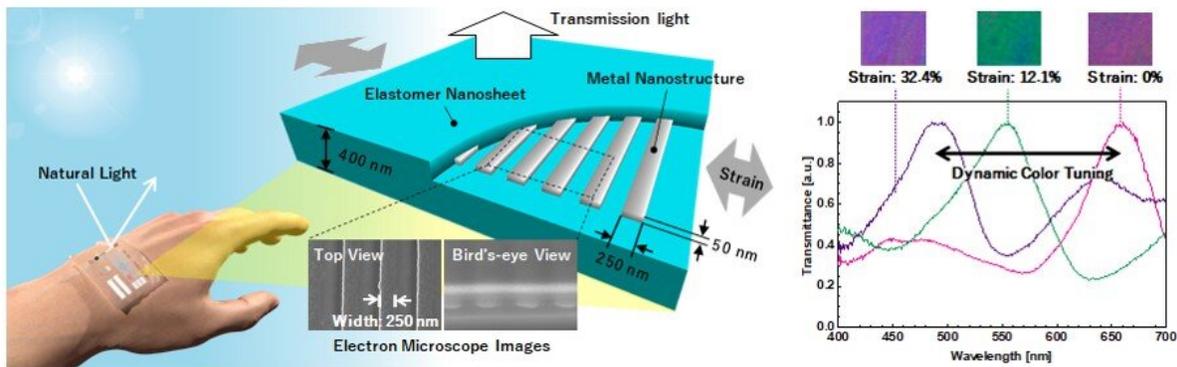


Stretchable variable color sheet that changes color with expansion and contraction

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Structure of stretchable color sheets and color change with stretching and contracting. Credit: Toyohashi University Of Technology.

A Toyohashi University of Technology research team has succeeded in developing a variable color sheet with a film thickness of 400 nanometers that changes color when stretched and shrunk. The developed stretchable color sheets are expected to be applied to adhesive-type display elements, as they can adhere to skin or be transferred to various electronic devices at room temperature utilizing the high adhesiveness of elastomers.

A joint research team of Hayato Kumagai in the latter half of a doctoral course and Kazuhiro Takahashi, Associate Professor in the Department

of Electrical and Electronic Information Engineering of Toyohashi University of Technology, and Toshinori Fujie, Associate Professor (Lecturer) of the School of Life Science and Technology at the Tokyo Institute of Technology, have succeeded in developing a variable color sheet with a film thickness of 400 nanometers (less than one-hundredth of the thickness of a human hair) that changes color when stretched and shrunk. This variable color sheet utilizes the color generation by metal nanostructures formed in the elastomer sheet to achieve reversible wavelength control of transmitted light over a wavelength range of 495 to 660 nanometers through expansion and contraction. The developed stretchable color sheets are expected to be applied to adhesive-type display elements, as they can adhere to skin or be transferred to various electronic devices at [room temperature](#) utilizing the high adhesiveness of elastomers.

Surfaces with periodic arrays of metal nanostructures can produce an effect called surface plasmon, which is the collective oscillation of electrons that respond to particular wavelengths of lights. Using this effect, color filters that allow light to transmit through a narrow nanogap, without which light could not pass, can be manufactured. This is known as the phenomenon of extraordinary optical transmission. Unlike conventional color filters that use pigments, color filters utilizing this principle will not degrade over time and can be used as color filters for image sensors built into smartphones and other devices. Recently, dynamic color tuning, which forms metal nano periodic structures on elastic materials and displaces the period of the structures by expanding and contracting the sheet to change colors, has been studied as a method to control the wavelength of light that generates surface plasmons. This technology is expected to be applicable to flexible displays that are highly flexible in shape and form, as well as sensors that visualize structural strain, and the like.

However, in existing research reports, the thickness of the sheet

supporting the nanostructures was in the order of millimeters, making it difficult to combine it with the drive mechanism using micromachine technology. In addition, the driving force required for the expansion and contraction of the support sheet is dependent on the thickness of the sheet. Therefore, thicker sheets pose the challenge of increasing the drive voltage of the micromachine device.

To solve the challenge, the research team developed stretchable color sheets using elastomer nanosheets made into thin film with a thickness of one micrometer or less, made of a polystyrene-polybutadiene-polystyrene block copolymer (SBS), a type of rubber material used in automobile tires and other products. By embedding metallic nanostructures in elastomeric materials made into nano-thin film, extraordinary optical transmission using surface plasmons was confirmed. By applying strain to the nanosheets, we confirmed that the light transmitted through the sheets changed to blue, green, and red, and succeeded in dynamically controlling the extraordinary optical transmission with surface plasmon.

Furthermore, we have demonstrated the wavelength of the transmission peak can continuously change in the range of 495 to 660 nanometers, and repeated expansion and contraction is possible. The [driving force](#) to expand and contract the color sheet which we developed is smaller by 2 to 3 orders of magnitude than conventional values and can be driven sufficiently by the force generated by ordinary microactuators. In addition, the adhesiveness of the elastomer makes it possible to attach the sheet to any surface, enabling the detection and visualization of structural strain. By combining it with micro-machine technology, we can expect to realize a variable color filter.

The research team believes that the method could be applied to display elements that electronically change coloration by driving the stretchable color sheets with a micro-actuator. With the flexibility and adhesiveness

of the sheet, it is expected to be used for electronic skin where it is pasted on human skin and displays images.

More information: Hayato Kumagai et al, Stretchable and High-Adhesive Plasmonic Metasheet Using Al Subwavelength Grating Embedded in an Elastomer Nanosheet, *Advanced Optical Materials* (2020). [DOI: 10.1002/adom.201902074](https://doi.org/10.1002/adom.201902074)

Provided by Toyohashi University of Technology

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