HIGH THROUGHPUT LABEL-FREE BIOSENSING WITH INTEGRATED PHOTONIC SILICON-ON-INSULATOR MICRORING RESONATORS

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Abstract We have demonstrated simultaneous detection of multiple antibodies in a highly specific way. We discuss important considerations for high throughput sensing with silicon-on-insulator photonics, including detection limit, non-aggressive microfluidics packaging, receptor binding through a thin PEG 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.

Optical cavities are considered promising devices to satisfy the high demands for real-time screening of complex fluids. The shift of resonance wavelength when biomolecular interaction takes place at the cavity's surface is a direct measure for the number of binding events and can be used for sensing. Using silicon-on-insulator (SOI) as material platform offers high sensitivity through miniaturization and low cost fabrication by means of standard technology steps as used in CMOS fabs, in particular 193nm deep-UV lithography. A detection limit of 3ng/ml is determined based on concentration measurements and a thorough study of all factors that have an impact on the sensor's resolution, such as noise, resonance shape and measurement step.

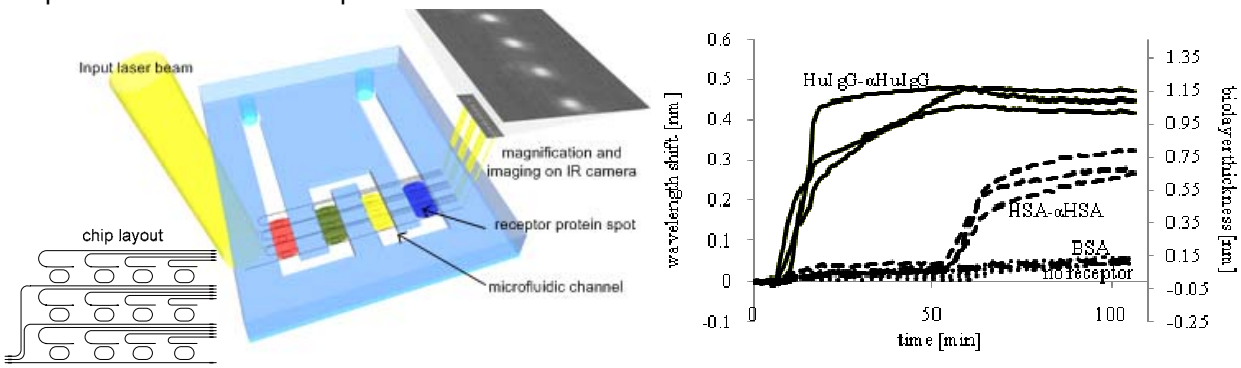

Figure 1. (left) Illustration of the biosensor platform, not to scale. (right) Multiplex biosensing experiment with 3 different molecules spotted on the SOI chip.

The device is illustrated in Fig. 1 (left). Four rings of 10x14µm are connected to one bus waveguide, three of the series of rings are placed in parallel. The input waveguides are addressed simultaneously with a collimated bundle from a tunable laser source. The output signals are vertically coupled to free space by means of integrated grating couplers and are imaged with an infra-red camera. Hence the setup allows for extremely high alignment tolerances. The quality of a biosensor critically depends on the quality of the interfacial layer. We obtain extremely selective biomolecular interaction by grafting a 2.5nm poly (ethylene glycol) (PEG) polymer layer to the silicon [1]. We use a stamp-and-stick method to transfer the channels on the SOI chip without damaging the fragile receptor molecules. In the experiment of Fig.1 (right), three different proteins were spotted on the resonators: HuIgG, HSA and BSA. The fourth column of resonators was left untouched. Two different diluted body fluids are successively pumped through the channels; goat serum with 128µg/ml anti-HuIgG (1.9mg/ml protein) and goat serum with 82.6µg/ml anti-HAS (1.5mg/ml protein). The non-specific background signal is extremely low compared to the specific signal.
When two orthogonal resonating modes (TE and TM) interact simultaneously with biomolecules, we can extract information on the layer thickness and the refractive index, thus on the density and the height of the layer. We show simulations for optimal design of the resonators, compromising on high sensitivity and good separation of both parameters. Theory is matched with experiments through determination of thickness and refractive index of layers with known parameters.

[1] K. De Vos, J. Girones, S. Popelka, E. Schacht, R. Baets and P. Bienstman, " SOI optical microring resonator with poly(ethylene glycol) polymer brush for label-free biosensor applications," Biosensors and Bioelectronics, (2009), 24(8), p.2528-2533.