Silicon Optical Microresonator Based Biosensors

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Silicon on Insulator (SOI) technology platform enables the dense monolithic integration of planar nanophotonic optical components and electronic devices. Applying SOI technology to optical sensing, lab-on-chip applications can be envisioned that test for virtually any biomolecule. [1]

Silicon optical microresonators based on SOI technology platform are one method currently being researched to provide an effective microfluidic biosensor that can be used for pathogen detection, chemical reaction monitoring, and other sensing applications. Monolithic optical resonators in SOI substrates offer the advantage of micron-scale size suitable for lab-on-chip applications.

Optical resonators consist of a waveguide and a resonant cavity (Figure 1).

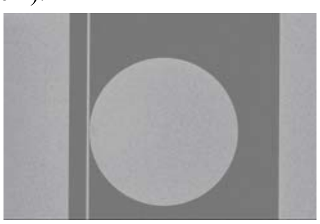

Figure 1: SEM Picture of Silicon Optical Microresonator. Radius: 20µm, height of the waveguide and resonator: 230nm [1]

When light is coupled to the waveguide from a laser source, the resonator traps all the light coupled from the waveguide at certain resonant wavelengths. This is then repeated over a spectrum of wavelengths because of mode changes (m=1, 2 ...) If the refractive index above the optical resonator changes, its resonance changes as well (Figure 2). [2]

$$\lambda_{resonance} = \frac{L}{m} n_{eff}$$

Figure 2: λ is the resonance wavelength; L, the length of the cavity; m, the mode (1, 2...); and n, the refractive index

Thus, to use optical resonators as a sensing device, a microfluidic channel is placed above the resonator to flow different indicies or molecules above the resonator. As a tunable laser sweeps through wavelengths of light, a photodetector detects the output light intensity of the waveguide. In single waveguide resonators, a dip in output intensity indicates a resonant mode. In optical resonators, high quality factors, the measure of the photon lifetime during resonance, are of utmost importance because a higher quality factor leads to a higher sensitivity and thus, smaller molecule detection.

In brief, silicon optical microresonators are fabricated under a perfected electron beam lithography process that provides the highest possible quality factor for the resonator based on its dimensions [2]. A Polydimethylsiloxane (PDMS) microchannel is then fabricated using a soft lithography process and is secured over the microresonator chip after an O_2 plasma surface activation provides the seal between the chip and resonator.

To test the device, bulk refractive index oils are first placed in the flow cell to measure the quality factor of the resonators using the aforementioned setup. Real-time testing using the highly selective biotin/avidin receptor/protein system then continues in order to perfect sensitivity and demonstrate commercial application.

Current research indicates an ultra-high quality factor on the order of 10^6 and refractive index sensitivity on the order of 10^{-5} refractive index units; sensitivity comparable to current state-of-the-art devices. [1,3]

Future designs of optical resonator based sensors will include microspectrometers [1] for lab-on-chip detection and analysis as well as designs for multi-analyte detection on multiple resonators throughout the same chip. Within a few years we may see this technology realized with the introduction of everyday biosensors in our homes.

References

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