| Tailor-made crystals |

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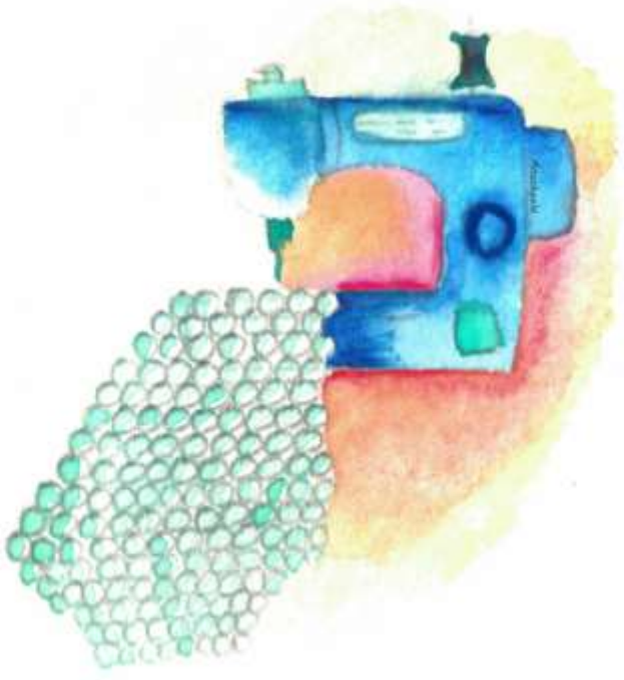
If physicists were asked to come up with a list of things they are completely smitten by, there is an enormous chance that colloids shall feature in that list. Now, what is a colloid? A colloid is a particle whose diameter ranges in the scale of 1 nanometer to one micrometer. The fascinating thing about these particles is that when dispersed in a medium, it cannot be dialysed through a membrane.

You encounter colloids way more often than you think. The glass of milk which you gulped down in the morning is a colloid and with the onset of winter, early commuters to work will be familiar with the morning fog, which also happens to be a colloid!

Colloids find use in studying the properties of a particular object, say for example a cube. As children, most of us have played with Lego blocks. Consider each colloidal particle to be like a Lego block, piecing together to constitute your desired object. These particles have been used to construct solids before. Several groups such as Alfons van Blaadern (Utrecht University), Clemens Bechinger (University of Gothenburg) and Roel P. A. Dullens (Oxford University) have perfected the art of arranging colloidal particles into desired crystal structures. The conventional way in which this was done was with the help of light traps. Light, when shone on a colloidal particle, exerts a certain amount of force on it which keeps it in a specific point, say X.

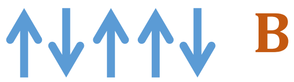


Similarly, colloidal particles can be trapped in various such points which when connected would result in your target crystal structure. The bonds between these 'lego pieces' is strengthened with the help of introduction of certain attractants like complementary DNA sequences. These sequences or patches of complimentary sequences would join each other, thus, cementing the colloidal particles. The word 'cementing' is important because while it makes sure you have a crystal structure of your choice, it becomes a drawback. And how is that exactly?

Though static laser traps confine the colloidal particles to the blue print of your target crystal structure, it does little in terms of retaining the elastic properties of the original crystal. If you want to study a particular object, it is necessary that the fundamental properties of that structure are retained when you are constructing the solid. The method described earlier restricts the newly manufactured crystal from exhibiting elastic forces and when it is displaced from one point in space to another, energy is consumed. Imagine using Velcro to patch up particles to construct the solid of your choice. The Velcro holds the particles in place, giving you a fixed structure. As a result, you have a crystal which looks exactly as what you desired but does not behave the way you thought it would!

To combat this problem, researchers in TIFR Hyderabad have come up with an innovative approach of constructing crystals by trapping these colloidal particles in dynamic laser traps. Though these traps confine the colloidal particles in certain ways, they do not restrict their elastic properties. As a result, particle A, B and C can move in freely but are stationary with respect to each other. What you get is a tailor-made crystal which looks exactly the way you desired and behaves like the original!

This was made possible by a number of clever computer simulations which would allow affine transitions and filter out the non-affine transitions, acting a lot like a sieve. Before your mind goes into this spiral wondering what the jargon in the previous statement exactly intended to convey, let us try to understand the terms 'affine transformation' and 'non-affine transformation'. Imagine the movement of a rectangle in a space. After the movement, if the opposite sides of the rectangle remain parallel, it is an 'affine transformation'. If they cease to be parallel after the movement, they are 'non-affine transformations'. The basic idea of the approach adopted by the researchers can be explained with the help of a simple analogy. Consider a group of individual compass needles (each compass is one arrow), with respective specific spins (the spins are denoted by the direction of the arrowheads).



Now imagine an external magnetic field being applied (denoted by B). This external magnetic field will orient the arrows in the direction of the exerted force, while suppressing the ones which are not oriented otherwise. The logic behind the equations used to suppress the non-affine transformations is similar.

This equation was established during a previous study conducted by Saswati Ganguly, who obtained her doctoral degree under the guidance of Prof. Surajit Sengupta. Saswati says, "We wanted a conceptually simple way to stabilize colloidal solids with desired structure, while retaining their fundamental physical properties." Her work laid a strong basis for future studies undertaken in the group. Pankaj Popli, the first author of this work and a graduate student in Prof. Sengupta's group believes that a similar strategy can be used to stabilise complex patterns in robotic flocks swimming in water or flying through air.

Reference: Pankaj Popli, Saswati Ganguly, and Surajit Sengupta. "Translationally invariant colloidal crystal templates." Soft matter 14.1 (2018): 104-111.