Drawing their inspiration from nature, researchers develop a brand new type of anti-reflective plastic

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Credit: AI-generated image (disclaimer)

Nature has long been a source of inspiration for both scientists and artists alike. Some of the most ingeniously designed products and gadgets familiar to millions of people worldwide owe their origin to seemingly simple forms and patterns found in plants and wildlife. The ability to adapt these natural forms to develop ever more innovative products and processes has given rise to the field of biomimetics — literally meaning 'imitation of life'.

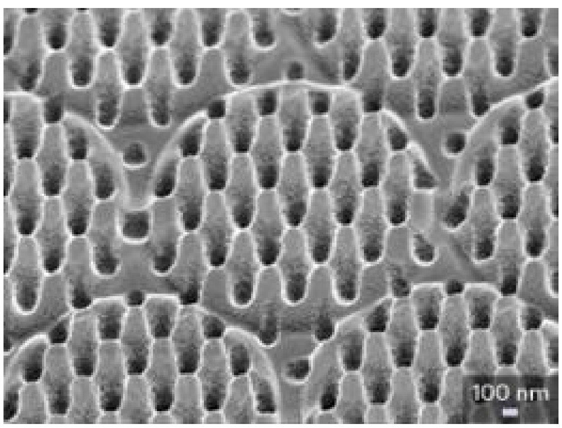
One of the most notable examples of biomimetic design to date is Velcro, famously inspired by the tiny, adhesive hairs found on the underside of geckos' feet. Insects, too, have provided intriguing clues for the development of many new technologies ranging from self-cooling systems inspired by termite mounds to cicada wing-inspired nanosensors. Now, a team of researchers based at the A*STAR Institute of Materials Research and Engineering (IMRE) working in collaboration with industry partners have succeeded in developing a new type of high-quality, anti-reflective plastic inspired by another unlikely source: the eyes of a moth.

The eyes have it

Moths are renowned for their ability to see well in the dark. Moth eyes are coated with a special anti-reflective layer that lends them the unusual distinction of having one of nature’s least reflective surfaces. Composed of a hexagonal array of conical nanostructures, the anti-reflective layer enables moths to maximize light capture and minimize reflection, thereby reducing the chances of being spotted by predators, even in settings that appear pitch-dark to the human eye.

“Our group has been working on bio-inspired surfaces for a number of years,” explains Low Hong Yee, senior scientist and team leader of the project at the IMRE. “The anti-reflection properties found on some insect eyes are rather well-known and it was natural that we looked into the moth-eye structures. Mimicking moth-eye nanostructures have been attempted by others — however, our unique approach is in the combination of micro- and nanostructures in a hierarchical arrangement. These structures are even closer to mimicking the insect eye.”

Using a high-precision method known as nanoimprinting, the IMRE team were able to ‘reconstruct’ the moth-eye nanostructures and utilize direct patterning techniques to reduce surface glare. Nanoimprinting is a technique closely associated with the semiconductor and data storage industries — however, the method is becoming more and more widely used in other domains as a means to fine-tune the physical and optical properties of many different kinds of components, for example, in the optics and biomedical industries.



Scanning electron microscope image showing the engineered anti-reflective nanostructures that mimic structures found on the surface of a moth’s eye. Credit: IMRE

One of the main advantages of nanoimprinting is that materials can be manipulated in terms of their physical as opposed to their chemical properties. New plastics can therefore be developed without the need to use harmful chemicals. Indeed, this type of nanoimprinting is viewed as a way of moving towards cost-effective, environmentally sustainable manufacturing practices.

Anti-reflective plastics currently on the market typically exhibit a reflectivity of around 1% of visible light. In contrast, the new plastic developed at IMRE reflects less than 0.2% of visible light — attaining a five-fold increase in anti-reflective power. The new plastic maintains a reflectivity of less than 0.7% even at angles of up to 45 degrees. Combined with the reduced amount of glare, the new plastic may find a host of applications in the development of new and improved TV displays, windows and organic solar cells.

"We are also developing complementary research that allows the technology to be easily ramped up to an industrial scale," says Low. Several companies are now in the process of licensing the anti-reflective nanostructure technology from Exploit Technologies Pte Ltd, the technology transfer arm of A*STAR.

Partnering with industry

The new plastic is notable for being the first successful outcome of the IMRE-led Industrial Consortium On Nanoimprint (ICON), a multi-agency effort backed by Singapore's leading trade and industry development bodies, including the Economic Development Board, International Enterprise Singapore and SPRING Singapore. By encouraging companies to adopt versatile, industry-ready nanoimprinting technology, ICON is dedicated to building collaborative pre-competitive research and development projects.

By focusing on strengthening academia-industry partnerships, ICON is raising the bar for innovative research in Singapore. "The ultra-low reflection as required by our industrial partner was a challenge for the team," says Low. "We proposed a new design rule that has not been reported by others, both theoretically and experimentally. We had a sound hypothesis and we had earlier developed a unique hierarchical nanoimprint process; these two starting points helped us to focus and develop our designs experimentally."

As a testament to the potential of the technology, many industry experts have also added their voices in extolling the work of the consortium. Wilson Kim Woo Yong, director of global marketing at Young Chang Chemical Co., Ltd., comments, “The outstanding results from this consortium work will benefit our company's expansion into new markets such as in the touch-screen panel and solar business sectors."

Tatsuo Shirahama, president of Innox Co. Ltd., states, “We have been very impressed with the developed technology and with the excellent team of researchers working on the anti-reflective structures.”

“The results from the consortium work are key in the decision making for our future strategic planning,” says Yuji Akatsu from NTT Advanced Technology (NTT-AT).

"This is an exciting innovation — mimicking nature through the nanoimprint technology to solve real-world problems,” comments Andy Hor, IMRE’s executive director. “I am very pleased that the collaboration with industry has helped move this R&D from the laboratory to application in the industry. The development of the new plastic is a testament to the strength of Singapore’s advanced R&D capabilities, the benefits of nanoimprint technology and the confidence that companies place on our technologies.”

With regard to future directions for her research group, Low hints that there may be more nature-inspired innovations in store: “Soon, we will be releasing the results of a second consortium project, which is also a biomimicry project,” she says. “It is a project that will aim to develop anti-microbial plastic, taking clues from marine species.”

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