Abstract

Integrated Silicon Photonics has emerged as a powerful platform in the last two decades amongst high-bandwidth technologies, particularly since the adoption of CMOS compatible silicon-on-insulator (SOI) substrates. Microring resonators are one of the fundamental blocks on a photonic integrated circuit chip offering versatility in varied applications like sensing, optical buffering, filtering, loss measurements, lasing, nonlinear effects, understanding cavity optomechanics etc.

This thesis covers the design and modeling of microring resonators for biosensing applications. The two applications considered are: homogeneous biosensing and wrist pulse pressure monitoring. Also, the designs have been used to fabricate ring resonator device using three different techniques. The results obtained through characterization of these devices are presented. Following are the observations made in lieu of this:

1) **Design modeling and analysis** - The analysis of ring resonator requires the study of both the straight and bent waveguide sections. Both rib and strip waveguide geometries have been considered for constructing the device as a building block by computing their respective eigen modes for both quasi-TE and quasi-TM polarizations. The non-uniform evanescent coupling between the straight and curved waveguide has been estimated using coupled mode theory. This method provided in estimating the quality-factor and free spectral range (FSR) of the ring-resonator. A case for optimizing the waveguide gap in the directional coupler section of a ring resonator has been presented for homogeneous biosensing application. On similar lines, a model of applying ring resonator for arterial pulse-pressure measurement has been analyzed. The results have been obtained by employing FD-BPM and FDTD including semi-vectorial eigen mode solutions to evaluate the spectral characteristics of ring
resonator. The modeling and analytical results are supported by commercial software tools (RSoft).

2) Fabrication and Characterization - For the fabrication, we employ the design of ring resonator of radius 20µm on SOI substrate with two different waveguide gaps of 350 and 700 nm. Three different process flows have been used for fabricating the same device. The first technique involved using negative e-beam resist HSQ which after exposure becomes SiO₂, acts as a mask for Reactive-Ion Etching (RIE); helping in eliminating an additional step. The second technique involved the use of positive e-beam resist, PMMA for device patterning followed by metal deposition with lift-off. The third technique employed was Focused Ion-beam (FIB) which is resist-less patterning by bombarding Ga⁺ ions directly onto the top surface of the wafer with the help of a GDS file.

The characterization process involved estimation of loss and observing the behavior of optical fields in the device around the wavelength of 1550 nm using near-field scanning optical microscopy (NSOM) measurement. The estimation of roughness-induced losses has been made by performing Atomic Force Microscopy (AFM) measurements.

In summary, the thesis presents novel design and analysis of SOI based microring resonators for homogeneous biosensing and wrist pulse pressure sensing applications. Also, the fabrication and characterization of 20 µm radius ring-resonator with 500 × 500 nm rib cross-section is presented. Hence, this study brings forth several practical issues concerning application of ring resonators to biosensing applications.