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BioPACIFIC MIP unites two UC campuses to advance a new model for materials research

Professor Craig Hawker holds up an over-the-counter antioxidant pill. It contains alpha-lipoic acid, which is naturally found in the body and plays a role in human metabolism.

Today, Hawker is talking about a very different use for the compound. UC researchers are repurposing it as a monomer, or chemical building block, to make entirely new molecules. The big idea is to create environmentally friendly, biologically based polymers to replace — and improve upon — today's petroleum-derived plastics.

Indeed, no one would hurry to swallow plastic. Yet [Hawker](#), co-director of the California NanoSystems Institute at UC Santa Barbara, can take the alpha-lipoic acid and then smile.

"I've just taken a monomer, which is perfectly safe," he said. "Our vision is to develop currently unknown derivatives of this that will have different, helpful properties."

This is one of many avenues of exploration underway at the BioPolymers, Automated Cellular Infrastructure, Flow, and Integrated Chemistry Materials Innovation Platform

(or [BioPACIFIC MIP](#), for short). The project was launched with backing from the National Science Foundation (NSF) in 2020 by a team of scientists and engineers from the California NanoSystems Institute nodes at UCSB and UCLA.

Kicking off a virtuous cycle of scientific creativity

Beyond the future-forward goal of supplanting forever-plastics, the UC researchers also play a role in spearheading an emerging template for science and engineering. BioPACIFIC MIP is one of only four NSF Materials Innovation Platforms (MIPs), started up with the second round of awards.

MIPs tackle important questions or problems in materials science and engineering by connecting theorists and experts from across the U.S. in devising and understanding substances with new properties. The collaborations embody a looping work process summarized as “design, build, test, learn” and back again. Those teams build state-of-the-art facilities that do triple duty: In addition to enabling their research, the infrastructure is available to outside users in academia and industry while — importantly — serving as home base for the training and mentoring of students and early-career investigators in advanced research methods.

A little past midway through the five-year NSF grant, the initiative is paying dividends for research and education at UC Santa Barbara, UCLA and beyond.

“We were looking at how to modernize the way we tackle big problems,” said [Javier Read de Alaniz](#), director of BioPACIFIC MIP and associate director of the CNSI at UC Santa Barbara. “The answer was to modernize the tools, and that led us to tap into the Materials Innovation Platform model. A few years in, we’re seeing this infrastructure impact not only in-house BioPACIFIC MIP research but also researchers across the country.”

The challenge of doing something new

Breaking a new path with BioPACIFIC MIP was a substantial undertaking, particularly doing so during a pandemic that sent labs into temporary hibernation and wreaked havoc on global supply chains.

The initiative's leaders agree that the first pivotal task was finding the right people to build and shepherd new facilities. A key attractor was BioPACIFIC MIP's startup-like atmosphere, where staff can count on variety in their work and the opportunity to help guide the direction of the entire endeavor. A national search led to the recruitment of expert project scientists who oversee a collection of instruments they assembled and customized with an eye toward the latest advances in automation.

"The equipment we have enables science that's not possible elsewhere," Heather Maynard, co-director of BioPACIFIC MIP, and associate director of technology and development at the CNSI at UCLA. "It creates the opportunity to start new, cutting-edge research programs, and it's open to users across the country."

The path to assembling that cache of instruments and bringing it online was beset by some pandemic-borne delays. Installations depending upon a strict sequence of steps were hit with postponements when those steps popped out of order. Waits for repairs to malfunctioning technology stretched from weeks to multiple months.

Through it all, the BioPACIFIC MIP team held up with patience and perseverance. "Everybody had a roll-up-your-sleeves mentality," said Adam Stieg, UCLA site executive director for BioPACIFIC MIP and CNSI at UCLA's associate director of technology centers. "There were myriad challenges to overcome. It was just blood, sweat and tears that got us through it to a certain degree."

At the same time, inaugurating a national hub based on a fresh model offered the team leeway to set its own course. The federal grantors' support extended beyond just the financial.

"The NSF gave us a huge amount of leeway about how we decided to tackle this," said [Tal Margalith](#), BioPACIFIC MIP's executive director and executive director of scientific initiatives and innovation for CNSI at UC Santa Barbara. "We can be much more nimble than traditional centers with infrastructure and ways of working that have existed for decades. We can identify a gap and put resources behind filling it."

The connections between the sister CNSIs, based at UC campuses less than 100 miles apart, eased the process of growing a Materials Innovation Platform from the ground up. Organizational efficiencies proved a sort of tailwind, but BioPACIFIC MIP leaders identify a shared culture of collaboration as the driving force.

“Things go that much smoother, and quicker, because everyone’s ready to say yes to trying something different,” said Hawker, the Alan and Ruth Heeger Chair in Interdisciplinary Science. “It feels as though it’s part of the CNSI framework, a subtle expectation that everyone will show up and do the heavy lifting when it’s needed.”

Speed means more than just speed

At BioPACIFIC MIP, key instrumentation turbocharges the process of producing and analyzing chemical building blocks and never-before-seen materials. This happens through chemical reactions at the Chemical Synthesis Facility at UCSB; with engineered yeast and bacteria in UCLA’s Living Biofoundry; and via 3D printing and other fabrication techniques at UCSB’s Additive Manufacturing Facility. High-throughput instruments on both campuses enable hundreds of samples to be rapidly profiled based on disparate characteristics of the materials that make them up.

The robotic automation tools available in BioPACIFIC MIP facilities can rapidly acquire high-resolution measurements and perform intricately precise tasks that are infeasible from human hands. The advantage goes beyond doing things faster.

“It’s not just about accelerating your research,” said Read de Alaniz, UCSB professor of chemistry and biochemistry. “It’s doing something different, that you weren’t able to do before. All of a sudden, you can start to ask new questions in your research.”

Access to these high-tech facilities comes packaged with assistance from the staff experts who put them together, another reason why the people factor is primary at BioPACIFIC MIP.

On the one hand, users can capture rich data and try out new molecular configurations even if they’re not well-practiced with the equipment. On the other hand, they gain collaborators who can introduce them to capabilities they were previously unaware of, and the possibilities that come with them.

“It’s not just the equipment; it’s the people,” Stieg said. “They’re active participants in research and they’re excited for the opportunity to develop and deploy new technologies. Finding the right people during the pandemic was very challenging, but we have assembled an extraordinary team.”

BioPACIFIC MIP's combination of leading-edge instrumentation and expertise is also a boon for the project's educational mission. Students and postdoctoral researchers work with techniques and technologies that are becoming commonplace in industrial settings but hard to find at other universities.

Leaders note that BioPACIFIC MIP's workforce development focus is central. "There is a gap between how we currently train students in the sciences and what most of them go on to do in industry," Hawker said. "BioPACIFIC MIP brings us up to date by giving trainees experience working in multidisciplinary teams, and showing them how to accelerate and automate workflows. It's one way of fulfilling our responsibility to prepare the next generation for the realities of the careers they'll be pursuing."

Dreaming up the fantastic plastics of tomorrow

BioPACIFIC MIP's students and trainees work together with faculty and staff to lay the groundwork for a future where society escapes the catch-22 of synthetic polymers: We're accruing an abundance of garbage because objects made from them stick around for decades and longer after their useful life has expired. Meanwhile, the supply of raw material, petroleum, is not bottomless.

The researchers are using biobased building blocks, such as the incredible edible monomer that is alpha-lipoic acid, to construct molecular backbones for new types of plastic that break down on a scale of months rather than many decades. Set against the evidence piling up about deleterious health effects of certain widespread synthetic plastics, their work could also make consumer products safer.

"When we're working with something ingestible, we know it breaks down into a substance that's proven to be safe," Read de Alaniz said. "We no longer have to worry about that monomer breaking down into a more toxic version of the plastic. It changes the types of materials we can think about designing."

To that end, the BioPACIFIC MIP team is investigating ways to imbue the bioplastics with useful characteristics: What if the material was antimicrobial? Or capable of breaking down on command?

The initiative's leaders plan to feed the wealth of data their experiments produce into machine-learning algorithms to uncover previously obscured relationships between structure and function. Ultimately, this could flip materials design on its head, replacing trial and error with an intentional approach that starts with desired characteristics.

"This is what the research community needs and the NSF supports, to be freed from relying solely on our training and our intuition," Stieg said. "We want to be able to harness the power of large datasets to inform us. Hopefully, we'll be able to realize entirely new design rules that unlock a world of possibility for materials discovery."

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About UC Santa Barbara

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.