REQUEST FOR INFORMATION
No. I2022008633TJ

Laser Directed Energy Deposition Platform for Graded and Tailored Refractory Alloys and Composites

(Updated: November 29, 2021)

I. SCHEDULE OF EVENTS

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Issue Date .... April 27th, 2022

Due Date and Time .... May 20th, 2022 (04:00 pm, PT)

II. ISSUING OFFICE AND CONTACT

ISSUING OFFICE:

The Procurement, Contracts and Materials Management (PCMM) department of Oregon State University (OSU) is the issuing office and is the sole point of contact for this Request for Information. All concerns or questions pertaining to this Request for Information should be appropriately addressed to the individual identified below:

CONTACT PERSON:

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III. INTRODUCTION

INTRODUCTION:

This is a Request for Information (RFI), issued by Oregon State University (OSU) Procurement, Contracts and Material Management (PCMM) on behalf of College of Engineering, School of Mechanical, Industrial and Manufacturing Engineering. The purpose of this RFI is to solicit information from potential suppliers who have experience with and can provide metal additive manufacturing platforms for high temperature refractory alloys for graded alloys and tailored composites.

BACKGROUND:
High temperature alloys in extreme environments from hypersonics to propulsion towards fusion energy is a primary OSU research continuum for new materials. The processing platform needs to provide multi-independent powder and if feasible, multi-independent wire feeds for managing real-time alloying, melt-pool mixing, oxygen content, cooling rate, and advanced process control including composition correlation. Capabilities such as multiple melt lasers, thermal control lasers, material matched lasers (e.g. green for Cu), net shape femtosecond laser ablation, high

temperature heated build plates (e.g. up to 1000 deg C for W), less than 10ppm oxygen and nitrogen content control, open architecture sensor capability, a preferred 300mm x 300mm x 600mm Phase 1 build envelope, and related capabilities to enable rapid research learning cycles. Among the challenges are practical limitations of a Phase 1 system being too large with commensurate long chamber environmental stabilization time, power requirements, and overall experiment cost. OSU is seeking to understand the appropriate advanced research platform that can be scaled over time towards Phase 2 commercial requirements of size, speed, cost and qualification.

OREGON STATE UNIVERSITY:

Founded in 1868, Oregon State University is a comprehensive, research-extensive, public university located in Corvallis. Oregon State is one of only two American universities to hold the Land Grant, Sea Grant, Space Grant and Sun Grant designations. Oregon State is also the only Oregon institution to have earned the Carnegie Foundation classifications for Highest Research Activity and Community Engagement, a recognition of the depth and quality of its graduate education and research programs.

Through its centers, institutes, Extension offices and Experiment Stations, Oregon State has a presence in all of Oregon's 36 counties, including its main campus in Corvallis, the Hatfield Marine Sciences Center in Newport and OSU-Cascades Campus in Bend. Oregon State offers undergraduate, master's and doctoral degrees through 11 academic colleges enrolling more than 31,000 students from every county in Oregon, every state in the country and more than 110 nations.

IV. REQUIREMENTS

The OSU Advanced Technology and Manufacturing Institute is seeking to develop a laser directed energy deposition (LDED) machine tool capable of supporting the development of graded and tailored refractory alloys and composites (GTRAC) for hypersonic, aerospace and nuclear applications. This will happen in two phases. In the first phase, a research tool will be needed capable of supporting the identification and mitigation of various process defect modes discovered through the course of preliminary materials development. In the second phase, a machine tool with integrated process control will be needed to scale in size and production quantity, with the design based upon findings from the first research phase. This RFI seeks information regarding capabilities that can facilitate the first phase research tool.

Refractory alloys and composites processed by additive manufacturing are generally prone to oxygen pick-up, micro cracking, grain boundary weakening via oxide impurities, and significant residual stress owing to high liquidus temperatures, and relatively high ductile-to-brittle-transformation temperatures (DBTT). Thus, the Phase 1 research tool must include capabilities for investigating the mitigation of these and other defect modes that will be discovered in Phase 1 research programs. Examples include pre-heated build plates at least above the DBTT, regulated atmospheres (less than 10 ppm oxygen and nitrogen), pre-heating lasers for localized thermal rate control ahead or behind the deposition laser and femtosecond lasers for reducing melting-induced residual stress. These capabilities will require that the research tool be flexible, enabling the ability to utilize different laser sources and multiple sensor systems for investigating process fidelity.

Beyond this, the research tool must also be capable of supporting the local tailoring of refractory composites and grading between refractory alloys and composites. This tool will need to produce individual components capable of handling plasma oxidation and sputtering, withstanding high temperature structural loads as well as rapidly removing large thermal loads via high thermal conductivity. This set of properties is beyond any single monolithic refractory alloy or composite. To meet these requirements, the LDED research tool must be capable of 1) locally doping weld beads to enable the formation of metal matrix composites; and 2) grading between several different alloys and/or composites during fabrication. The research tool must include multiple, individually addressable powder nozzles to enable the doping and grading of refractory alloys and composites. In addition, it would be desirable that the research tool would also include at least one wire feeder that could operate simultaneously with powder feeders to enable more efficient doping of the weld bead. Powder recyclability for single powder and multi-powder setups is of interest but not essential. Further, the research tool will require the ability to try different sensor systems (e.g., camera, thermocouple, etc.,) for detecting defect "signatures" necessary to control evolving microstructure and properties in phase 2. Particularly, OSU needs to explore what in-operando information (e.g., temperature, melt pool dynamics, melt pool dimension, and temperature gradient) can be extracted from these sensors. Accordingly, the LDED research tool must provide access interface for IR cameras, thermocouples, and spectroscopy (optical fiber) probes to monitor the melt pool during printing.

We are interested in examples from suppliers who have assisted public or private groups with similar aspirations, especially suppliers who have developed (or currently are developing) solutions with any of the capabilities listed above. Below is a list of technical areas of interest for the supplier to consider. OSU does not expect a detailed point by point response. Rather, OSU is seeking to understand what capabilities will help OSU explore these topics. This includes non-proprietary information about solutions to accomplish any (but not necessarily all) of the following:

1. Processing of the following base elements and materials
    a. Nb
    b. Mo
    c. W
    d. Long-term interest in grading from refractory materials to ceramics
2. Control over the following aspects of refractory microstructures
    a. Composition including oxygen and nitrogen content
    b. Grain size and texture
    c. Porosity/density
3. Ability to mitigate defects (e.g., thermal cracking of various types, porosity, excessive residual stress)
4. Ability to control the following parameters
    a. Laser wavelength, power and scan speed
    b. Powder/wire feed rates/ratios – ability to mix powders or dope the weld bead
    c. Chamber and shielding gas oxygen and nitrogen content
    d. Temperature of the build plate over the duration of the build cycle
        i. Above the brittle-to-ductile transition temperature (active heating)
        ii. Below the temperature for remelting the material (active cooling)
    e. Evolving temperature of the workpiece
    f. Heating and cooling rates of the material
5. Accessibility for sensors
    a. Watching window(s) in the chamber wall/ceiling to monitor the melt pool

   b. Wiring interfaces allowing routing electrical and optical cables through the chamber

<u>This also includes capability information about any (but not necessarily all) of the following:</u>

1. Lasers
   a. Ability to remove/add lasers, e.g., one for melting and one for thermal control
   b. Femtosecond laser for mitigating residual stress
   c. Green laser for processing of Cu-based alloys for grading with refractory alloys
2. Ability to remove/add sensor systems
3. Mass delivery
   a. Multiple powder deposition nozzles (number of individually addressable nozzles for mixing or doping on-the-fly or alternate process)
   b. Wire deposition
   c. Powder recycling when using a) single powder; and b) multiple powders
   d. Ability to mix powders or dope the weld bead
4. Thermal control
   a. Preheat of powder feedstock in controlled/inert atmosphere
   b. Preheat of wire feedstock in controlled/inert atmosphere
   c. Preheated build plate
   d. Ability to remove heat from workpiece to avoid thermal accumulation and remelting of the material
5. Environmental control (oxygen and nitrogen concentration sensing, forming gas atmospheres)
   a. Build volume including hard vacuum vs. gas purging
   b. Powder and/or wire delivery
6. Other attributes of interest for the research tool
   a. Build volume (minimum of 200 mm in each dimension with inclusion of sensors and heating system)
   b. Degrees of freedom (e.g. 3-axis)
   c. Ability to use kinematic mounts for movement between metrology, machining and post processing heat treatment
7. Other attributes of interest for the phase 2 machine tool
   a. Degrees of freedom (e.g. 5-axis)
   b. Ability to scale in build size (OSU is working on capability roadmaps with clients)
   c. Ability to scale in build rate (OSU is working on capability roadmaps with clients)
   d. Ability to incorporate machining as a hybrid tool

V. SUBMITTALS

Respondents are requested to submit the following:

- Description of responding supplier.
- Narrative and supporting documentation describing the respondent's approach to fulfilling OSU's requirements.
- Marketing material/Spec sheets of goods or services referenced in the narrative.
- A cost estimate for recommended base line equipment and any recommended options/add-ons.
- Examples of similar equipment made by the supplier in use at similar institutions, including specific features implemented.

To be considered, responses to this RFI must be received no later than the due date and time indicated in the Schedule of Events. Responses must be sent to the contact person identified in Section II of this RFI.

Information gathered in this process could potentially be incorporated in an Invitation to Bid (ITB) or Request for Proposal (RFP). Any resulting RFP or ITB will be openly competitive and therefore responses should not be exclusive or restrict competition. This RFI does not obligate OSU to issue an RFP or ITB nor to include information submitted by respondents.

A contract will not be issued directly from this RFI, nor will issuance or acceptance of submittals or subsequent conversations bind OSU into any type of contractual obligation or relationship.