Photonics microring biosensor platform

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Abstract— **We developed a biosensor platform based on optical microring resonators in Silicon-on-Insulator. We applied a poly(ethylene glycol) coating, integrated the chip with microfluidics and build a read-out system. The device was found to be suitable for multiplexing and sensitive to 10ng/ml molecular concentration.**

I. Introduction

A label free biosensor responds to the interaction of a biomolecule with a receptor molecule attached to the sensor's surface. This overcomes the reliability, stability and quantification problems that commercial tools, based on the detection of a label attached to the molecule, face. An array of label free biosensors coated with different receptor molecules allows thus for fast high throughput screening of for instance a blood sample [1][2]. The optical chip contains an array of extremely small ringresonators ($10x10\mu m^2$). Formed by integrated waveguides, a ringresonator can only contain light from which the wavelength fulfils the resonance condition. When biomolecular interaction occurs at the ring's surface the refractive index locally changes, the resulting resonance wavelength shift can be used for sensing (figure 1A). Silicon-on-Insulator (SOI) offers a very high refractive index contrast, therefore extremely small devices can be made with high quality, resulting in high sensitivity. The devices are fabricated using standard CMOS processing equipment, the mass fabrication technique results in cheap disposable chips.

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The properties of the biosensor critically depend on the quality of the receptor coating layer. Instead of using straight forward chemistry based on silanes, we successfully applied poly(ethylene glycol) (PEG) layers on top of the waveguides to reduce interaction with non-specific molecules in the sample. In the next step we attach different antibody receptor molecules to different sensors using a microliter spotter. To speed up the measurements, we fabricated microfluidic channels and bonded these to the SOI chip. Figure 1B and 1C show a conceptual drawing and a picture of the device. A dedicated optical setup was build which enables scanning of a proof-of-principle biosensor chip with tenths of sensors, consisting of a tunable laser for light incoupling and an infrared camera for capturing of light.

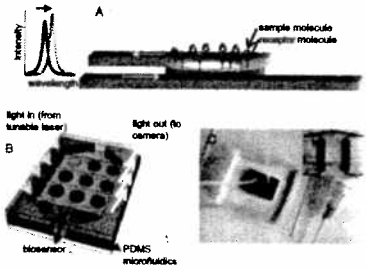

Figure 1. A)microring biosensor principle, B)platform illustration, C)SOI chip with microfluidics image.

II. PEG surface coating

The interfacial layer has to effectively block non-specific interactions and provide enough binding sites for the receptor molecules. Commonly used coatings of low molecular silanes

do not have sufficient resistance to non-specific adsorption. This is improved by attaching an ultra thin layer of a hydrophilic polymer like poly(ethylene glycol) (PEG). We investigated heterobifunctional PEG's with two different endgroups to avoid attachment to the surface through both terminal groups. Chemical characterization confirmed that we obtained good homogeneity, low contact angles (25°) and very thin layers (2.5nm).

III. SOI MICRORING RESONATORS AND PDMS MICROFLUIDICS

SOI microrings are designed to have maximal sensitivity through a maximal extinction and a high quality factor (~20000). We can simulate the minimal detectable thickness, and extract a minimal detectable mass coverage of about 17 pg/mm^2. With a surface area of only 21.84μm^2 a minimal mass of 0.37fg could theoretically be detected [2]. We simulated various microfluidics designs with Comsol and fabricated them in PDMS using a replica molding technique. After surface activation of the PDMS with oxygen plasma, we bond the channels to the chip. The bonding procedure is carefully optimized since the receptor molecules do not sustain high temperatures or usage of a glue.

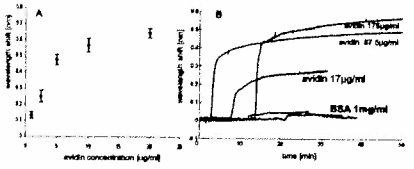

Figure 2. A)Resonance wavelength shift versus avidin concentration, B)Specific and non-specific interaction.

IV. BIOSENSING EXPERIMENTS

The high affinity avidin/biotin couple has been used as model biosensing couple to demonstrate repeatability and detection capabilities of the microring resonators. Bovine Serum Albumin (BSA), a protein with similar molecular weight to avidin but with low affinity to biotin, has been used as a model for non-specific interactions. Phosphate Buffer Saline (PBS) was used as running buffer. Figure 2A shows the resonance wavelength shift for different avidin concentrations. We extrapolate a sensitivity of 10 ng/ml, which compares well with literature values [1]. Figure 2B illustrates the resistance to non-specific interactions of the intermediate heterobifunctional PEG layer. It shows the response signal of the chips to avidin concentrations of 17, 87.5 and 175 $\mu g/ml$ and to 1 mg/ml BSA. The response of 17 $\mu g/ml$ arises 140 times over the noise level, while even for 1 mg/ml BSA the response was only 15 times above the noise level. This is a major improvement over measurements done earlier with silane coated chips.

V. CONCLUSIONS

Photonic chip design, microfluidics, chemistry coating and biological molecular spotting are optimized towards sensitivity and multiplexing. We realized real time, fast and multi-dimensional biosensing with a sensitivity down to 10ng/ml avidin. Next more interesting biological systems will be investigated, which brings the system close to real lab-on-a-chip applications.

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REFERENCES

[1] F. Vollmer, S. Arnold, *Whispering-gallery-mode biosensing: labelfree detection down to single molecules*, Nature Methods, 5(7), 2008.

[2] K. De Vos, I. Bartolozzi, P. Bienstman, E. Schacht, R. Baets, *Silicon-on-Insulator microring resonator for sensitive and label-free biosensing*, Optics Express, 15, 2007.

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