論文の内容の要旨

論文題目　Fabrication and Characterization of Silicon Microcavity Resonators for Chemical Sensing
(化学センシングに向けたシリコン微小共振器の作製と評価)

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The objective of this work is to design, fabricate, measure, and demonstrate the silicon microcavity resonator sensor for chemical sensing. The basic concept of this photonic sensor is based on the measurement of infrared absorption spectrum, the fingerprint for identifying chemical molecules.

In order to realize the sensor for infrared absorption sensing, ring resonator based on single mode silicon strip waveguide is designed as the basic structure of the sensor. The analysis on ring resonator shows that high quality factor is demanded to make the sensor with high sensitivity. During the device fabrication, a special design is applied to control the electron beam spot size and beam scanning step during the electron beam lithography process and this method is demonstrated to be efficient for fabricating better waveguide. Aiming to obtain better waveguide quality, we also apply the direct and indirect treatment methods on waveguides. For the indirect treatment, an upending resist reflow process is used for the investigation of waveguide sidewall smoothing. The result shows that the roughness is estimated to be reduced from 7.4±0.5nm to 6.2±0.5nm, demonstrating that the resist reflow is a simple way to smooth the sidewall roughness of many kinds of waveguides. On the other hand, the direct treatment, a hydrogen plasma treatment on silicon waveguide is performed for the investigation of waveguide sidewall smoothing and waveguide trimming. Due to the etching effect during the hydrogen plasma treatment, the small amount of surface silicon is removed. The result indicates that after the treatment, the typical loss of waveguide is reduced from 63 cm^{-1} to 37 cm^{-1}. The fingerprint of OH-group absorption at near infrared is demonstrated that it can be measured via a ring resonator. The absorption coefficient of OH-group at near infrared (around 1537 nm) is estimated to be about 19 cm^{-1}. About 7% of OH-group concentration could be the detection limit of this sensor based on the equipment used. By using the “model-solid” method, the calculation of strained silicon shows that the band gap of silicon shrinks under strain. The band gap tuning by strain is proved by using a silicon beam structure via the photoluminescent measurement. However, although high strain is generated in the silicon beam, a calculation result shows that there was no obvious photoelastic effect in the beam. The symmetric and complementary strain distribution in the beam is the main reason. From the PL results, obvious resonant peak shifted for the bending silicon beam, which meant that the refractive index changed. The strain caused the variety of refractive index, leading to the shift of resonant peak.