Carrier density modulation and ionic effects in electrically reconfigurable MOS stack

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Indium tin oxide (ITO) has been recently rediscovered as a promising material for advanced optical devices. The latest research has shown that this long-known transparent conductive oxide (TCO), exhibits exceptional physical properties that can provide a basis for constructing energy-efficient and ultrafast systems with tunable optical responses [1, 2].

In this work, we report on the experimental realization of an electro-optical, cavity-based modulator with ITO serving as an active material. The device has been fabricated solely using the e-beam physical vapor deposition technique. It has the form of a multilayer stack consisting of silver, silicon dioxide, and ITO layers, with an overall thickness of less than 1 µm. The structure is capable of direct electro-optical modulation without the need for integration with waveguide systems. Furthermore, it has a large active area of 4 mm^2, which makes it suitable for free-space operating.

Our spectroscopic ellipsometry measurements in UV/VIS/NIR range have delivered evidence that depending on the bias polarity, the accumulation or depletion layer formation occurs near ITO/SiO2 interface. We show that the associated change in refractive index for 1550 nm wavelength can be as high as 0.75 for an applied voltage as low as 2 V. We also show that there is a voltage threshold above which the structure's relative reflectivity changes drastically by 25%. We believe that the effect is due to the formation of conductive channel in the SiO_2 layer through which silver ions can migrate (Fig. 1) [3].

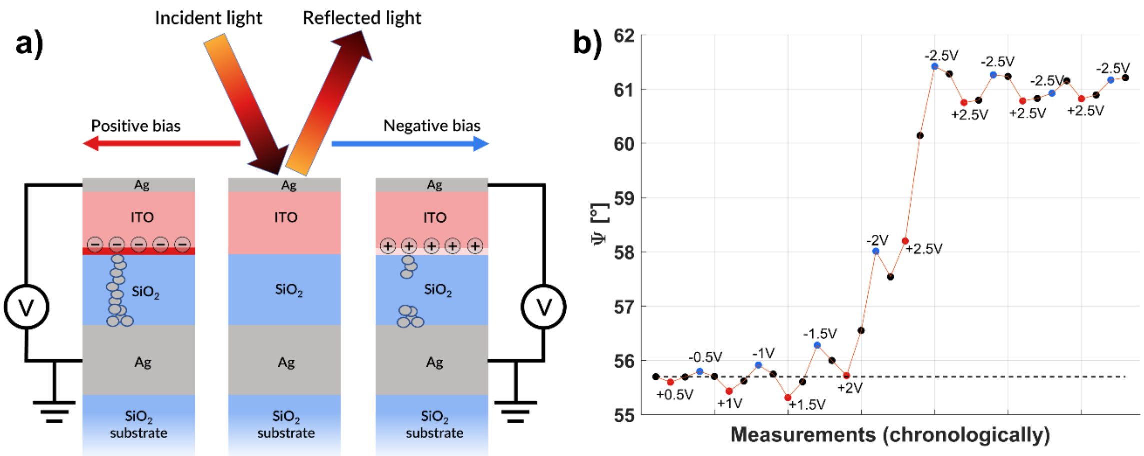

Fig. 1 a) Schematic of a MOS device geometry and operating principle. When the positive bias is applied to the bottom Ag electrode, an accumulation layer is formed on the ITO-SiO2 interface. Whereas with a negative bias, the depletion layer is formed. The positive voltage can also procure the formation of a conductive channel inside the dielectric. b) Electrically induced changes in the multilayer's optical parameters, expressed in terms of Ψ value. The points are arranged in the order of the measurements taken and each point corresponds to a different voltage applied.

[1] Feigenbaum, E., Atwater, H. A. et al., Nano Letters **10**, 2111 (2010)
[2] Sorger, V. J., et al., Nanophotonics **1**, 17 (2012)
[3] Lee, J., Lu, W. D. Advanced Materials **30**, 1702770 (2017)