N 型 GeOI 基板を用いた高Q値リング共振器の試作

Fabrication of High-Q Ring Resonator using n-type GeOI wafer

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Introduction: In the past decades, germanium (Ge) has become one of the most prospective candidates for electronic-photonic integrated circuits because of its superior properties in both electronic and photonic applications compared with silicon (Si) [1,2]. Smaller bandgap of Ge made it suitable for a low-cost photodetector in C-band, and Ge also has good transmission properties in mid-infrared (MIR) range [2]. We demonstrated the Ge CMOS photonics platform which uses a Ge-on-Insulator (GeOI) wafer. With its large refractive index contrast we realized a low bending loss of 0.2 dB/90º even when the radius was 5 μm [3]. A 7-μm-radius ring resonator was also fabricated with an unexpected low Q factor of 170 which was attributed to high propagation loss caused by the free-carrier absorption in p-type Ge [4]. In this work, we used n-type Ge to improve properties of an n-GeOI ring resonator.

Experiments: An n-type Ge wafer (100) was pre-cleaned and covered by SiO_2. H^+ ion implantation was then performed for Smart-Cut™. Followed by wafer bonding and splitting, the GeOI wafer was then treated by chemical mechanical polishing (CMP) and annealed in vacuum ambient for recovering crystal quality. The well-prepared GeOI wafer showed the n-type conduction with an electron density of 2.4×10^{15} cm^{-3} measured by hall measurement. Waveguides and rings were fabricated by EB lithography and measured through grating couplers around 1.95 μm.

Results & Conclusions: We fabricated a 7-μm-radius ring with width of 500 nm for single mode transmission. Figure 1 showed the plane view of a ring resonator with a gap of 110 nm where the waveguide width and height was 500 nm and 250 nm, respectively. The Q factor was over 5000 which was around 30 times larger than our previous result. The extinction ratio was over 18 dB. We measured the Ge ring with varied temperatures of 20.0, 25.0, 30.0, 35.0 and 40.0 °C as shown in Fig. 2. The resonance peak shift of the Ge micro ring proportional to the temperature change with $d\lambda/dT$ of 0.182±0.002 nm/°C with keeping similar Q factors. This result indicated the feasibility of a high-quality GeOI ring resonator operating at a wavelength of 1.95μm, which will be useful for future MIR communication and sensing systems.

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References: [1] J. Michel et al., Nature Photonics, 2010, 4(8): 527-534. [2] R. Soref et al., Nature photonics, 2010, 4(8): 495-497. [3] J. Kang et al., Optics express, 2016, 24(11): 11855-11864. [4] J. Kang et al. Optical Fiber Communication Conference. Optical Society of America, 2016.

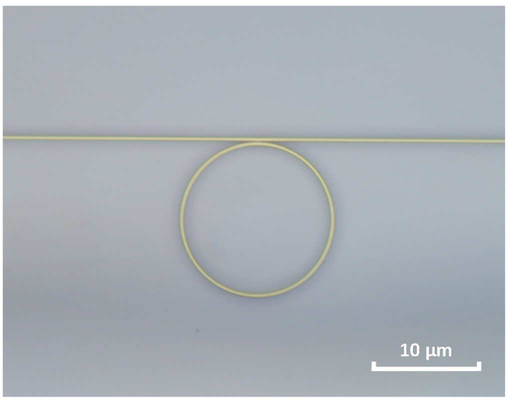

Fig. 1 Plane view of the 7-μm-radius ring resonator.

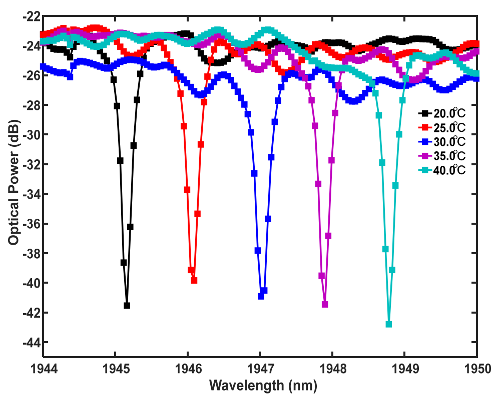

Fig. 2 Temperature-dependent transmission spectra of ring resonator from 20.0°C to 40.0°C.