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Photonic Biosensors

Optical detection of bioware agents

Overview

Guided wave devices are a unique technology to interrogate fluid properties and operate as high density immunoassays for detection of biowarfare agents. Through our work on low-loss high-Δn, Si2N3/SiO2 planar lightwave circuits, we have realized micro-ring resonators with Q > 2.4x105 fabricated in a standard CMOS production facility. To that end, we have been optimizing waveguide thickness to minimize loss, allowing us to proceed with fluid sensitivity measurements. We designed and fabricated a Mach-Zehnder interferometer with a microring attached to one arm to measure the induced phase change by the ring resonator. A critical step has been control the thickness of guiding region above the rings to maximize sensitivity. We have also designed a fluidic microchannel that permits selected delivery of two distinct fluids to the microresonator rings. Critical to device operation is the use of coupling diode sources to the evanescent device such that the resonant frequency can be monitored during antigen capture or for fluid detection experiments. We have also experimented with additional conjugation approaches to improve film stability for antigen capture.

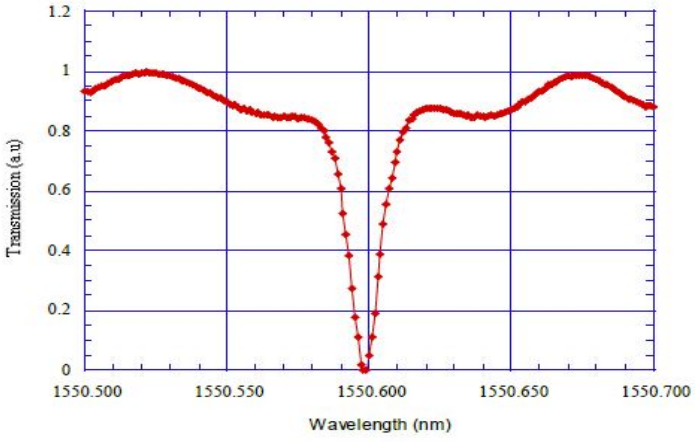

Figure 1. Evanescent microresonant ring with a Q= 240,000. Diameter was 400 µm x 0.2 µm.

Approach

The sensitivity of the evanescent waveguide based photonic biosensor depends on establishing a high quality (Q) factor for waveguide ring resonator. We have successfully demonstrated a Q in excess of 200,000 (Fig. 1) using our microresonators. Crucial to our success was minimizing propagation losses in the Si3N4/SiO2 waveguides. Scattering losses and material absorption due to H-O bonds in SiO2 were reduced by annealing (1050 -1200 °C). The design comprised a thin silicon-nitride rib buried in an upper and lower cladding of silicon dioxide on a <100> silicon wafer. The lower SiO2 cladding was built up using a 2-µm-thick steam silicon dioxide followed by 3 µm of plasma enhanced chemical vapor deposition (PECVD) tetraethylorthosilicate (TEOS) SiO2. A 0.2 µm silicon nitride (Si3N4) waveguide layer was deposited on the lower cladding using a low

pressure chemical vapor deposition (LPCVD) process. The microring resonators and waveguides were patterned with the deep UV (245 nm) photolithography and etched using reactive ion etching (RIE) to define the waveguides. Finally, an upper cladding of 4µm PECVD TEOS silicon dioxide was deposited completing the fabrication. The cross-section of the silicon nitride waveguide was designed to permit single mode operation at 1550 nm wavelength. Our design used measured material index of refraction of 1.448 for PECVD TEOS SiO2 and 1.98 for annealed LPCVD Si3N4 at 1550 nm wavelength.

Planar waveguide ring resonators of 200 µm and 100 µm radius were fabricated. The microring resonators were coupled to straight waveguides using evanescent wave directional couplers of various gap dimensions. The coupling coefficients for each of the gaps were measured using identical couplers on the same wafer. These couplers were designed with the goal that one of them would achieve the critical coupling condition to the microring resonators.

In our previous work, we successfully immobilized antibodies onto the surface of the PETEOS waveguide material. However, there was some concern over the polymerization of the films causing multilayers on the surface. To address this issue, we have used the epoxide-based compound (3-glycidoxypropyl) dimethylethoxysilane (3-GPDES), which prevents polymerization on the PETEOS surface. This improved bioconjugation scheme allows subsequent reaction with available primary amines, thiols, or hydroxyls.

For additional information or questions, please email us at BioNano@sandia.gov.

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