U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Clean. Reliable. Nuclear.

Materials R&D

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Office of Nuclear Energy

Advanced Materials R&D Program

- The ART Advanced Materials R&D Program supports the Advanced Reactor Pipeline
- Focused is on providing the technical basis needed to support the regulatory requirements for structural materials required for fast reactors, gas-cooled reactors, molten salt reactors and microreactors that could be deployed in the near-to-mid-term.

High Temperature Design Methodologies

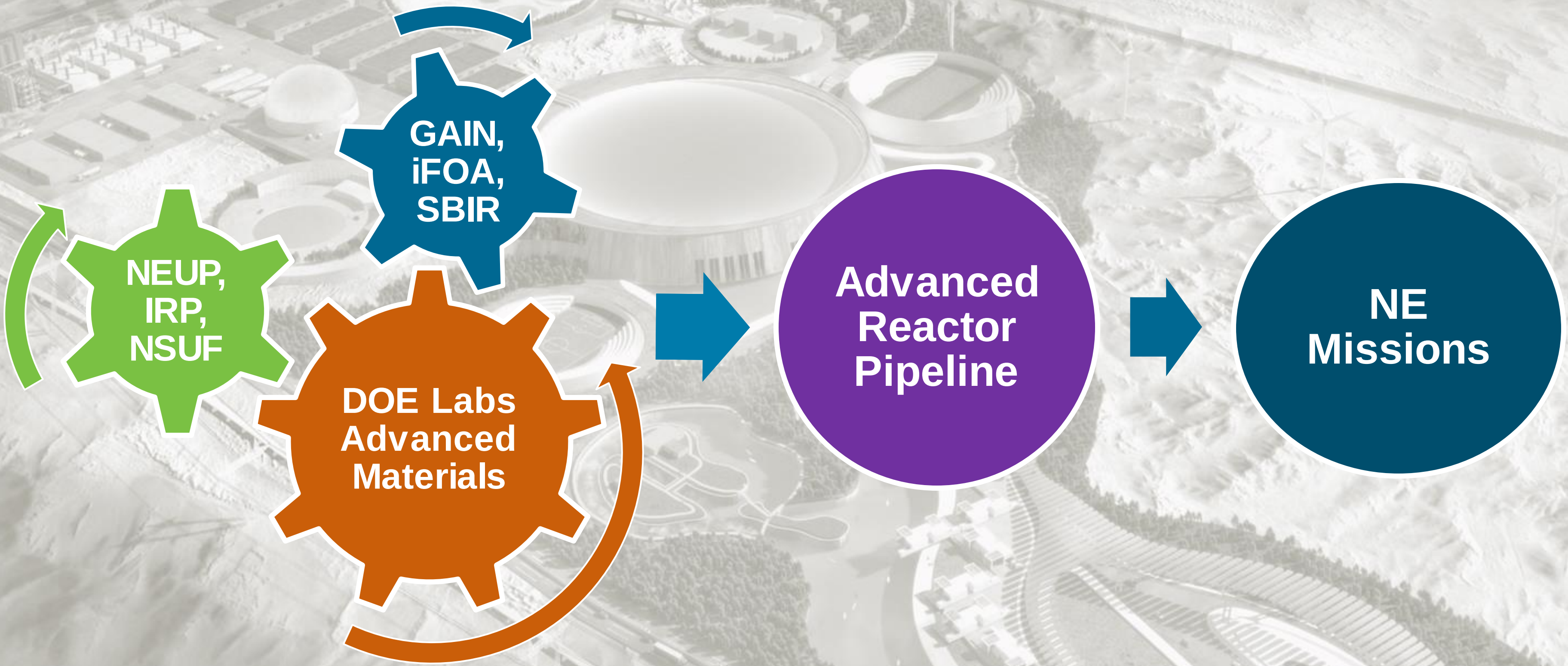
Existing Materials

Support Licensing

New Materials

Innovative Materials Solutions

NEUP, IRP, NSUF, GAIN, FOA, SBIR Programs Contribute to Additional Advanced Materials R&D



Gas-cooled Reactor

- High Temperature Design Methodologies (ANL, INL, ORNL)
  - Support ASME Division 5 Code committees participations (7 Lab staff)
  - Complete Alloy 617 Code Case balloting
  - Support update of Division 5 code rules for Class A and Class SM components
  - Extend qualified lifetime and temperatures of existing Class A materials
  - Develop new EPP+SMT creep-fatigue design methods
  - Notch and multiaxial stress state effects on creep rupture (Alloy 617)
  - Develop and initiate testing on improved weld consumables for Alloy 800H
- Graphite (INL, ORNL)
  - AGC and HDG irradiation campaigns
  - Graphite material properties
    - Baseline properties, irradiation properties, oxidation (acute and chronic), irradiation damage study, mechanisms and model development
  - Support ASME Division 5 Code committees participations and ASTM graphite standard (D02.F) activities (5 Lab staff)
- Data Management (ORNL)
  - Maintain GEN IV Materials Handbook operations to support GIF VHTR Materials PMB

Fast Reactor

- Qualifying New Material – Alloy 709 (ANL, INL, ORNL)
  - Conduct mechanical testing (tensile, fatigue, creep, creep-fatigue, SMT) to support a new Alloy 709 Code Case
  - Fabrication processes for different Alloy 709 product forms
  - Develop matching filler metal compositions and welding parameters to optimize Alloy 709 weldment properties
  - Conduct sodium compatibility testing of Alloy 709 in flowing sodium loops
- Qualifying Existing Material to Support Licensing and Long-term Plant Operations – Grade 91(ANL)
  - Conduct sodium compatibility testing of Grade 91 in flowing sodium loops
    - Study carburization and de-carburization behavior of Grade 91 in sodium

Molten Salt Reactor

- Salt and Materials Interactions (ORNL)
  - Evaluate corrosion performance of candidate structural materials by conducting exposures static exposures and flowing tests in natural circulation loops
  - Evaluate compatibility of candidate graphite grades with relevant molten salts
  - Evaluate effects of environmental variables such as salt chemistry on degradation of structural materials and graphite
  - Conceive a roadmap and conduct targeted experiments in support the development of predictive physics-based corrosion modeling and component lifetime prediction
- Materials Surveillance Development (ANL)
  - Develop in-situ, passive surveillance specimen designs and fabricate down-selected scoping test articles
  - Develop methods to correlate damage to time-dependent indentation test data from surveillance specimens
- ASME Section III Division 5 Class B Materials (ANL)
  - Introduce existing high nickel alloys to ASME Section III Division 5 Class B designs
  - Develop design methods to introduce the design lifetime concept to Class B rules

Microreactor

- Core Block Code Case for Heat Pipe Reactor – Grade 91 (ANL, ORNL)
  - Extend EPP strain limits and creep-fatigue code cases to Grade 91
  - EPP primary load code case for Grade 91
  - EPP+SMT creep-fatigue design method for Grade 91
  - Notch sensitivity correlation for Grade 91, using crystal plasticity finite element method
  - Unified viscoplastic material model for Grade 91
  - Include provisions in the Code Case to account for the effects of irradiation
- Elevated Temperature Cyclic Properties of Advanced Manufactured Materials (INL)
  - Evaluate elevated-temperature fatigue and creep-fatigue properties of 316L stainless steel manufactured using powder metallurgy (PM) hot isostatic pressing (HIP)
  - Pursue procurement of 316H and Grade 91 (wrought products already qualified for ASME Section III Division 5) manufactured using PM HIP

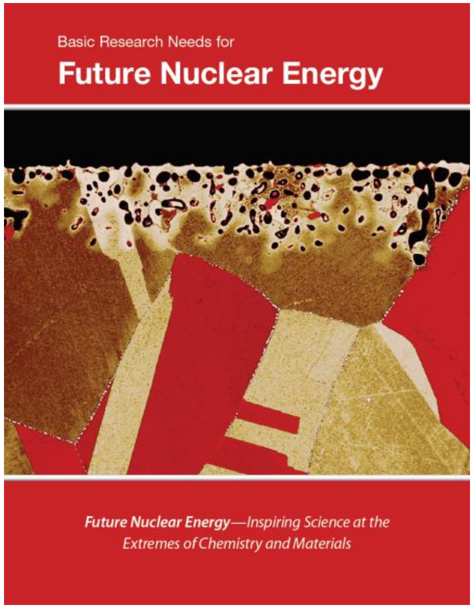
Other Structural Materials Related Efforts

- High Fidelity Ion Beam (LANL)
  - High Fidelity Simulation of High Dose Neutron Irradiation led by the University of Michigan
  - Objective: Utilizing unique facilities and capabilities, demonstrate the capability to predict the evolution of microstructure and properties of structural and cladding materials in a nuclear reactor and at high doses, using ion irradiation as a surrogate for reactor irradiations
- NEUP-IRP ASME Nuclear Code Case for Compact Heat Exchangers (Led by University of Wisconsin, Madison)
  - Develop the required information to certify the use of compact heat exchangers in the ASME Code for nuclear applications
  - Develop an understanding of operational issues in operating these heat exchangers in nuclear systems
- NEUP projects
- SBIR projects – Bimetallic structures and SiC/SiC composite fabrication

DOE Office of Basic Energy Sciences

- Basic Energy Sciences (BES) supports fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels in order to provide the foundations for new energy technologies and to support DOE missions in energy, environment, and national security.
- The two BES programs that fund the bulk of basic research underpinning nuclear technologies are Heavy Element Chemistry (Philip Wilk) and Mechanical Behavior and Radiation Effects (John Vetrano)
- A major tool for strategic planning at BES is the "Basic Research Needs" workshop series (https://science.osti.gov/bes/Community-Resources/Reports)
- In August, 2017 BES held a workshop entitled "Basic Research Needs for Future Nuclear Energy" with input from DOE-NE on the technological needs.
- These workshops, consisting of close to 100 members of the basic and applied research community, develop a series of "priority research directions" that help to guide the basic science research directions

BRN for Future Nuclear Energy – Priority Research Directions



- Enable design of revolutionary molten salt coolants & liquid fuels
  How can we characterize and predict the structure, dynamics, and energetics of molten salts including evolving chemical composition across length and time scales?
- Master the hierarchy of materials design and synthesis for complex, reactor environments
  How do we design, synthesize, and process superior materials able to function and perform over decades in the extreme environments of advanced nuclear reactors?
- Tailor interfaces to control the impact of nuclear environments
  How can the multitude of inextricably linked chemical and physical processes that occur at interfaces be controlled?
- Reveal multiscale evolution of spatial and temporal processes for coupled extreme environments
  How can computational and experimental techniques be integrated to bridge spatial, temporal, and energy scales that underpin materials' behavior and chemical transformations in coupled extreme environments?
- Identify and control unexpected behaviors from rare events and cascading processes
  How do we identify, anticipate and control rare events that initiate cascading processes and cause aberrant properties and materials responses?

https://science.osti.gov/-/media/bes/pdf/reports/2017/BRN-FNE_rpt.pdf