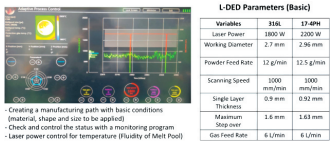
- Advanced nuclear reactor and spent fuel storage systems require structural and functional materials with better performance than those currently used. Innovative Materials Process Development Team is developing new materials for nuclear applications based on innovative alloy design scheme and advanced manufacturing processes.

On-going R&D Activities

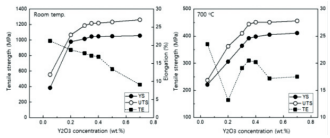
- Development of high-strength radiation-resistant materials
- Development of reduced-activation materials for fusion reactor applications
- Development of advanced neutron absorbing materials for spent fuel storage applications
- Process optimization of additive manufacturing for nuclear applications
- Codification of material database for new material in industrial standards
- Qualification of long-term creep resistance of new structural materials



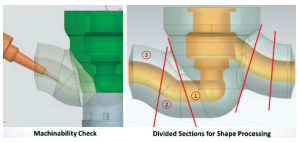
Oxide Dispersion Strengthening Steel



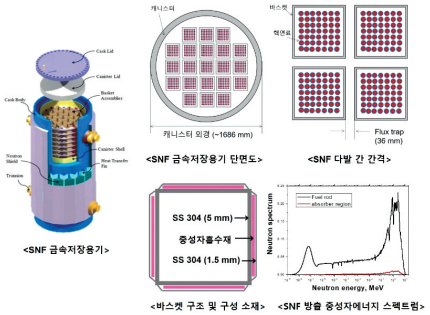
Additive Manufacture Process Optimization



Composition Optimization



Manufacturing Process Development

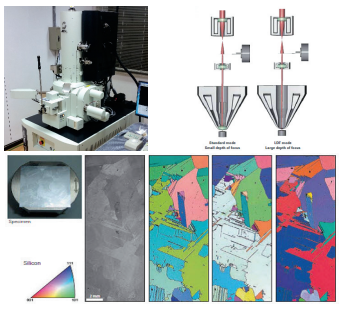


Neutron absorbing materials for SNF

Technology and Facilities

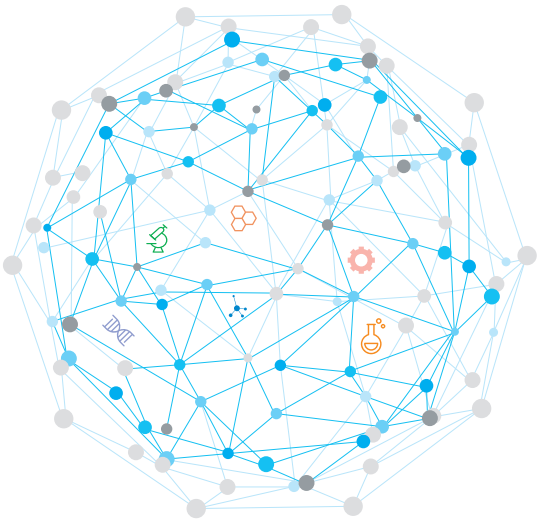
- Horizontal rotary ball mill system (Zoz CM08, CM20) for mechanical alloying
- Powder atmosphere control equipment
- Uniaxial high temperature pressurization equipment
- Internal pressure creep tester
- Creep testers (~ 40 sets) for development of material database
- Field-emission-gun scanning-electron-microscope combined with EDS/EBSD system
- Furnaces: box-type and horizontal tube-type furnaces for heat-treatments
- 3-dimensional powder mixing equipment
- Vibratory polisher for metallography samples with high quality surface

Creep testers



FE-SEM with EBSD / EDS system

Fab system for ODS alloys



Materials Safety Technology Research Division
in Korea Atomic Energy Research Institute

KAERI
한국원자력연구원
Korea Atomic Energy Research Institute
34057 대전광역시 유성구 대덕대로989번길 111
111, Daedeok-daero 989 beon-gil, Yuseong-gu, Daejeon, 34057