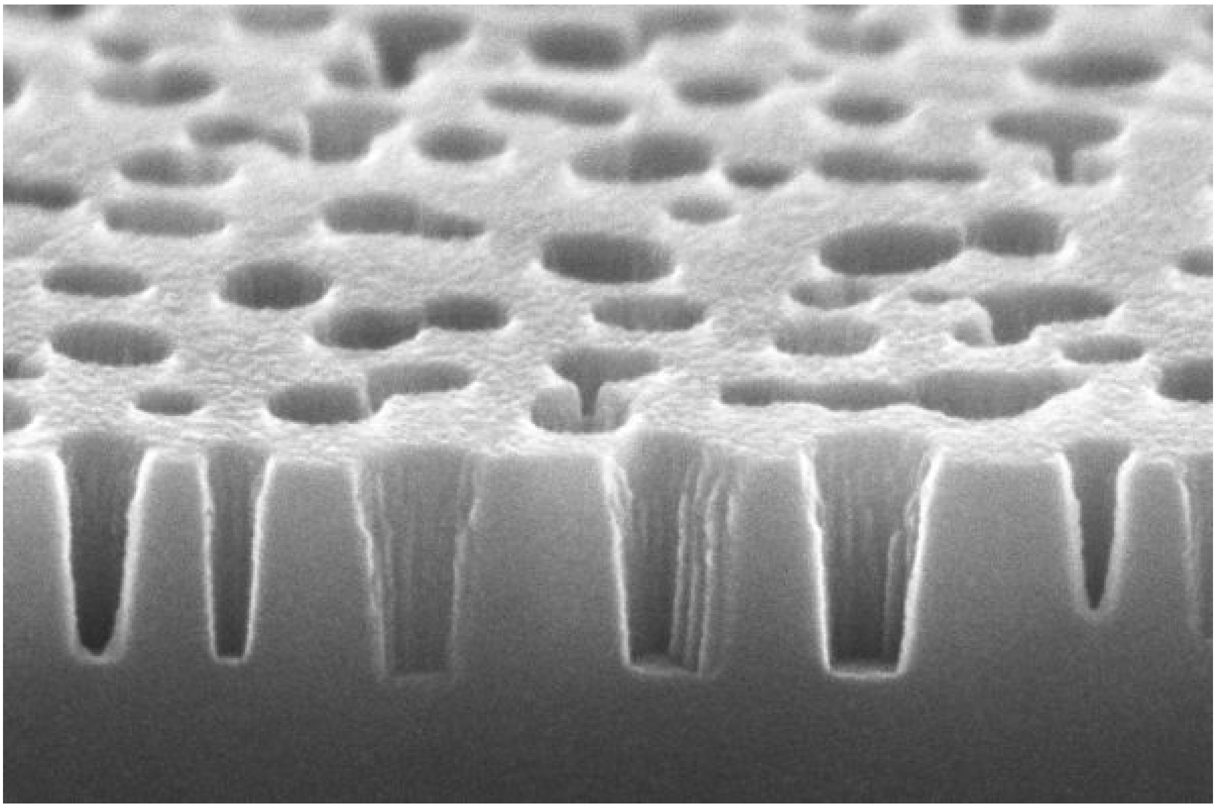


Novel lithography-free method yields durable antireflective glass surfaces

A team of researchers from ICFO and Corning Incorporated has developed a new method for fabricating anti-reflective (AR) surfaces achieved through nano-structured surfaces using a lithography-free process. The innovative method, described in the journal ACS Applied Materials and Interfaces, utilizes thermally dewetted silver as an etching mask to create nanohole structures on glass surfaces, significantly reducing light reflection.

May 27, 2024

Anti-reflective (AR) surfaces are valued for their ability to minimize unwanted reflections, enhancing the efficiency of various optical devices such as laser optics, camera lenses, eyeglasses, touchscreen displays, and solar harvesting systems. Several alternative strategies to that of the traditional multilayer anti-reflective coating procedure have been developed to increase the performance and versatility of optical devices. Using bio-inspired nano-scale structures, such as nanopillars or nanoholes, directly onto a substrate surface enables the manipulation of light paths and reduces the reflection across a broad spectrum

and wide range of angles.
However, the fabrication of these nano-structured surfaces with the desired properties is rather complex, often involving multistep lithography methods, limiting their widespread adoption due to cost and scalability constraints.
Now, in a new study, ICFO researchers **Iliyan Karadzhov, Bruno Paulillo, and Juan Rombaut**, led by ICREA Professor at ICFO **Valerio Pruneri**, in collaboration with Corning Incorporated researchers **Karl W. Koch and Prantik Mazumder**, describe a simplified method that achieves nanostructured AR surfaces. This approach uses thermally dewetted thin silver films as etching masks to generate subwavelength nanohole structures on the glass surfaces, characterized by its simplicity and cost-effectiveness by avoiding complex lithography. The results of this study have been recently published in the journal **ACS Applied Materials and Interfaces.**
The fabrication process involves three main steps. Initially, silver nanoparticles are obtained by quickly thermally annealing an ultra-thin silver film onto a glass substrate. These particles then serve as a base for a secondary etching mask, created by depositing a thin nickel layer over the silver nanoparticles and performing selective chemical wet etching. Finally, this mask is used in a dry etching process to carve nanoholes of varying depths into the glass surface.
"**Nanoholes are tiny, irregularly arranged cavities on a surface that significantly reduce light reflection by smoothly transitioning the refractive index from air to substrate,**" explains **Iliyan Karadzhov**, an early-stage researcher at ICFO in the NANO-GLASS project. "**They were chosen for their superior mechanical durability compared to other nanostructures like nanopillars and their ability to provide excellent AR properties with minimal light scattering,**" adds the first author of the study.
The final arrangement and depth of these nanoholes are determined by the initial thickness of the silver film and the duration of the dry etch process. The team fabricated several samples with varying initial masks and hole depths, testing their performance by measuring both transmittance and reflectance in the visible and near-infrared ranges. The newly developed AR surfaces exhibited a broadband omnidirectional response that achieves transmittance levels exceeding 99% in both the visible and near-infrared ranges, as well as maintaining high transmittance even at steep angles of incidence (up to 60 degrees).
The samples also demonstrated mechanical robustness and durability in abrasion tests. "**One challenge was ensuring that the nanohole structures remained intact during abrasion tests while maintaining high optical performance,**" recalls **Karl W. Koch**, a researcher at Corning Incorporated. "**This was overcome by optimizing the nanoholes' geometry and the fabrication process to balance the mechanical and optical properties. Another challenge was scaling the fabrication method for large-area applications, which was addressed by leveraging scalable techniques like thermal dewetting,**" he adds.
"**This process not only simplifies the fabrication of nanostructured antireflective surfaces but**

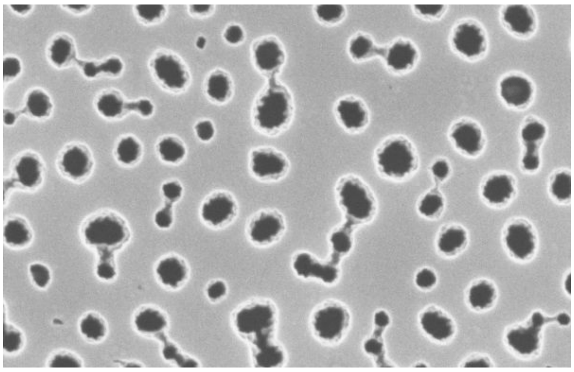
also enhances the mechanical resistance to abrasion, a critical factor for various applications," has stated **Prantik Mazumder**, a Corning Incorporated researcher.

"**This new lithography-free method provides new possible solutions to the development of optoelectronic devices that require high transmission and durability**," concluded **Valerio Pruneri**, the leading author of the study and NANO-GLASS project coordinator.

This research has been partially funded by the Nano-Glass project, a Marie Sklodowska-Curie Innovative Training Network (MSCA-ITN-2020), focused on research of glass materials and their nano-structuring. The project is aimed at developing innovative nano-structuring designs and methods for advanced glass screens for a better display of information as well as new optical fibers for information security.

Original article

Karadzhov, I., Paulillo, B., Rombaut, J., Koch, K.W., Mazumder, P., and Pruneri, V.
Mechanically-durable antireflective subwavelength nanoholes on glass surfaces using lithography-free fabrication. ACS Appl. Mater. Interfaces 2024, 16, 15, 19672-19680. DOI: http://doi.org/10.1021/acsami.3c15391



Top view of the nanoholes carved on the glass substrate taken with Scanning electron microscope (SEM) showing their distribution.

The three main steps of the new method