Light up logic: Engineers perform computational logic with light

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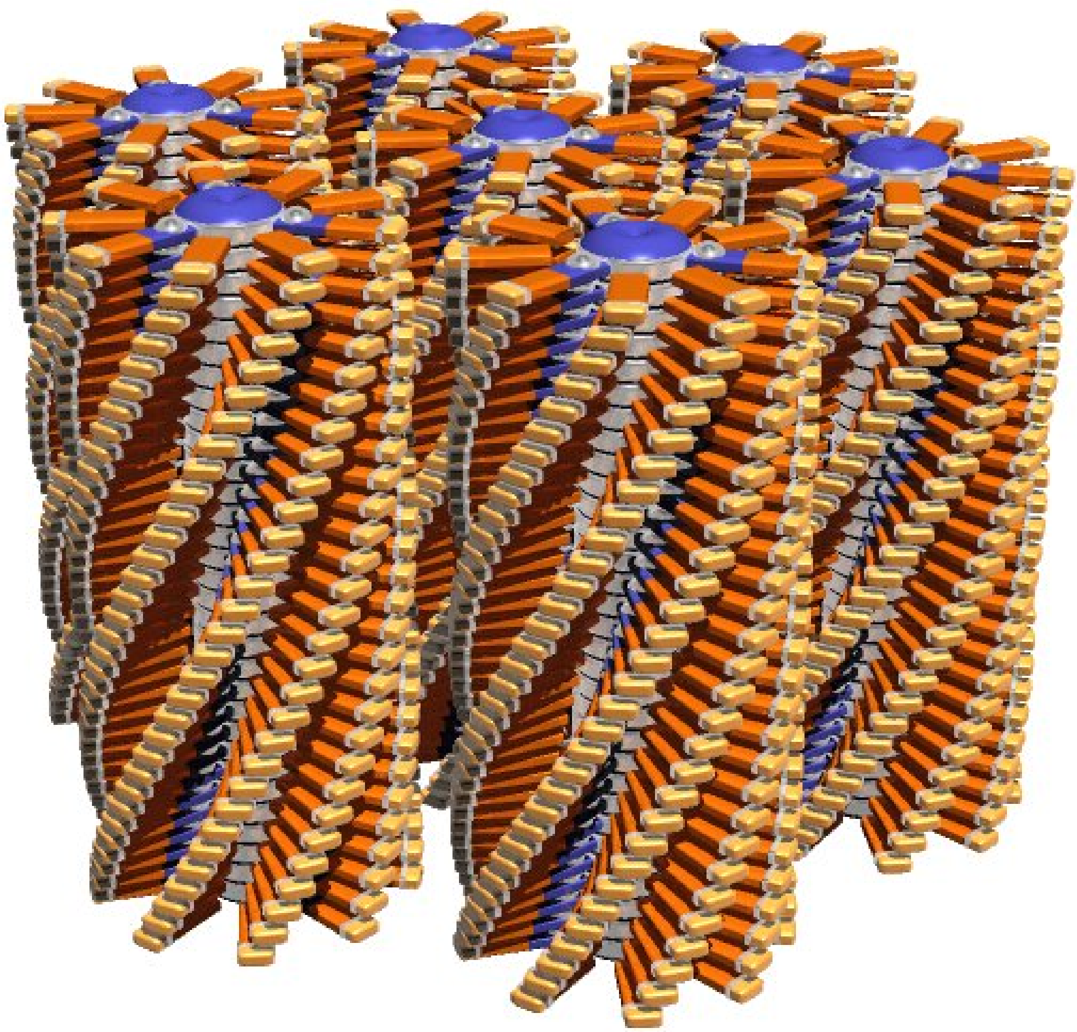


Columnar liquid crystals are similar in size to current semiconductor transistors. Credit: (c)2019 Aida Group

For the first time, researchers have performed logic operations with a chemical device using electric fields and ultraviolet light. The device and the pioneering methods open up research possibilities, including low-power, high-performance computer chips.

Semiconductor chips comprise minuscule electronic transistors on beds of silicon. Such devices cannot be made much smaller because quantum effects will begin to predominate. For this reason, engineers are seeking new techniques and materials to perform logic and memory functions.

Doctoral student Keiichi Yano, lecturer Yoshimitsu Itoh and Professor Takuzo Aida from the Department of Chemistry and Biotechnology at the University of Tokyo have developed a device with functions useful to computation. Conventional computers use electrical charge to represent binary digits (ones and zeroes), but the new device uses electric fields and UV light. These allow for lower power operation and create less heat than conventional chips.

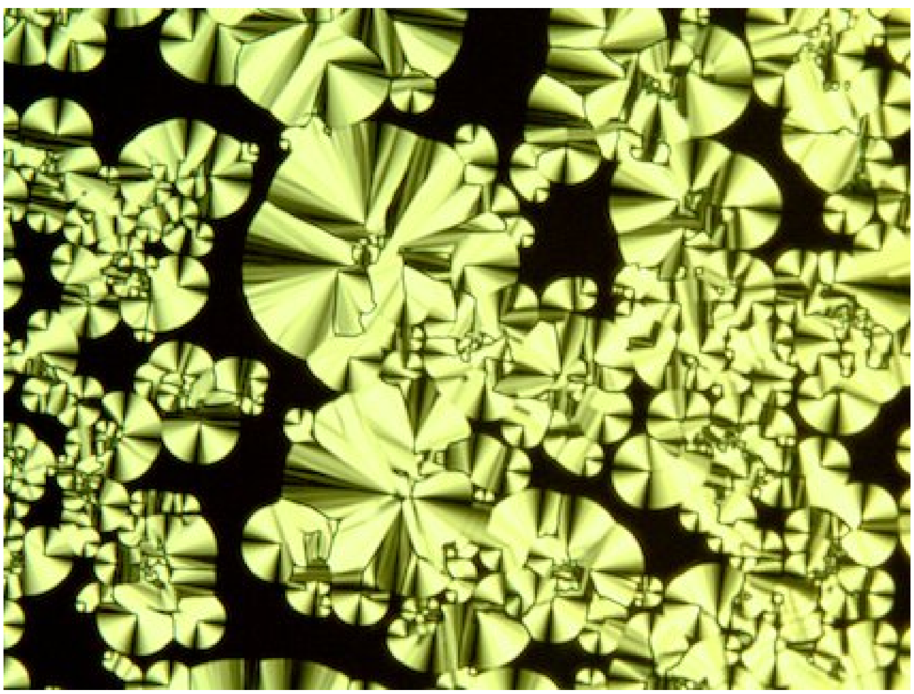
The device is also vastly different from current semiconductor chips, as it is chemical in nature. This property gives rise to its potential usefulness in the future of computation. It's not just the power and heat benefit; this device could also be manufactured cheaply and easily. The device features disk and rod-shaped molecules that self-assemble into spiral staircase-like shapes called columnar liquid crystals (CLC) in the right conditions.

"One thing I love about creating a device using chemistry is that it's less about 'building' something; instead, it's more akin to 'growing' something," says Itoh. "With delicate precision, we coax our compounds into forming different shapes with different functions. Think of it as programming with chemistry."

Before a logic operation begins, the researchers sandwich a sample of

CLCs between two glass plates covered in electrodes. Light that is polarized—vibrating in a single plane—passes through the sample to a detector on the other side.

In the sample's default state, the CLCs exist in a randomly oriented state that allows the light to reach the detector. When either the electric field or UV light is individually switched on then off, the detected output remains the same. But when the electric field and UV light are switched on together and then off again after about a second, the CLCs line up in a way that blocks the detector from the light.



The sample of CLCs changes its state in a second but can last for hours. Credit: (c)2019 Aida Group

If the output states of light and dark and the input states of the electric field and UV light are all assigned binary digits to identify them, then the process has effectively performed what is called a logical AND function—all inputs to the function must be "one" for the output to be "one."

"The AND function is one of several fundamental logic functions, but the most important one for computation is the NOT-AND or NAND function. This is one of several areas for further research," explains Yano. "We also wish to increase the speed and density of the CLCs to make them more practical for use. I'm fascinated by how self-assembling molecules like those we use to make the CLCs give rise to phenomena such as logical functions."

More information: Keiichi Yano et al, Nematic-to-columnar mesophase transition by in situ supramolecular polymerization, *Science* (2019). DOI: 10.1126/science.aan1019

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