Ferroionic 2D Material Integration for Enhanced Electro-Optic Functionality in Silicon Photonic Circuits

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Tunable optical materials are crucial in integrated photonic circuits, where precise refractive index control is essential for diverse applications [1,2]. Two-dimensional (2D) materials like transition metal dichalcogenides (TMDs) have shown promise [3,4], but efficient phase modulation in the short-wave infrared (SWIR) with low loss remains challenging.

In this work, we demonstrate the strong electro-refractive response of multilayer ferroionic $CuCrP_2S_6$ (CCPS) integrated into silicon photonics (SiPh) microring resonators (MRRs) in the near-infrared. The migration of Cu ions under an applied electric field enables refractive index tuning of approximately 2.8×10^{-3} RIU, while preserving extinction ratios and resonance linewidths. The devices exhibit low optical losses, with a modulation efficiency of 0.25 V·cm and a consistent blue shift in resonance wavelengths across both voltage polarities, outperforming previous TMD-based phase shifters.

Additionally, we observe polarization-dependent electro-optic tuning, with distinct responses for transverse electric (TE) and transverse magnetic (TM) modes. The dual optoelectronic and ionotronic capabilities of CCPS-based devices offer potential applications in phased arrays, optical switching, environmental sensing, optical imaging, and neuromorphic computing.

References

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[4] Y. Yu, et al. Giant Gating Tunability of Optical Refractive Index in Transition Metal Dichalcogenide Monolayers," Nano Lett. 17(6), 3613– 3618 (2017).

Figures

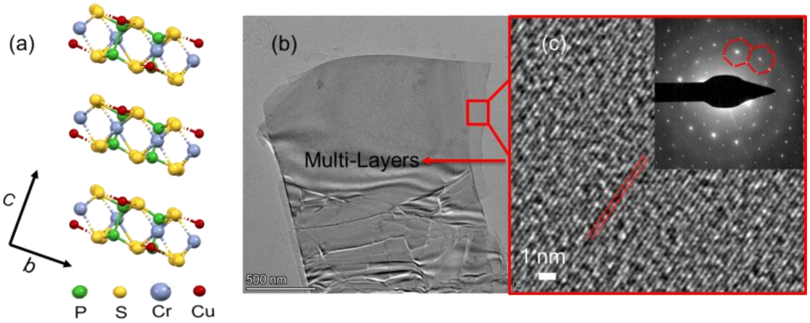

Figure 1: Structural characteristics of CCPS (a) 3D visualization of bc plane (ball-stick model) (b) high-resolution transmission electron microscopy (HRTEM) of multilayer CCPS captured at the red squared area.

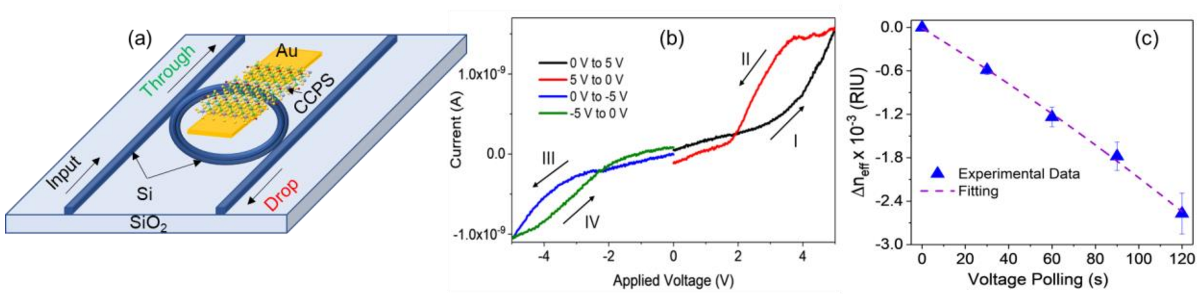

Figure 2: (a) Schematic configuration of the photonic design and CCPS integration (b) full I−V curves swept in the order 0 V→ 5 V → 0 V → -5 V → 0 V labeled as I, II, III, IV (c) the change in real part of effective index of refraction as a function of the polling time at E= 1×10^4 V/cm.