Nanotexured surfaces could be transformative – If given a chance to flourish

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Professor Parvaneh Mokarian, founder of the technology and SUN-PILOT coordinator from Trinity College Dublin and AMBER centre looks at the possibilities and applications of nanotextured surfaces

Despite the promising functionality of nanotextured surfaces and their potential for a wide range of applications, their use has not been broadly adopted by the industry. In this article, we will discuss the reasons and possible solutions.

Surface structuring is a method whereby structures (typically sub-wavelength) are formed on the surface of the substrate either by etching or by coating. In nature, many hierarchical nanostructures enable unique functionalities.

Examples include antireflective moth eyes, antifogging properties of mosquito eyes, iridescent colours of butterflies, antibacterial cicada wings, self-cleaning lotus leaves, strong surface adhesion of gecko's feet, mechanically robust eggshells, the water collection capability of a Namib desert beetle from the air, and many more.

Biomimicking nanostructured surfaces in research

Over the last decade, there has been a huge interest and progress in the academic community to biomimic these functionalities by developing different methods for fabrication of nanostructured surfaces.

Techniques such as photolithography, nanoimprint lithography, laser interference lithography, rapid thermal annealing, direct etching and others have been used to fabricate nano-scale structures. However, these processes struggle to combine good periodicity, large-area patterning and deep submicron resolution while maintaining scalability and minimising cost-vs-throughput.

Block copolymer (BCP) patterning is an emerging nanopatterning technique which has recently gained interest in the photonics community because it can produce nanoscale features on both curved and flat surfaces with uniformity over large areas without the requirement of stitching. In the optics field, these tiny features are an alternative option to dielectric coatings for optical properties such as antireflection (so you can see the display on your smartphone and laptop without the glare, or have more efficient solar panels), optical filters (e.g., to protect pilots' eyes by blocking damaging laser light shined into the cockpit), optical sensors (for autonomous cars) and potentially for use in photonic computing.

BCP technology is the focus of SUN- PILOT, a multi-million Euro European Horizon 2020 project (Grant agreement ID: 760915). An initiative bringing together academic and commercial partners from across Europe, the aim in SUN-PILOT is to develop a cost-effective means of producing periodic nanostructures, utilising a solution based technology by means of block co-polymers self-assembly. "This is a class of polymers made of two chemically incompatible polymers joined by a very strong covalent bond." says Professor Parvaneh Mokarian, founder of the technology and SUN- PILOT coordinator from Trinity College Dublin and AMBER centre.

Industries like the automotive trade can help nanotextured technologies thrive

Along with research institutes and SMEs, two major industrial sectors from six different European countries participated in the SUN-PILOT consortium: Optics and automotive industries. Whilst the optics industry might seem to be the obvious beneficiary of nanopatterning technology, should it be developed at an industrial scale, there are many more sectors, for example, injection moulding of plastic parts for the automotive industry, which can benefit.

In the automotive industry, there is interest to make nanotextured anti-fingerprint and anti-bacterial touch screens without applying any coatings which could impede the clear vision of the driver. Aesthetic "structural colouring" of plastic car parts, by nanopatterning the mould, instead of highly polluting dying processes and highly expensive graining of the mould for injection moulding of the plastic parts is another example.

SUN-PILOT delivered a disruptive technology at a pilot level to boost the performance and cost ratio of devices for the optics industry. It did so by piloting the fabrication of scratch and wear-resistant nanopatterned antireflective optical surfaces. Nanopatterning stainless steel mould proved very difficult. This is due to the fact the mould material is very robust and resistant to many chemicals including the ones used in plasma etch, a process used to carve tall nanopillars on the surface.

The project achieved its goal by optimising and applying an alternative method applicable to moulds made by any nanopatterning method, for injection moulding to produce functional surfaces at a lower cost than existing lamination methods. The life cycle analysis also shows that the SUN-PILOT nanopatterning technique is greener than conventional coating methods for both the optics and automotive industries.

A range of benefits like self-cleaning surfaces, energy storage, solar cells, and more

These sub-wavelength nanostructures can introduce significant advantages in various applications, including self-cleaning surfaces, energy storage, solar cells, catalysis, sensors, the next generation of implants, water splitting, antibacterial surfaces, metasurfaces, photonic computing, etc only if they could be manufactured at an industrial scale.

The academic community has done a great job towards understanding the science and coming up with novel fabrication methods for nanostructured surfaces. SUN-PILOT was the beginning of a pilot line trial in this field. There are other active projects in Europe in this field (e.g., EngSurf-Twin, Grant agreement ID: 952288).

However, at this stage to push these technological advances further, the focus should perhaps shift to offering engineering solutions to facilitate large-scale manufacturing in real industrial set ups. In other words, the industry should partner up with academia, research institutes and SMEs, and develop pilot line trials for large-scale manufacturing on their or approved business partner facilities. Having said that, the adaptation of early-stage manufacturing technologies has never been easy for large industries as they often have very streamlined supply chains.

Altering their cost-cutting model to try and accommodate a premature technology is not an easy decision to be made for most companies. And yet, the practical partnership is the most realistic option to give it a chance to transition from the lab to the market. That’s where the policymakers and funding agencies could play a crucial role. We must accept that developing novel processes in “deep tech” takes time often beyond the political life of decision and policymakers.

The real advantage for societal benefit and sustainable progress is only tangible through continuous support and funding. In Europe, funding agancies could provide more financial support or incentives to encourage the companies to enter a partnership with universities or their start-ups. The aim should be to specifically adapt pilot line trials in their advanced manufacturing site and to reduce the risk before committing to large-scale manufacturing. Doing so will deliver the real impact for potentially a transformative technology.”

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