Silicon-Organic-Hybrid Independent Simultaneous Dual-Polarization Modulator: Device Theory and Design

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Abstract

The Complementary Metal-Oxide-Semiconductor (CMOS) technology is a gateway to fabricating low cost electronic and photonic components to date. The Silicon-based nanophotonics platform leverages CMOS technology to fuel the effort to provide increasingly high-speed and high-bandwidth devices at low costs in response to global demands in telecommunication infrastructure. The current industry standard for modulators used in transmitters, uses the plasma dispersion effect in a p-n junction. This effect is relatively slow compared to the low response time of the solid-state, linear, electro-optic Pockel's effect typically in the sub-picosecond range. Since this effect cannot be generated in Silicon due to its linearity as an optical material, alternative CMOS-compatible materials such as nonlinear crystals or organics like electro-optic polymers (EOPs), have been investigated. The clear benefit and application of Silicon-Organic-Hybrid (SOH) structures is utilized in specific telecommunication devices such as modulators, switches, and tunable couplers, with the aim to reduce manufacturing and operating costs while boosting operating speeds.

Typical SOH modulators focus on the r33 coefficient of the electro-optic tensor to modulate transverse electric (TE) polarized light propagating through the EOP waveguide. Thus an applied electric field directly induces a birefringence that affects the phase response of the EOP to a specific polarization. It is believed that chromophores within the EOP matrix operate in three dimensions implying three degrees of freedom. The orientation of the chromophores with respect to the polarization of incident light determines the refractive index response. When restricting the chromophore orientation in the direction parallel to propagating light, there are still two orthogonal dimensions available. These two dimensions correspond directly to the polarization dependent refractive index of the material, indicating that it is theoretically possible to modulate the phase of each polarization separately yet simultaneously through the same waveguide. This is ensured by thermally poling the waveguide in the third dimension (i.e. along the direction of propagation) so that chromophores orientation is manipulated through this unused degree of freedom. This proposition is investigated through the simulation of a device that can modulate TE and TM polarized light independently, yet simultaneously.

The features used in COMSOL Multiphysics® include the Wave Optics > Electromagnetic Waves and AC/DC > Electrostatics module for the simulation and modeling of optical phase modulation under the influence of applied electric fields. Completing our model required the basic features of defining and meshing the device geometry, utilizing built-in

variables and features for analysis, and defining the unique polymer material and its response toward simulated chromophore behaviour. Results of the simulation are used to define the expected optical modulation with respect to the chromophore orientation from an applied electric field. Thus our SOH simultaneous dual-polarization modulator is expected to facilitate an additional carrier of information thereby allowing for parallel processing by exploiting other dimensions of the polymer matrix.

Figures used in the abstract

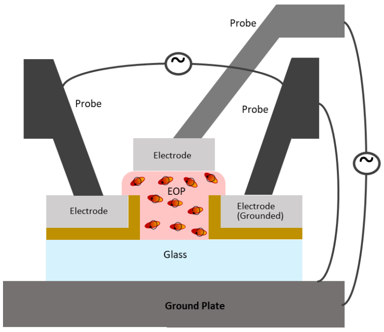

Figure 1