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Materials scientist Daniel Oropeza receives prestigious award to advance high-temperature 3D ceramics

Daniel Oropeza, an assistant professor of materials at UC Santa Barbara, has been selected as the 2024 recipient of the Lawrence Livermore National Laboratory (LLNL) Early Career Faculty Initiative grant. A joint endeavor between LLNL and UC National Laboratories at the UC Office of the President, the initiative seeks to foster long-term academic partnerships and provide UC early-career faculty members with funding and lab support for their research. Oropeza, the second-ever recipient of the award, will receive up to $1 million in funding over five years to pursue innovative research in advanced manufacturing.

“Receiving this award is an incredible honor and helps me establish and fund key research directions,” said Oropeza, who joined the UCSB faculty in July 2023. “It’s also exciting because of the unique opportunity it offers my research group and UCSB to establish close connections with the researchers and access to the expertise and facilities at the Lawrence Livermore National Laboratory.”

“The five-year, $1 million, 2024 Lawrence Livermore National Laboratory Early Career UC Faculty grant is a tremendous achievement for Daniel Oropeza,” said **Umesh Mishra,** dean of the UCSB College of Engineering. “We are extremely proud

of this significant accomplishment, which will allow him to advance his novel work on high-temperature materials and continue his upward trajectory to become a next-generation leader in structural materials, a field in which UCSB has long been internationally renowned for its impactful and collaborative research."

Oropeza's winning proposal, "Near-net shaping of high-density, complex, spatially tailored ceramics for extreme environments," aims to explore the unique challenges posed during the processing of ultra-high-temperature ceramic materials. With the high-temperature stability of these materials being useful for platforms such as nuclear reactors, high-speed flight and renewable energy conversion, Oropeza's research aligns closely with LLNL's mission to enable national and global security. However, the properties of these materials also make it difficult to manufacture the ceramics at moderate costs and in reasonable timeframes.

"The big challenge with high-temperature 3D ceramics is that they are generally brittle, and if you try to form them or alter their shape, they fracture easily," said Oropeza.

In collaboration with LLNL research staff, Oropeza and his team plan to study how *near-net-shape fabrication* and hot pressing can be combined to achieve uniform densities and unique geometries. With near-net-shape fabrication, the initial processing of the item is very close to its final form, limiting the need for such costly finishing methods as machining or grinding. In hot pressing, heat and pressure are combined to turn a collection of individual powder particles into a single, solid component.

"We plan to create a multi-material deposition system," explained Oropeza. "Using this system, we will co-deposit a high-temperature ceramic and a sacrificial material that will encapsulate the material we care about."

Once researchers complete the high-temperature pressure-assisted densification process, they will remove the sacrificial material.

"The idea is that by using this approach, we will be left with high-density and high-temperature ceramics in complex and near-net shapes," said Oropeza. "This approach has never been tried on these materials, so there is a wide array of interesting fundamentals for us to explore, such as how multi-material hot pressing works and how the two materials intermix."

The team aims to create scalable processing models that can elucidate the fundamentals during material manufacturing and predict processing issues. A key element in the project will be designing a mechanized test bed to perform the multi-material hot press in an automated fashion.

“Automation enables repeatability and high-throughput fabrication of samples and complex geometries,” explained Oropeza, who, in the process, plans to leverage his prior experience developing a testbed. “Machine design is an interesting endeavor, so I’m really excited that the students will receive hands-on experience with that and that Livermore is a part of it, because they have a very strong history of developing custom equipment for new processes.”

After developing small-scale hot-pressing models and testing them in his research lab, Oropeza will try to scale up his new model by validating it at LLNL, modifying it if needed.

“Daniel Oropeza’s research on high-density ceramics pushes the frontiers of materials science and is an exemplar of the cutting-edge science and technology we require for our national security mission,” said Michael Zika, LLNL principal associate deputy director for Strategic Deterrence. “I look forward to seeing the excellent work and long-term relationships that will come from our sustained partnership with Oropeza and his research group.”

“Professor Oropeza’s recognition through the LLNL Early Career UC Faculty Initiative is a testament to his innovative research, and shows that his work on advanced ceramics is at the forefront of materials science,” said **Omar Saleh,** chair of UCSB’s Materials Department. “The partnership with Lawrence Livermore will provide a tremendous opportunity for him to expand the scope of his research.”

The award will partially fund a postdoctoral researcher and fully support a graduate student in Oropeza’s lab. The graduate student will also spend four weeks every year performing collaborative research at LLNL every year.

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