Insects offer new ideas on materials use, structure strength via 4D time-lapse imaging

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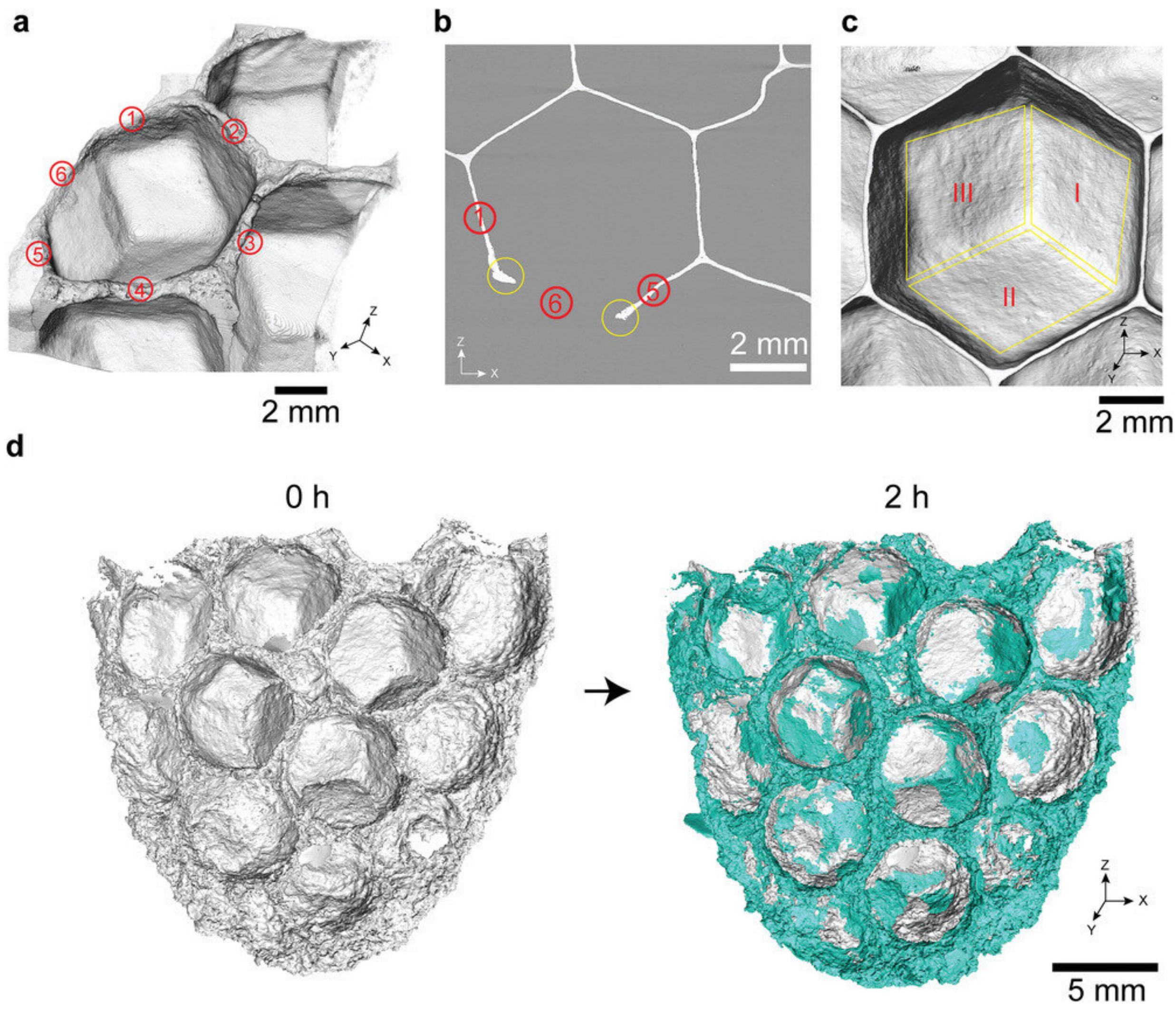


Description of a nascent cell and time-resolved rendering showing the locations where new material is added. a) Six constituent edges of a nascent cell at the growth front. Also seen are the partially formed walls at positions 1 and 5 showing a gradual decrease in wall depth as they approach position 6. b) 2D slice showing a partially constructed hexagonal cell where only five of the six walls are constructed. c) A cropped comb cell with three rhombic rear panels indicated by I, II, and III. d) 4D timelapse cartoon showing the locations where the bees add new material. Credit: *Advanced Materials* (2022). DOI: 10.1002/adma.202202361

Purdue University engineers and entomologists are making some sweet discoveries about how honeybees build and structure their honeycombs, which could lead to new fabrication techniques taken from the buzzing builders.

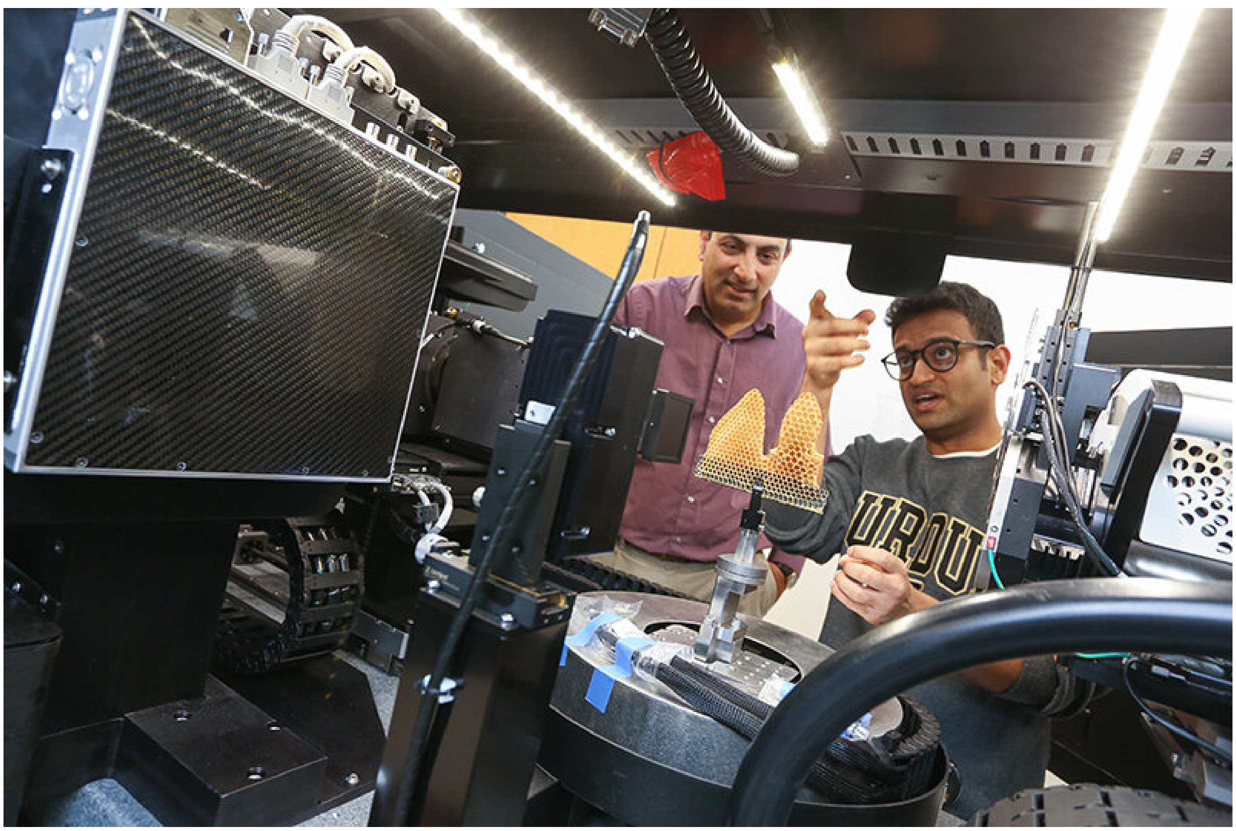
Nikhilesh Chawla, the Ransburg Professor of Materials Engineering at Purdue, is one of the first to utilize four-dimensional (4D) imaging to delve further into the complexities of the honeycomb. The imaging allows a time-lapse view of the bees' work without cutting into their home.

The innovative view of the bees' construction found techniques that could eventually translate into new concepts for structural materials or additive manufacturing for the construction industry. Chawla said some of the junctions between the honeycomb cells were created using less material, with the resulting porous connections resembling Swiss cheese.

"It's a lesson in materials utilization that could lend itself to new ideas and practices in structures," Chawla said. "Their honeycombs are still perfectly fine. From that perspective, humans may not actually need as much material in some areas that are not quite as important from a structural point of view."

Honeycombs are the self-built, multifunctional homes for honeybees, providing a place to store food and serving as a nursery for eggs and larvae in addition to shelter. Made from wax produced by the bees, the hexagonal cells are easily recognized.

Chawla's work shows how humans can draw important lessons from the plant and animal world in a discipline called biomimicry, which investigates naturally occurring materials and behaviors and draws inspiration to design new products, systems and buildings. Chawla said there are aspects of honeycombs already used in several applications, from construction and structural materials to shoes.



Nikhilesh Chawla, the Ransburg Professor of Materials Engineering at Purdue University, and Rahul Franklin, a graduate research assistant in materials engineering, prepare to examine a honeybee comb sample with a 3D X-ray microscope at the Flex Lab in Discovery Park. Examining the combs has uncovered new techniques used by the bees that could translate into new building concepts. Credit: Purdue University photo/Dave Mason

The Purdue research team is made up of Chawla; Brock Harpur, assistant professor of entomology in the College of Agriculture; and Rahul Franklin, a graduate research assistant in materials engineering. Their work was published in the journal *Advanced Materials*.

Chawla said people don't truly understand how bees make the honeycombs. For example, most theorize the honeycomb chambers start as cylinders and then are molded by the bees into the well-known hexagonal shape.

But a sophisticated three-dimensional (3D) X-ray microscopy technique combined with a time lapse provided an unprecedented means of studying and quantifying the honeycomb's microstructure.

The resulting 4D imaging showed chambers are built with panels. Research also found bees go to great lengths to strengthen the honeycomb structure by first creating a vertical spine for support and then building the hexagon cells out horizontally.

"Over time, they continue to make the spine thicker because they understand there is more weight from the wax on it, and they need that backbone to be strong and rigid before they can add more and more of these cells growing outwardly," Chawla said.

Chawla's overall research focuses on four-dimensional materials science. The approach—called tomography—uses nondestructive X-rays to add time as a fourth dimension to 3D measurements and analyses. The 4D approach is important in examining structural evolution, including deformation and corrosion that take place over time.

Learning from honeybees is just the first step in the Purdue team's biomimicry research. Successfully applying those lessons with tools like 3D printing is next. Chawla said there are plans to build honeycombs of different sizes and even different shapes and evaluate their durability with compression tests.

In addition to honeybees, Chawla's biomimicry research involves looking at the porous cellular structure of cacti and how fluids are moved up and down throughout the plant.

"It's just a lot of fun to work with these kinds of natural materials because you just never know what you're going to find," he said.

The work is published in the journal *Advanced Materials*.

More information: Rahul Franklin et al, Unraveling the Mechanisms of the Apis mellifera Honeycomb Construction by 4D X-ray Microscopy, *Advanced Materials* (2022). DOI: 10.1002/adma.202202361

Provided by Purdue University

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