High speed and ultra-low voltage driven optical modulators and waveguide biophotonic sensors

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1. Objective

(1) High speed and ultra-low voltage driven optical modulators

Electro-optic (EO) polymer modulators have shown high performance with a large 3 dB bandwidth of 110 GHz because of low dielectric (refractive index) dispersion of the EO polymers. We demonstrated the lowest half-wave voltage (V_π) of 0.65 V [1] - 1.0 V [2] (Our paper to *Nature Photonics* was cited by 155 papers, other papers to *Applied Physics Letters* were cited by a total of 298 papers), due to high in-device EO coefficient (142–170 pm/V at 1550 nm wavelength) based on the hybrid waveguide structure to enable high poling efficiency of the EO polymers. EO polymers are suitable candidate materials for optical modulators in future on-chip optical interconnections [3]. We aim to demonstrate ultra-low voltage driven polymer modulators for high speed and low power consumption in future computer after the modulator is integrated into CMOS circuit.

(2) Waveguide biophotonic sensors

Electrical and optical biosensors have been designed to function independently for detecting biomaterials. In previous systems, electrical and optical connections between the biosensors must be employed for monitoring potentially hazardous biomaterial such as an organophosphorus (OP) compound (e.g., sarin). To simplify the devices and the network, we directly doped a green fluorescent protein (GFP) into a sol–gel silica waveguide core [4], although previously it was difficult to handle living protein inside solid-state waveguide device structures. The results enable real-time detection of sarin and other biochemicals by means of an in-line fiber sensor network. We report the real-time detection of an organophosphorus (OP) compound using a sol–gel silica planar waveguide doped directly with a green fluorescent protein (GFP) and an organophosphorus hydrolase (OPH) on a yeast-cell surface display [5]. We aim to demonstrate a biophotonic waveguide sensor network for detection of dangerous virus using antibiotic-doped waveguides.

2. Project Outline

The graduate students will work on electro-optic polymer modulators and waveguide biophotonic sensors under the supervision of Prof Yasufumi Enami. Responsibilities will include managing and executing programs involving the design, fabrication, and demonstration of novel polymer EO modulators and waveguide biophotonic sensors.

(1) High speed and ultra-low voltage driven optical modulators

(a) Technical responsibilities will involve fabrication of a sol-gel waveguide, RF sputtering, and photolithographic process in clean room.

(b) Technical responsibilities will also involve measurement of the EO coefficient of the EO polymers using optical setup.

(c) Responsibilities will also include process of polymer and sol-gel silica waveguides, etching of the electrode using mask aligner and maskless lithography, and observation of the devices using SEM and AFM.

(d) Skill in optical throughput measurement of waveguide devices, and EO coefficient and $V\pi$

measurements for EO polymer modulators.

(e) Skill in electron-beam lithography, RIE, ICP, Asher, and dicing machine would be a plus, but is not necessary,

(2) Waveguide biophotonic sensors

(a) Technical responsibilities will involve fabrication of a sol-gel waveguide, and photolithographic process in a clean room.

(b) Responsibilities will also include process of sol-gel silica waveguides using mask aligner.

(c) Skill for optical throughput measurement of the waveguide devices.

(d) Skill for optical detection using optical fiber and OTDR.

3. Required Skills and Knowledge

Position requires a Master degree in Applied Physics, Electrical Engineering, or Optics. The successful candidate for this project will have the following knowledge: (a) Fundamental Optics, (b) Wave Optics, (c) Optical Waveguides, (d) Photonics, and the following skills: (a) Microfabrications, (b) Optical Measurements, and (c) Fiber Optic Network.

References

[1] Y. Enami, et al., "Hybrid crosslinkable polymer/sol-gel waveguide modulators with 0.65V half-wave voltage at 1550nm", ***Applied Physics Letters,*** vol. 91, pp. 093505-1-3 (2007).

[2] Y. Enami et al., "Hybrid polymer/sol-gel waveguide modulators with exceptionally large electro-optic coefficient" ***Nature Photonics,*** 1, 180 (2007).

[3] Y. Enami, et al., "Electro-optic polymer/TiO_2 multilayer slot waveguide modulators", ***Applied Physics Letters,*** vol. 101, pp. 123509 (2012).

[4] Y. Enami et al., "Sol–gel silica planar waveguide doped with green fluorescent protein for in-line biosensors", ***Applied Physics Letters***, vol. 91, pp. 203507-1-3 (2007).

[5] Y. Enami et al., "Detection of organophosphorus compound based on a sol–gel silica planar waveguide doped with a green fluorescent protein and an organophosphorus hydrolase", ***Applied Physics Letters***, vol. 98, pp. 233503 (2011).

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