DE-FOA-0002385 Request for Information on Accelerated Materials R&D, Testing/Qualification, and Cost-Effective Manufacturing Routes for Harsh Service Environments Materials

August 19, 2020

DATE: **AUGUST 19, 2020**
SUBJECT: **REQUEST FOR INFORMATION (RFI)**

Description

The Advanced Manufacturing Office (AMO) and the Office of Advanced Energy Systems (AES) are jointly seeking information on accelerated materials research, development, and demonstration (RD&D), testing/qualification methods, and cost-effective manufacturing routes for the development of components, systems, and products exhibiting significant, or step-change improvements over current state-of-the-art in system energy performance under harsh service conditions and extended service lifetimes. Harsh environments include high temperature and corrosive environments, conditions of high mechanical wear/stress/load, thermal cycling, and exposure to hydrogen, irradiation, and other embrittlement mechanisms.

The Department of Energy (DOE) has invested significantly over the last decade in RD&D of new materials for service in harsh environments, particularly in energy-production. AMO and AES now seek to gather input from stakeholders on the technical and commercial prospects of novel material development and new manufacturing capabilities—including but not limited to the advantages and technical challenges associated with new material breakthroughs, strategies for de-risking the cost and performance of novel materials, and considerations for scale-up of new materials manufacturing methods. AMO and AES seek individual input on high-reaching targets/metrics and identification of key problem sets to be addressed. The intent is to define critical crosscutting problems/barriers whose solutions represent near-term commercially viable paths to obtaining materials that can produce a step change improvement in energy performance under harsh service conditions beyond current state of the art.

Establishing a baseline understanding of the fundamental challenges pervasive across multiple industries and the technical potential of material systems for use in harsh service conditions aids in expanding the design space of material development and manufacture for energy applications. Harsh service materials technologies are inherently interdisciplinary, and major opportunities exist for national initiatives that tie together materials research and development efforts across fields and that address large-scale manufacturing challenges for these materials so that faster, more cost-efficient production methods can be developed and scaled up to high-volume capability.

Background

The physical limitations of materials in demanding environments have long constrained and continue to limit engineers in the design of innovative high performance products and processes. Aggressive service environments can involve high temperatures, thermal cycling, corrosive chemicals, oxidizing atmospheres, high mechanical wear/stress/load, neutron irradiation, and hydrogen attack. These aggressive environments—and the associated material's stability and durability challenges—are common across multiple applications, materials systems, and economic sectors. Accelerated materials development (discovery, testing, and qualification) and associated manufacturing methods are needed for alloys, ceramics, composites, coatings, and surface treatments subject to stringent application demands under harsh service conditions. Additionally, such advancements must meet cost requirements and provide energy savings, emissions reductions, and other benefits. By way of example, consider the following brief descriptive summaries (details will be given in the Categories and Questions section):

- **Corrosion:** The economic costs of materials corrosion can hardly be overstated, as corrosion presents a significant challenge in nearly every industrial sector. In the energy industry (pipelines, electricity production, and power distribution systems), corrosion-related failures can result in service outages. In energy-intensive industries (steel, chemical, petrochemical, etc.), process disruptions caused by component failures, necessitate startup/shutdown cycles that result in productivity loss and energy loss, especially in high-temperature production processes. The performance improvements needed for operation in corrosive environments call for chemically and mechanically robust materials that can economically replace traditional alloy materials as a promising route towards accelerated materials development.

- **High-temperature Processing:** Maximum operating temperatures of devices and industrial processes are limited by their design, including the phase stability of the materials used in component products and manufacturing equipment, respectively. Opportunities exist to develop new high-performance, low cost materials as competitive and viable alternatives to traditional materials used in high-temperature metals processing, chemical and petrochemical processing, energy production and industrial process heating applications.

- **Friction and Wear Losses**: In 2012, it was estimated that about 30% of all energy consumed by the U.S. transportation sector was expended in overcoming contact friction and wear losses.[1] Such losses are also substantial in other sectors, for example, the global estimate for contact friction and wear losses in the industrial sector (including mining, agriculture, primary metals, pulp and paper, chemicals/refining and food processing) has been estimated at around 20%.[2]

- **Alloy Embrittlement**: New materials with improved resistance to hydrogen and radiation (neutron) embrittlement could better support existing energy production and industrial infrastructure applications as well as facilitate use of alternate feedstocks/fuels for vehicle electrification. The use of hydrogen as an energy carrier will require materials that enable safe hydrogen storage at high gravimetric and volumetric densities. Likewise, advanced nuclear fuel cladding materials capable of withstanding higher radiation doses would enhance accident tolerance at nuclear power plants.

Purpose

The purpose of this RFI is to solicit feedback from industry, academia, research laboratories, government agencies, codes and standards communities, and other stakeholders on issues related to materials and materials manufacturing process technologies that improve system energy efficiency/performance and extend useful life where harsh service conditions exist. This information will be used by AMO and AES to inform strategies and in support of energy savings and cost reduction goals, as well as to inform future planning and adjustments to their research and development (R&D) portfolios.

Disclaimer and Important Notes

This RFI is not a Funding Opportunity Announcement (FOA); therefore, AMO and AES are not accepting applications at this time. Either AMO or AES may issue a FOA in the future based on or related to the content and responses to this RFI; however, they may also elect not to issue a FOA. There is no guarantee that a FOA will be issued as a result of this RFI. Responding to this RFI does not provide any advantage or disadvantage to potential applicants if AMO or AES chooses to issue a FOA regarding the subject matter. Final details, including the anticipated award size, quantity, and timing of AMO or AES funded awards, will be subject to Congressional appropriations and direction.

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development; this RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this notice will be treated as information only. AMO and AES will review and consider all responses in their formulation of program strategies for the identified materials of interest that are the subject of this request. Neither AMO nor AES will provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that AMO and AES are under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind AMO or AES to any further actions related to this topic.

Proprietary Information

Because information received in response to this RFI may be used to structure future programs and FOAs and/or otherwise be made available to the public, **respondents are strongly advised to NOT include any information in their responses that might be considered business sensitive, proprietary, or otherwise confidential.** If, however, a respondent chooses to submit business sensitive, proprietary, or otherwise confidential information, it must be clearly and conspicuously marked as such in the response.

Responses containing confidential, proprietary, or privileged information must be conspicuously marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Federal Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

If your response contains confidential, proprietary, or privileged information, you must include a cover sheet marked as follows identifying the specific pages containing confidential, proprietary, or privileged information:

> **Notice of Restriction on Disclosure and Use of Data**
>
> Pages [List Applicable Pages] of this response may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for the purposes described in this RFI DE-FOA-0002385. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

In addition, (1) the header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure" and (2) every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

Evaluation and Administration by Federal and Non-Federal Personnel

Federal employees are subject to the non-disclosure requirements of a criminal statute, the Trade Secrets Act, 18 USC 1905. The Government may seek the advice of qualified non-Federal personnel. The Government may also use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The respondents, by submitting their response, consent to AMO or AES providing their response to non-Federal parties. Non-Federal parties given access to responses must be subject to an appropriate obligation of confidentiality prior to being given the access. Submissions may be reviewed by support contractors and private consultants.

Request for Information Categories and Questions

Applied research needs for materials used in harsh environments and their manufacturing methods possess commonalities with other AMO mission spaces, including composites, advanced sensors, additive manufacturing, and advanced materials manufacturing.[3] Importantly, scalable materials manufacturing methods are sought that are capable of reducing the process times or costs. The key categories / market opportunities for harsh service condition materials challenges are traditionally broken down by the type of environment, although combinations of these conditions are often encountered. In considering specific applications that fall under the following categories, respondents are asked to provide an estimate of the energy savings that should be targeted.

Category 1: Corrosive Environments

The need for materials with corrosion resistance is broadly relevant across economic sectors. Because degradation mechanisms are highly dependent on specific material features and service environment conditions, it is very difficult to define universally-applicable performance criteria for materials. Therefore, AMO and AES seek input on more general topics such as:

Questions:

1. What can be done to improve methodologies used for discovery and development of new corrosion-materials that meet the requirements of a particular energy production or energy-intensive application?
2. What advanced manufacturing methods can be used for the production of corrosion resistant materials?
3. What knowledge gaps exist for specific corrosive environments in manufacturing or other energy-intensive or energy production applications that provide an opportunity for new materials to significantly reduce energy requirements in those applications? What are the harsh service conditions? How much energy can be saved?
4. What is the framework and development timeline needed for qualifying new materials for high-corrosion applications, and is there a method for developing a formalized, industry-accepted pathway for materials development, design innovation, and manufacturing?
5. How do material supply chains, code qualifications, and industrial maturity factors introduce limitations on manufacturing scalability and economic feasibility for new materials?
6. Are there other environments (e.g., chemicals) that have similar materials challenges?

Category 2: Very High-temperature Environments

New alloys, ceramics, composites, and even plastics, with superior resistance to high-temperature oxidation, reduction, creep, fatigue, and phase transformation are needed for energy production, as well as in the energy-intensive transportation and industrial end use applications. Although it is impossible to define material property/performance criteria that are universally-applicable across all classes of materials and operating conditions/environments, very generally either steady-state creep (static loading), constrained or unconstrained thermal fatigue (cyclic loading), stress corrosion cracking, oxidation, reduction, phase transformation, decomposition, spallation, or undesired microstructural changes (e.g., coarsening) generally becomes a concern with metals, ceramics, and polymers beginning at some temperature range/interval (e.g., > 1,200°C for many ceramics, > 1,000°C for superalloys, > 200°C for many polymers/plastics).

Questions:

7. Can cost-effective, scalable, repeatable manufacturing (e.g., production and synthesis) and application (e.g., surface engineering) methods be developed for producing materials used at high-temperatures that afford a high degree of microstructural control, and/or that provide innovative component geometrical designs?[4]
8. What knowledge gaps exist for high-temperature failure modes in energy-intensive or energy production applications that provide an opportunity for new materials to significantly reduce energy requirements in those applications? What are the harsh service conditions (e.g., temperature range)? How much energy can be saved?
9. What accelerated creep-fatigue testing advancements, stakeholder buy-in, and validation is required to generate commercial confidence for bringing a new material to market?
10. What manufacturing design improvements are needed to de-risk joining challenges of dissimilar materials (e.g., metals to ceramics)?
11. What are suggested ways to investigate multi-stage fabrication, supply chain logistics, manufacturing

constraints, and quality assurance/quality control protocols for new materials development and scale-up?

Category 3: High Mechanical Wear/Stress

AMO and AES are seeking information on paths to reduce friction and wear losses in transportation, mining, and oil & gas drilling equipment, as well as in other energy-intensive and high mechanical load applications, such as those found in the agriculture, primary metals, pulp and paper, chemicals/refining and food processing industries. These may involve dynamic friction coefficients > 0.01, and/or nominal contact pressures > 2 GPa. Additionally, information is sought on materials and manufacturing of sensors and other components suitable for sustained and reliable operation under conditions of high static and dynamic pressure (> 240 MPa), for example, in mineral extraction, well drilling, hot or cold isostatic processing, or other heavy-duty industrial processes.

Questions:

12. What are the best approaches for discovering new bulk materials and surfaces with improved strength, stiffness, and corrosion resistance (e.g., bulk metallic glasses as bearing and shaft materials) for operation under high dynamic friction or in states of high mechanical stress?
13. Can more rapid (with process times measured in minutes rather than hours) and more cost-efficient surface treatments, as well as high-performance surface/tribological coating methods, be developed?
14. What knowledge gaps exist for specific mechanical failure modes relevant to energy intensive or energy-production applications that provide an opportunity for new materials to significantly reduce energy requirements in those applications? What are the harsh service conditions? How much can energy be saved?

Category 4: Alloy Embrittlement

Alloy embrittlement can occur during material processing/manufacturing or exposure to certain harsh service conditions. Alloy embrittlement is most directly associated with a loss of a material's ability to absorb strain energy. An alloy's susceptibility to embrittlement in a service environment can overly constrain design, decrease service life, and result in increased maintenance/inspection requirements. An alloy's susceptibility to embrittlement during processing/manufacturing can result in additional steps or controls, often resulting in higher embodied energy. Therefore, AMO and AES are seeking information on the extent to which alloy embrittlement impacts material production, energy intensive industries, and energy production.[5] Topics of interest include:

Questions:

15. What are the most challenging service environments for alloy embrittlement (e.g., hydrogen, neutron, cryogenic, service fluids) and loading conditions? How do these service conditions impact material selection, operational costs, and/or system reliability?
16. What are the most challenging or energy intensive materials processing steps (e.g., degassing, hydrogen baking, etc.)?
17. What mitigation methods (e.g., barrier coatings, engineered residual stress, inspection, prediction/failure analysis) are currently being employed and what are the limitations?
18. What knowledge gaps exist for specific embrittlement conditions (e.g., cryogenic (20 K) hydrogen

environments) and/or embrittlement mechanisms relevant to energy intensive or energy-production applications?

19. What are the challenges associated with facilities and equipment necessary to address alloy embrittlement topics?

Category 5: Characterization of Other Harsh Environment Applications
In addition to the specific input requested under the foregoing categories, AMO and AES are also seeking information on other specific materials challenges not already covered, which are related to harsh service environments within the industrial sector.

Question:

20. What other specific harsh service applications in manufacturing or other settings provide an opportunity for new materials to lead to step changes in energy requirements? What are the harsh service conditions? How can energy be saved?

Request for Information Response Guidelines

Responses to this RFI must be submitted electronically to HarshMaterialsRFI@ee.doe.gov no later than 5:00pm (ET) on September 21, 2020. Responses must be provided as attachments to an email. It is recommended that attachments with file sizes exceeding 25MB be compressed (i.e., zipped) to ensure message delivery. Responses must be provided as a Microsoft Word (.docx) attachment to the email, and no more than 10 pages in length, 12 point font, 1 inch margins. Only electronic responses will be accepted. Please identify your answers by responding to a specific question or topic if applicable. Respondents may answer as many or as few questions as they wish.

Neither AMO nor AES will respond to individual submissions or publish publicly a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

Respondents are requested to provide the following information at the start of their response to this RFI:
• Company / institution name;
• Company / institution contact;
• Contact's address, phone number, and e-mail address.

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[1] Holmberg K, Andersson P, Erdemir A. "Global energy consumption due to friction in passenger cars." *Tribology International* 47: 221–234 (2012).
[2] Holmberg, K.; Erdemir, A. (2017) Influence of tribology on global energy consumption, costs and emissions. *Friction 5(3):* 263–284 (2017). https://doi.org/10.1007/s40544-017-0183-5.
[3] QTR 2015 Materials for Harsh Service Conditions: Technology Assessment. http://energy.gov/sites/prod/files/2015/02/f19/QTR%20Ch8%20-%20Materials%20for%20Harsh%20Service%20Conditions%20TA%20Feb-13-2015.pdf.
[4] National Academies of Sciences, Engineering, and Medicine 2020. *Advanced Technologies for Gas Turbines*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25630.

[5] The DOE's H-Mat consortium is currently exploring the compatibility of metallic and polymeric materials with hydrogen service in collaboration with industry and university partners. Please see https://www.energy.gov/eere/fuelcells/h-mat-hydrogen-materials-consortium.