Defects in liquid crystals offer new approaches to molecular design of materials

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For the first time ever, researchers have found that defects present in liquid crystals can be used as templates to assemble molecules into precisely defined 3-D nanoscale structures.

"It's a demonstration of principle," says Nicholas Abbott, the John T. and Magdalen L. Sobota Professor and Hilldale Professor of chemical and biological engineering at the University of Wisconsin-Madison. "What one can imagine is using defects in liquid crystals to assemble molecules into a range of useful structures, including channels that could facilitate the transport of other molecules, like nanoscopic tubes. By controlling the geometry of the system, we can send these channels from any one point, to any other point. Assemblies of many other shapes can also be made. It's quite a versatile approach. "

Abbott and his collaborators in the Materials Research Science and Engineering Center (MRSEC) at UW-Madison published details of their advance in the Sept. 21, 2015, edition of the journal *Nature Materials*.

Abbott, who researches interfacial and colloidal phenomena in a range of soft material systems, has been working with liquid crystals for about 20 years. "We've done a lot of work in the past at the interfaces of liquid crystals, but now we're now looking inside the liquid crystal," he says. "We're looking at how to use the internal structure of liquid crystals to direct the organization of molecules. There's no prior example of using a defect in a liquid crystal to template molecular organization."

Defects typically are imperfections within a material. However, the defects Abbott and his group are working with are formed by the geometry of the system, rather than by incorporating an impurity, he says.

When researchers manipulate the geometry of a liquid crystalline system, a variety of different defects can result. The defects Abbott's group worked with were shaped like ropes or lines they call "disclinations," formed when he and his collaborators introduced local changes into the topology of the liquid crystalline system.

In this case, they introduced amphiphilic (water- and fat-loving) molecules into the system and assembled those molecules inside the defects. They found that the geometry of the defect formed a three-dimensional nanoscale template for this assembly.

By crosslinking (adding a chemical group that can form a covalent bond) the assembly of molecules, they found they could remove the defect-based template—yet the assembly of molecules maintained the shape of the template on their own, thus forming a permanent structure. "The whole point is to use defects to direct molecules to assemble into structures of a desired geometry," he says.

The ability to use defects as a kind of molecular design tool is revolutionary, and introduces myriad possibilities for future research in a variety of fields.

So far, Abbott and his collaborators have been able to assemble lipids within defects. However, he also anticipates the possibility of assembling precursors of inorganic materials—such as metallic wires and various semiconducting structures—as well. There's also potential for mimicking selective transport through a membrane, designing a defect so that one type of molecule can move along it, and another can't.

"This is an enabling discovery," Abbott says. "We're not looking for a specific application, but we're showing a versatile method of fabrication that can lead to structures you can't make any other way."

The research is a beautiful example of how impactful liquid crystal research outcomes are in taking us from the nano-to-macro world, says Dan Finotello, program director at the National Science Foundation, which funds the MRSEC. "It is also an exquisite demonstration of MRSEC programs' high impact," he says. "MRSECs bring together several researchers of varied experience and complementary expertise who are then able to advance science at a considerably faster rate."

More information: Topological defects in liquid crystals as templates for molecular self-assembly, DOI: 10.1038/nmat4421

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