Abstract:

Label-free optical biosensors are particularly interesting because of their ability to tightly confine light while avoiding complications often associated with label dependent detection. However, many traditional optical biosensors often store the majority of their optical energy in the waveguide core, leaving only the evanescent field to interact with biomolecules. In this work we develop nanoporous polymer waveguides and ring resonators which allow increased interactions between core energy and biomolecules. Initial results indicate a 20% increase in device sensitivity between control and porous devices.

Summary of Research:

Significant research efforts have been made at developing advanced biosensing technology over the last few decades yet the amount of commercialized technology hasn’t increased significantly. Devices have been developed based on optical, mechanical, and electrical methods of signal transduction, and have been optimized on the nanoscale [1-4]. Optical devices are of particular interest because of their ability to detect minute quantities, as far down as ten attograms [3]. Many of these current devices rely on fabrication techniques and materials developed in the semiconductor industry, and face difficulties associated with widespread fabrication and the cost of devices. Recently, others have investigated the feasibility of using non-traditional nanofabrication techniques and materials to reduce costs and make devices that are easier to mass produce [2].

However, many of these cheaper polymer devices aren’t capable of matching the sensitivity of their Si counterparts. In this work we investigate how the sensitivity of polymer optical biosensors can be increased to match that of silicon devices and how polymers can provide other advantages in optical biosensing, including robustness and flexibility. Specifically, we use nanoimprint lithography as an alternative to traditional techniques and create porous polymer waveguides and ring resonators where biomolecules can interact directly with the core waveguide energy. Because the energy in the waveguide core is many
times higher than in the evanescent field, we expect porous devices to be more sensitive to changes in the cladding solution than typical ring resonators.

Nanoimprint masters are fabricated on silicon wafers, by depositing a 2 µm film of silicon dioxide, spinning SPR 955 - 0.9 (MicroChem Corporation, Newton, MA, USA) positive photoresist on top, exposing on an i-line autostepper, and developing the resist. The resulting pattern is then etched into the silicon dioxide using fluorine gas based chemistry, and the remaining photoresist stripped off. Waveguides are then fabricated by depositing a 2-3 µm silicon dioxide cladding onto a silicon wafer, spinning a blend of polystyrene and polymethylmethacrylate on top, and imprinting using the master. Later, dimethylsulfoxide can be used to dissolve PMMA from the composite structure, leaving a porous polystyrene waveguide behind. Figure 1 shows characteristic scanning electron micrographs of an example porous ring resonator. Light is coupled into waveguides using a 1550 nm tunable laser, a lensed fiber, and a set of translational stages, and is coupled out using a lens to collect light leaving the waveguide. Microfluidic channels fabricated using traditional photolithography and PDMS-casting are used to deliver fluids directly to the resonators.

By varying the refractive index of the cladding solution and plotting the resonant wavelength of each ring it’s possible to determine the sensitivity of each device (Figure 2). Further, by comparing initial sensitivity results between both pure and porous polystyrene devices it’s possible to measure an approximately 20% increase in the sensitivity of the device, as shown in Figure 3.

![Figure 2](image1.png)  ![Figure 3](image2.png)

Figure 2, left: A resonant peak of a polystyrene resonator is shown at three different cladding refractive indices. As the refractive index of the cladding increases, the resonant peak shifts to a longer wavelength.

Figure 3, right: By plotting the location of different resonant peaks as a function of cladding refractive index and calculating the slope, it’s possible to determine the sensitivity of our ring resonators. Initial results show that porous resonators are approximately 20% more sensitive than pure polystyrene controls.

We expect that an even larger change in the sensitivity of polymer ring resonators will be observed as we optimize the generation of pores in our devices. Further, we’ve recently fabricated resonators which we expect to have a higher Q-factor, allowing us to introduce more pores without reducing the rings’ ability to confine light significantly.

References:


