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CHANGING WHAT'S POSSIBLE

CHADWICK—Creating Hardened And Durable fusion first Wall Incorporating Centralized Knowledge

PROJECT DESCRIPTIONS

Ames National Laboratory – Ames, IA

Refractory Alloys with Ductility and Strength (RADS) - $3,000,000

Ames National Laboratory is investigating how tailored tungsten-rich refractory multi-principal-element alloys can address the critical lack of materials that can survive the first-wall environment in fusion power plants. The proposed project will create a new high temperature material using tungsten, vanadium, rhenium, and other elements with high melting points, and establish a manufacturing process to commercially manufacture the materials with assistance from plasma technology.

Commonwealth Fusion Systems – Devens, MA

Co-Optimization of an Integral, Layered Materials Solution for Compact Tokamak Vessels - $2,500,000

Commonwealth Fusion Systems will perform manufacturing and joining studies on industrially relevant volumes of tungsten and vanadium material to identify and optimize the most commercially feasible manufacturing process. The results of the materials' performance will directly inform the ARC fusion power plant design being conducted by Commonwealth Fusion Systems. The proposed project addresses the major engineering challenge of making and joining dissimilar tungsten and vanadium alloys for fusion power plants.

ExoFusion – Bellevue, WA

Novel Liquid Metal Plasma Facing Component Alloys - $500,000

ExoFusion will develop a new liquid material with low vapor pressure, melting point, and plasma contamination for fusion first walls. The liquid material would enable the continuous replenishment of the first wall material in the harsh environments of a commercial fusion power plant. The proposed approach involves doping a liquid metal with minor concentrations of elements with low atomic numbers.

Johns Hopkins University – Baltimore, MD

Complexion Engineered Nanocrystalline Tungsten Alloy Plasma Facing Materials for Long-Pulse Tokamak Operation - $3,090,000

Johns Hopkins University will make a nanocrystalline tungsten material that is expected to be twice as tough and ten times as irradiation resistant than state-of-the-art tungsten material. Nanocrystalline materials have been found to be especially resistant to irradiation because of the small size of their crystalline grains. By doping the nanocrystalline tungsten with minor alloying elements, the team will investigate if it is possible to create additional amorphous features at the boundary of the small crystalline grains. These features are expected to absorb irradiation defects to create a material that could potentially heal irradiation damage in service.

Lawrence Livermore National Laboratory (LLNL) – Livermore, CA

Design of Complex High-Performance Armor Materials - $3,400,000

Lawrence Livermore National Laboratory will rapidly design never-before-seen materials to enhance the realization, safety, and cost effectiveness of fusion power plants. The project will employ an integrated, high-throughput modeling and experimental framework to create new materials by thoroughly exploring the complex composition space offered by low-activation elements. LLNL's project will also use industrial laser technology to improve the surface of the new material to increase the chance of survival in a fusion power plant.

Pacific Northwest National Laboratory (PNNL) – Richland, WA

Ferritic and Vanadium Alloys with Nanoparticle Strengthening for Fusion (FAVA-NSF) - $3,000,000

Pacific Northwest National Laboratory (PNNL) will make new alloys with pure powders dispersed with nanoparticles shown to increase alloy strength and irradiation resistance. The powder material will be made into plates by spraying the powder and friction stir processing onto a surface. This new fabrication technique can be completed at room temperature and bypass problems related to microstructural inhomogeneities during melting.

Savannah River National Laboratory – Aiken, SC

Machine Learning for Alloy Discovery Coupled with Geometric Optimization for Functionally Graded Liquid Metal First Wall - $1,500,000

Savannah River National Laboratory will develop a suitable material and 3D print the geometrically complex structures that will control how much liquid metal is exposed to the fusion reaction without excessive evaporation. Using liquid metal in fusion power plants provides the opportunity to continuously replace the first wall and repair the irradiation damage from the fusion reactions. The project develops novel approaches to keeping the liquid in place, and its success will help validate that the inside surface of a fusion power plant chamber can be made of liquid instead of solid material.

Stony Brook University – Stony Brook, NY

Design and Development of Composited Low-Activation UHTC Materials for Very High Temperature First Wall Application - $2,500,000

Stony Brook University will increase the ductility, thermal conductivity, and irradiation resistance of ceramic materials through second phase additives into low activation ultra-high-temperature ceramics (UHTC). In the past, ceramics materials have not been seriously considered for fusion power applications due to their nature and rapid loss in thermal conductivity under irradiation. The successful development of more relevant ceramic materials for use as fusion first wall armor under excessive temperature and irradiation damage would represent a significant technological step forward.

Texas A&M Engineering Experiment Station – College Station, TX

Batch-wise Improvement in Reduced Design Space using a Holistic Optimization Technique for FUSion Environments (BIRDSHOT-FUSE) - $2,360,000

Texas A&M Engineering Experiment Station will leverage large datasets from existing material modeling codes to train machine learning tools in the discovery of new materials for fusion power plants. The project will use digital tools to perform materials discovery a thousand times faster than traditional means, screening up to hundreds of new material compositions in a day, and will verify their computations by making and testing a select number of materials. Out of a near-infinite design space, the project will identify and fabricate several optimized materials suitable to replace first wall materials in a fusion power plant.

University of California, San Diego (UC San Diego) – La Jolla, CA

High Flux Plasma-Materials Interaction Testing for Rapid Fusion Materials Development - $1,345,309

University of California, San Diego's (UC San Diego) Plasma Interaction with Surface Component Experimental Station (PISCES) facility is a unique long-standing scientific capability within the U.S. During the CHADWICK program, the PISCES facility will offer a range of plasma-materials interactions services to the material development teams. The facility will aid teams in testing how new materials will react to the plasma and irradiation environment expected in a fusion power plant.

University of Illinois, Urbana-Champaign (UIUC) – Urbana, IL

GRADED: Gradient composites with Radiation Amorphization-enabled Dimensional stability and Energy Dissipation - $2,500,000

University of Illinois, Urbana-Champaign will use 3D printing to make a graded material to create a transition from high temperature tungsten to a new copper alloy. Because tungsten does not naturally want to alloy with copper, the elements are hypothesized to separate under irradiation and create an amorphous boundary where the elements meet. The project will investigate the amorphous boundary's ability to soak up irradiation defects and reduce cavities, offering the potential to reverse the damage caused by the fusion irradiation environment.

University of Illinois, Urbana-Champaign (UIUC) – Urbana, IL

Centralized and On-Demand Radiation Transport and Techno-Economics (CORTEX) for Fusion Material Engineering - $1,870,000

University of Illinois, Urbana-Champaign (UIUC) will develop an open-source centralized library to assess and document the radioactivity of materials that are being used in fusion power plants. The tool will be made available to the fusion community to rapidly assess new materials and their techno-economic impact on the cost and anticipated electricity generation of fusion power plants. The proposed project addresses the challenge of siloed computational workflows across fusion engineering teams, which has historically hindered collaboration and workforce development.

University of Kentucky – Lexington, KY

Combinatorial Modeling, Screening, and Development of Tungsten-Ceramic Composites with Gradient Microstructure for Improved Radiation-Tolerant Plasma Facing Materials - $2,300,000

University of Kentucky will infiltrate porous tungsten alloys with ceramic material such as carbides or boron phosphide to increase the material's thermal conductivity. The project will use machine learning to optimize the volume fraction of porous tungsten versus the ceramics to maintain material performance after irradiation. The interfaces between the ceramic and tungsten material are also anticipated to function as irradiation damage sinks that can increase the irradiation tolerance of the composite material.