Docket #: S23-481

Manipulating Light with Nano-Actuated Electrically and Chemically Responsive Surfaces

The Stanford team has developed a method to dynamically control the topography of nano-scale surfaces using soft, responsive polymers, enabling new ways to actively shape the spectral, angular and polarization properties of light in response to electrical and chemical stimuli. This breakthrough paves the way for exciting applications in imaging, sensing, displays, endoscopic light delivery and flexible bio-interfaces that integrate with the human body.

Traditional nano-fabrication approaches produce static surface structures with rigid materials that are fixed upon fabrication. In contrast, the Stanford team utilizes soft materials to create switchable topographies. Electron-beam-exposure modifies the swelling of the conductive polymer PEDOT:PSS, allowing the swollen topography to be patterned based on applied electron-beam dose. By changing properties of the solutions (e.g. solvation energy, pH, osmolarity) or applying electrochemical potential, the polymer transitions from swollen to de-swollen states, achieving up to 700% contrast in swelling degree. By designing Electron-beam exposure patterns, arbitrary topographies can be encoded, which can then be switched ON and OFF on demand.

This innovation unlocks the potential for complex, tunable optical elements, wearable bio-integrated sensors, and biomedical applications like hyper-spectral imaging. More broadly, controlling micro- and nano- scale topography allows for control over many physical properties of surfaces, ranging from adhesion and friction to fluid flow. These properties are crucial to the interaction of cells and bacteria with surfaces. By bridging the gap between rigid nano-structures and soft, responsive materials, this approach provides a highly adaptable platform for advanced optical and bio-electronic applications.

Stage of Development:
Prototype

Applications

- **Wearable biosensors** - for example, contact lens-based sensors, wearable monitoring (e.g. of hydration, for athletes).
- **Hyperspectral, polarimetric or other computational imagers** that can be actively tuned to provide access to different information on demand
- **Tunable diffractive or nano-optics** - for example, non-volatile, tunable lenses or filters integrated with microfluidics
- **Bio-interfaces** - for example, a substrate for cell monitoring that both detects force from cells, by monitoring of the cavity deformation, and electrical signals, via the conductive PEDOT polymer.
- **3D cell interfaces** – for example, complex topographies that control properties of bacterial adhesion/locomotion or cellular interaction with electrodes or surfaces

Advantages

- **Dynamic control and reconfigurable design**
- **Soft sensors**
- **Device integratable with human body**
- **High resolution control of topography** (down to µm scale)
- **Ability to actively switch complex topographies**
- **Use of soft materials with responsiveness to environmental stimuli**

Publications

- Doshi, Siddharth, et al. Soft photonic skins with dynamic texture and colour control. *Nature* 649, 345–352 (2026).
- Renz, Benjamin, & Na Liu. Artificial skin mimics the octopus's art of disguise. *Nature* 649, 297–298 (2026).
- Peel, Michael. Synthetic skin based on octopus biology promises uses in robotics. Financial Times (2026)

- Castelvecchi, Davide. Octopus-inspired 'synthetic skin' changes colour and texture on demand. *Nature* (2026).
- Castañón, Laura. New material changes color and texture like an octopus. *Stanford Report* (January 7, 2026)..

Patents

- Published Application: WO2025137278

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