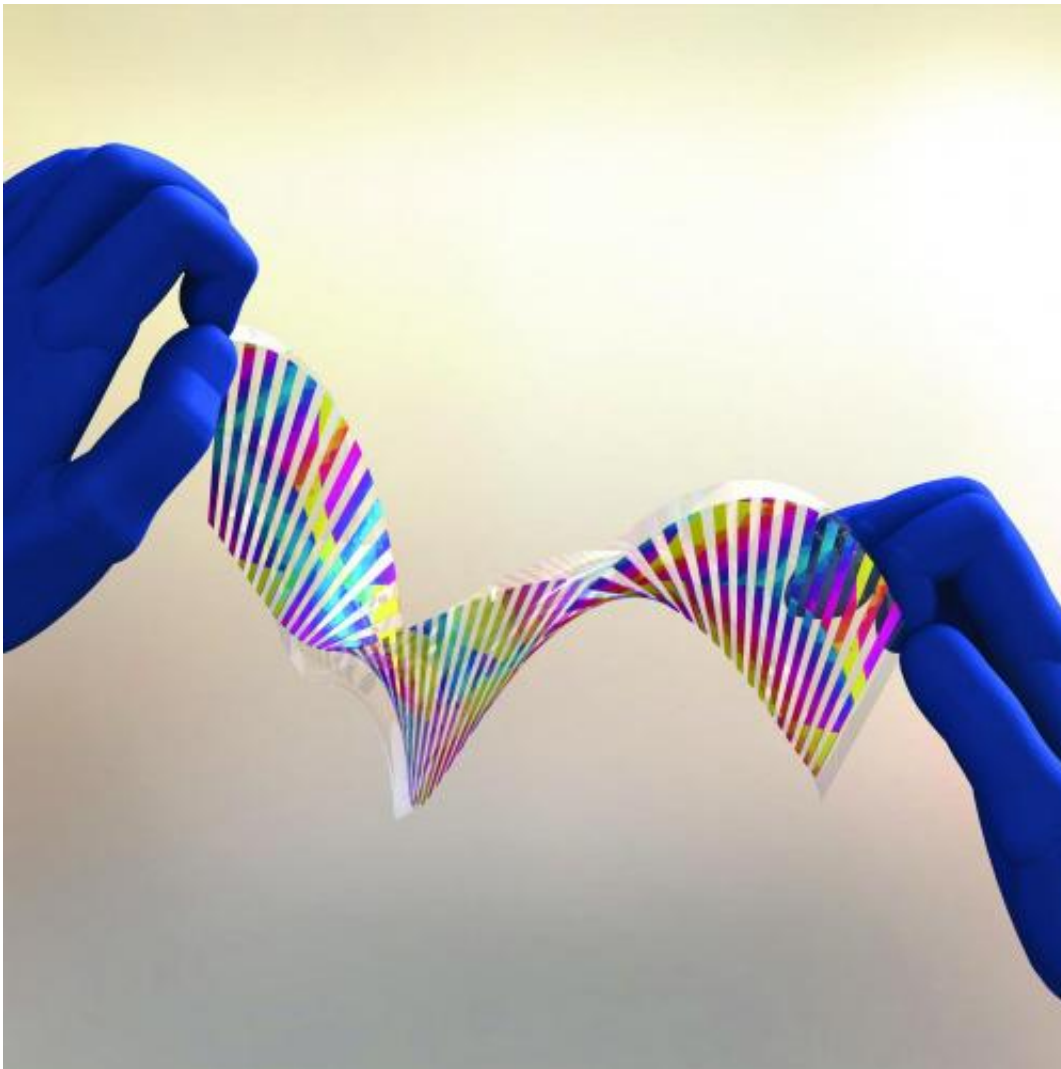


Engineers create chameleon-like artificial 'skin' that shifts color on demand

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Developed by engineers from the University of California at Berkeley, this chameleon-like artificial "skin" changes color as a minute amount of force is applied. Credit: The Optical Society (OSA)

Borrowing a trick from nature, engineers from the University of California at Berkeley have created an incredibly thin, chameleon-like material that can be made to change color—on demand—by simply applying a minute amount of force.

This new material-of-many-colors offers intriguing possibilities for an entirely new class of display technologies, color-shifting camouflage, and sensors that can detect otherwise imperceptible defects in buildings, bridges, and aircraft.

"This is the first time anybody has made a flexible chameleon-like skin that can change color simply by flexing it," said Connie J. Chang-Hasnain, a member of the Berkeley team and co-author on a paper published today in *Optica*, The Optical Society's (OSA) new journal.

By precisely etching tiny features—smaller than a wavelength of [light](#)—onto a silicon film one thousand times thinner than a human hair, the researchers were able to select the range of colors the material would reflect, depending on how it was flexed and bent.

A Material that's a Horse of a Different Color

The colors we typically see in paints, fabrics, and other natural substances occur when white, broad spectrum light strikes their surfaces. The unique chemical composition of each surface then absorbs various bands, or [wavelengths of light](#). Those that aren't absorbed are reflected back, with shorter wavelengths giving objects a blue hue and longer wavelengths appearing redder and the entire rainbow of possible combinations in between. Changing the color of a surface, such as the leaves on the trees in autumn, requires a change in chemical make-up.

Recently, engineers and scientists have been exploring another approach, one that would create designer colors without the use of chemical dyes

and pigments. Rather than controlling the [chemical composition](#) of a material, it's possible to control the surface features on the tiniest of scales so they interact and reflect particular wavelengths of light. This type of "structural color" is much less common in nature, but is used by some butterflies and beetles to create a particularly iridescent display of color.

Controlling light with structures rather than traditional optics is not new. In astronomy, for example, evenly spaced slits known as diffraction gratings are routinely used to direct light and spread it into its component colors. Efforts to control color with this technique, however, have proved impractical because the optical losses are simply too great.

The authors of the *Optica* paper applied a similar principle, though with a radically different design, to achieve the color control they were looking for. In place of slits cut into a film they instead etched rows of ridges onto a single, thin layer of silicon. Rather than spreading the light into a complete rainbow, however, these ridges—or bars—reflect a very specific [wavelength of light](#). By "tuning" the spaces between the bars, it's possible to select the specific color to be reflected. Unlike the slits in a diffraction grating, however, the silicon bars were extremely efficient and readily reflected the frequency of light they were tuned to.

Flexibility Is the Key to Control

Since the spacing, or period, of the bars is the key to controlling the color they reflect, the researchers realized it would be possible to subtly shift the period—and therefore the color—by flexing or bending the material.

"If you have a surface with very precise structures, spaced so they can interact with a specific wavelength of light, you can change its properties and how it interacts with light by changing its dimensions," said Chang-

Hasnain.

Earlier efforts to develop a flexible, color shifting surface fell short on a number of fronts. Metallic surfaces, which are easy to etch, were inefficient, reflecting only a portion of the light they received. Other surfaces were too thick, limiting their applications, or too rigid, preventing them from being flexed with sufficient control.

The Berkeley researchers were able to overcome both these hurdles by forming their grating bars using a semiconductor layer of silicon approximately 120 nanometers thick. Its flexibility was imparted by embedding the silicon bars into a flexible layer of silicone. As the silicone was bent or flexed, the period of the grating spacings responded in kind.

The semiconductor material also allowed the team to create a skin that was incredibly thin, perfectly flat, and easy to manufacture with the desired surface properties. This produces materials that reflect precise and very pure colors and that are highly efficient, reflecting up to 83 percent of the incoming light.

Their initial design, subjected to a change in period of a mere 25 nanometers, created brilliant colors that could be shifted from green to yellow, orange, and red - across a 39-nanometer range of wavelengths. Future designs, the researchers believe, could cover a wider range of colors and reflect light with even greater efficiency.

Chameleon Skin with Multiple Applications

For this demonstration, the researchers created a one-centimeter square layer of color-shifting silicon. Future developments would be needed to create a material large enough for commercial applications.

"The next step is to make this larger-scale and there are facilities already that could do so," said Chang-Hasnain. "At that point, we hope to be able to find applications in entertainment, security, and monitoring."

For consumers, this chameleon material could be used in a new class of display technologies, adding brilliant color presentations to outdoor entertainment venues. It also may be possible to create an active camouflage on the exterior of vehicles that would change color to better match the surrounding environment.

More day-to-day applications could include sensors that would change color to indicate that structural fatigue was stressing critical components on bridges, buildings, or the wings of airplanes.

"This is the first time anyone has achieved such a broad range of [color](#) on a one-layer, thin and flexible surface," concluded Chang-Hasnain. "I think it's extremely cool."

More information: L. Zhu, J. Kapraun, J. Ferrara, and C.J. Chang-Hasnain, "Flexible photonic metastructures for tunable coloration," *Optica*, 2, 3, 255-258 (2015) [www.opticsinfobase.org/optica/ ...m?uri=optica-2-3-255](http://www.opticsinfobase.org/optica/...m?uri=optica-2-3-255)

Provided by Optical Society of America

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