Silicon-Organic Hybrid (SOH) Integration for Low-Power and High-Speed Signal Generation

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ABSTRACT
Silicon-organic hybrid (SOH) integration combines silicon photonic devices with electro-optic organic cladding materials. We demonstrate that SOH modulators can be used to generate advanced modulation formats with high symbol rates at low operating voltages and low energy consumption. Moreover, we show that the SOH approach can be extended to plasmonic waveguide structures, leading to the plasmonic-organic hybrid (POH) concept.
Keywords: Silicon Photonics, integrated modulators, organic electro-optic materials, silicon-organic hybrid (SOH), plasmonics

PROGRESS IN SOH INTEGRATION

Silicon photonics has emerged as a promising platform for integrated photonics [1]. In particular, high-speed optical transceivers, which are indispensable for terabit/s telecommunication links and optical interconnects, can benefit from high integration density, mature CMOS processing, and the possibility of electronic co-integration. These transceivers rely on efficient electro-optic IQ modulators, which support advanced modulation formats at high symbol rates. Implementation of such devices, however, is impeded by the fact that unstrained bulk silicon does not exhibit any second-order nonlinearity, and hence conventional silicon-photonic modulators have to rely on carrier injection or depletion [2]. This limits the modulation efficiency of high-speed devices and leads to a usually rather high energy consumption around 1 pJ/bit for non-resonant Mach-Zehnder modulators [3], [4].

Silicon-organic hybrid (SOH) integration can overcome these limitations by combing silicon-on-insulator (SOI) slot waveguides with cladding layers that consist of highly efficient organic electro-optic materials [5], [6]. In this presentation, we give an overview on our recent progress in the field of SOH integration. Substantial performance improvements of SOH devices were enabled by novel, highly efficient electro-optic materials [7], [8]. We demonstrated modulation at bandwidths of more than 100 GHz [9] and symbol rates of up to 64 GBd, including operation at elevated temperatures of 80° C. With respect to higher-order modulation formats, we showed 16QAM signal generation at symbol rates of up to 40 GBd and line rates of up to 160 Gbit/s [10]. SOH devices feature high energy efficiency, too: At symbol rates of 28 GBd, drive voltages of only 0.6 V_{pp} are required for 16QAM generation, leading to an energy consumption of 19 fJ/bit [11]. This is the lowest value reported so far for 16QAM modulation at this speed. The extraordinary low operation voltage enables efficient frequency comb generation [12] as well as operation of the modulators by direct connection to standard output ports of field-programmable gate arrays (FPGA), without the need of drive amplifiers and analog-to-digital converters, even if 16QAM signals are to be generated [13]. We also demonstrated that electro-optic cladding materials can be combined with plasmonic waveguide structures. Using this so-called plasmonic-organic hybrid (POH) approach, we demonstrated data transmission based on both phase modulators and Mach-Zehnder amplitude modulators [14], [15].

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