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Photonic Biosensors in Silicon-on-Insulator

Gunay Yurtsever, Katrien De Vos, Tom Claes, Peter Debackere, Peter Bienstman and Roel Baets

Ghent University – IMEC, Photonics Research Group, Department of Information Technology (INTEC) , Sint-Pietersnieuwstraat 41, 9000 Gent, Belgium
gunay@intec.ugent.be

We report on recent research activities of our group on several photonic biosensors. The silicon-on-insulator (SOI) material platform and deep UV lithography is used to fabricate photonic structures for label-free detection of bio-molecular interactions and for tissue imaging [1]. For label free sensors, several approaches are being investigated: ring resonators, slotted waveguides and surface plasmon interferometry. Additionally, we investigate basic SOI photonic structures for optical coherence tomography (OCT) components for tissue imaging.

We demonstrated simultaneous detection of multiple antibodies in a highly specific way based on microring resonator arrays. We will discuss important considerations for high throughput sensing with silicon-on-insulator photonics, including detection limit, microfluidics packaging, receptor binding through a thin poly ethylene glycol layer, and camera based parallel readout. We introduce simultaneous measurement of refractive index and thickness of thin molecular layers, used to study conformational biomolecular changes [2].

We numerically optimized SOI slot waveguides for label-free biosensing of proteins and will present a slot-waveguide-based ring resonator in SOI with a footprint of only 13 µm x 10 µm. Experiments showed that it has 298 nm/RIU sensitivity and a detection limit of $4.2\text{x } 10^{-5}$ RIU for refractive index changes of the complete top cladding. We prove that surface chemistry for selective label-free sensing of proteins can be applied inside a 100 nm- wide slot region and demonstrated that the application of a slot waveguide instead of a normal waveguide increases the sensitivity of an SOI ring resonator with a factor 3.5 for the detection of proteins [3].

Evanescent field sensors provide another means for the label-free detection of target molecules and for real-time monitoring of solutions and binding events that occur near the sensor surface. Experimental evidence supporting the use of a surface-plasmon interferometer as a biosensor is presented. The device is shown to be capable of bulk refractive index sensing (bulk refractometry) and has a spectral interrogation sensitivity of 315.145 nm/ RIU. Qualitative agreement between measurement results and theoretical data has been obtained. Furthermore, we have shown this device is capable of detecting bulk refractive index changes, a first and indispensable step toward label-free biosensing. The measured blueshift, although not yet as large as theoretically predicted, shows the potential of this device to be used as a sensitive and label-free bio-sensor [4].

Optical Coherence Tomography (OCT) is an non-invasive, 3D imaging modality that is analogous to ultrasound but instead of using sound waves it uses broadband light and measures the echo time delay of backscattered photons. Typically, OCT can image tissue cross sections with 10 micron resolution at depths exceeding 2 cm in transparent tissues (human eye, animal embryos) and 2-3 mm in highly scattering (non-transparent) tissues, such as the skin. Miniaturization of OCT has the potential to expand its applications and serve other areas in health care and industry. We present a basic Micheson interferometer in SOI for OCT. Integrated components designed for OCT in SOI can significantly reduce the size of the system [5].

References:

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