Towards high quality transferred barium titanate ferroelectric hybrid integrated modulator on silicon

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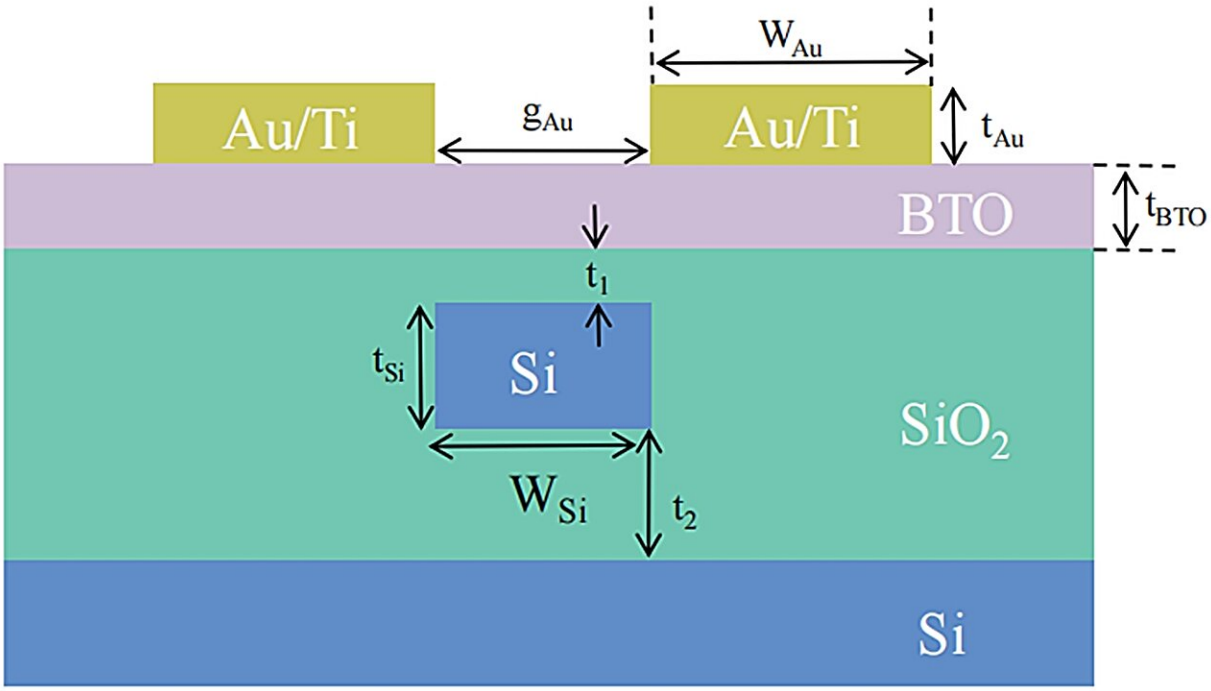


Credit: *Light: Advanced Manufacturing* (2024). DOI: 10.37188/lam.2024.031

Future optical communication and signal processing systems will require high-volume optical links, wherein photonic integrated devices play a key role. Si photonics is currently among the most advanced techniques for realizing low-cost PIC. However, despite their enormous potential,

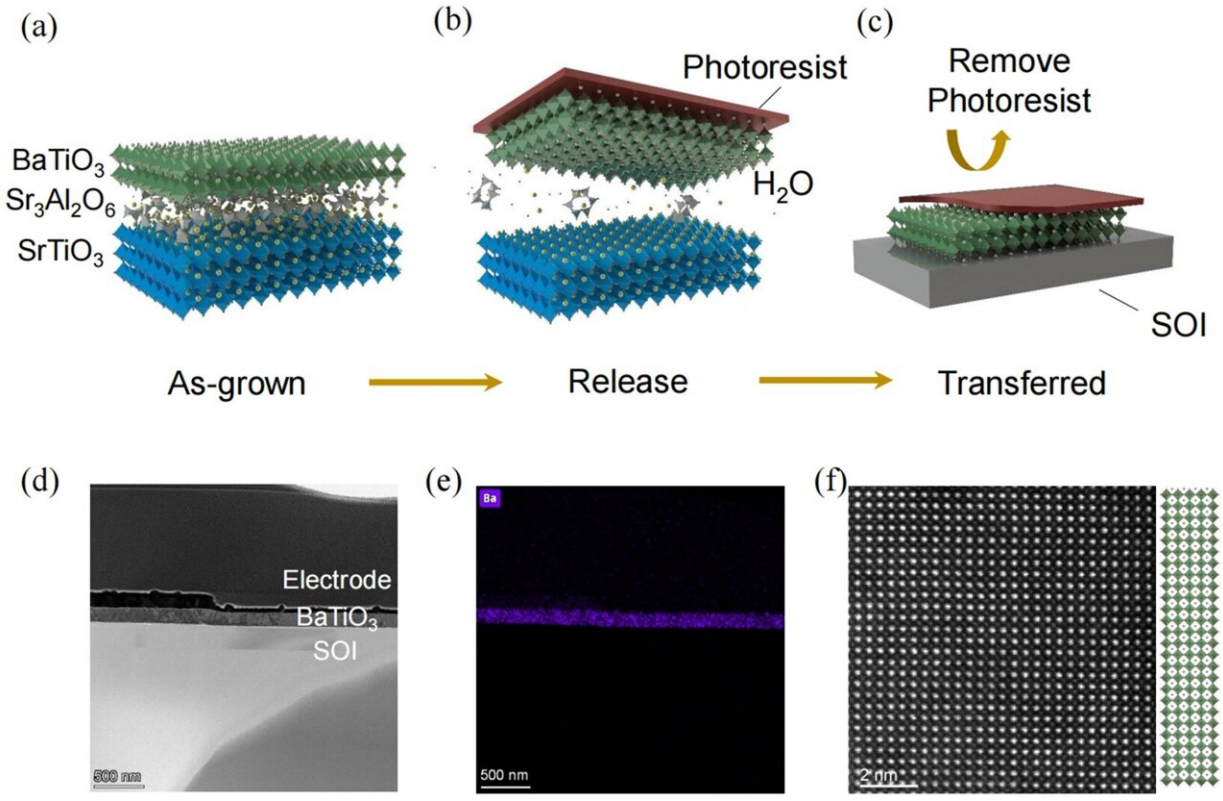
there remain basic restraints on light modulation in SOI waveguides. The absence of a linear EO coefficient is challenging because of the crystal structure of Si.

Many methods have been proposed to overcome these limitations. The most commonly used method involves facilitating the Pockels effect in other materials, through which EO modulation permits the realization of excellent modulation performance without additional losses. Among them, BTO is known for its high Pockels coefficient.

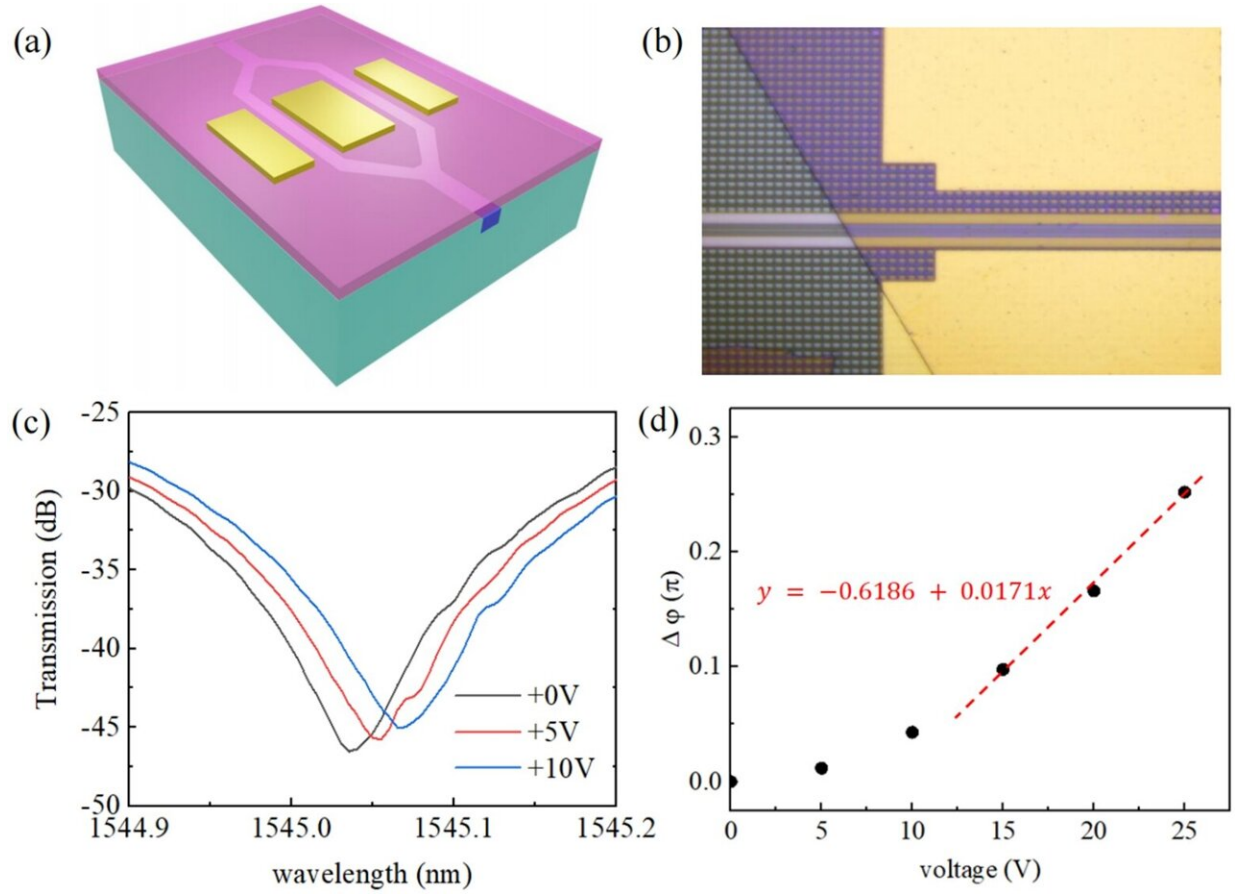
In a new paper published in *Light: Advanced Manufacturing*, a team of researchers, led by Professor Junjia Wang from Southeast University, and Professor Guohua Dong from Xi'an Jiaotong University, have proposed a new way to transfer barium titanate onto silicon.

This study demonstrated EO modulation using the hybrid integration of BTO on a SOI waveguide structure enabled by the target transfer method. The method enables the use of optimized thickness and rotation angle to enhance the EO modulation in the SOI waveguide. The MZI device exhibited a large modulation efficiency with $V_{\pi}L$ as low as 1.67 V·cm.

The researchers summarized the advantages of their modulator saying, "We have fabricated free-standing single-crystalline BTO film based on the epitaxial growth of a BTO/$Sr_3Al_2O_6$ (SAO)/$SrTiO_3$ (STO) heterostructure, BTO/SAO heterostructures were deposited onto the STO layer via pulsed laser deposition (PLD).



(a)-(c) Schematics of single crystal BTO peeling-off and transfer process from strontium titanate (STO) to the SOI substrate; (d) Cross-sectional transmission electron microscopy (TEM) image of a contact/BTO/SOI heterostructure; (e) Energy dispersive X-ray spectroscopy (EDS) element mapping of Ba element; (f) Atomic resolution scanning transmission electron microscopy (STEM) image of BTO layer. Credit: *Light: Advanced Manufacturing* (2024). DOI: 10.37188/lam.2024.031



(a) Simulated schematic of the MZI device; (b) Optical micrograph of the MZI device at the waveguide; (c) Measured transmitted light intensity spectra at selected voltages of +0 V, +5 V and +10 V; (d) The curve is calculated with respect to different voltages, with the red line being the tangential of the curve. Credit: *Light: Advanced Manufacturing* (2024). DOI: 10.37188/lam.2024.031

"The free-standing films can be successfully transferred onto SOI wafers. The transfer method can improve the effective EO coefficient by changing the rotation angle of the BTO layer. Consequently, we can obtain epitaxial BTO films with excellent ferroelectricity and flexibility on top of SOI waveguides.

"We investigated the modulation efficiency of the BTO by measuring the transmission curve of the device at different bias voltages and tested the EO response of the device in the communication band. At three different voltages, the electric field affects the effective refractive index of the BTO film and thus modulates the phase of the light, the modulation efficiency $V_{\pi}L$ value as low as 1.67 V·cm."

More information: Mengxue Tao et al, Towards high quality transferred barium titanate ferroelectric hybrid integrated modulator on silicon, *Light: Advanced Manufacturing* (2024). DOI: 10.37188/lam.2024.031

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