High Q-factor micro-ring resonator fabrication by charge dissipation in electron beam lithography

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Silicon Nitride (Si_3N_4 or SiN in short) optical micro-ring resonator draws many attentions in integrated photonics society because of its small footprint and high quality factor (Q-factor). Optical frequency comb, a series of equally spaced optical frequency elements, is one of the widely used applications of the micro-ring resonator. However, to realize a fully integrated photonic chip with a several mW level chip-scale laser source, the quality factor above a million or higher is required. The quality factor of the micro-ring resonator is mostly limited by a propagation loss of the photonic waveguide. Among many types of losses, this paper focuses an elastic Rayleigh scattering loss cause by a surface roughness on a sidewall of the photonic waveguide. Since the sidewall roughness is transferred from a patterned e-beam resist, the electron beam lithography process should be optimized to avoid any shot noises. The SiN based integrated photonic platform consists of at least 3 µm of SiO_2 under-cladding layer as well as SiN device layer and FOx-16 negative tone e-beam resist. The insulating dielectric layers can trap electrons during the e-beam exposure, leading increased shot noise due to the coulomb force between the trapped and incoming electrons. To efficiently dissipate the electrons[1,2], we used a conductive aluminum layer below the e-beam resist. The e-beam evaporator metal deposition tool is used to deposit 10 nm of an aluminum layer. After spinning FOx-16, the 900 nm-thick resist was soft-baked at 120 °C for 3 mins. Vistec VB6-UHR 100 keV e-beam lithography tool is used with 1 nA beam current. After the exposing the patterns, the resist was developed by 25 % TMAH for 70 secs. During the development, the 10 nm of Aluminum layer was also etched. Stoichiometric LPCVD deposited SiN layer was etched by ICP-RIE tool with CHF_3 and O_2 gas. 3 µm of SiO_2 top cladding was deposited as a protection layer. A tunable near-infrared laser source was used to characterize the propagation loss of the fabricated photonic waveguide by measuring the quality factor of the micro-ring resonator. With 560 nm height and 2 µm width of the photonic waveguide, the intrinsic quality factor is measured as 5.6 million, which is equivalent to the propagation loss of 0.064 dB/cm.

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[1] J. Zhang *et al.*, Microelectron. Eng. **88,** 2196-2199 (2011).
[2] J. K. Yang *et al.*, J. Vac. Sci. Technol. B, **27**, 2622-2627 (2009)

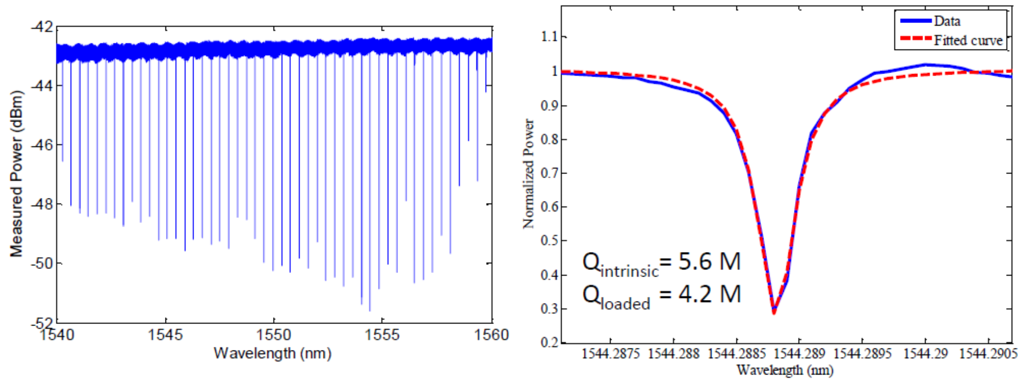

Figure 1: Measured optical transmission of the fabricated micro-ring resonator with a broad bandwidth (left) and magnified plot around 1544.2887 nm (right)

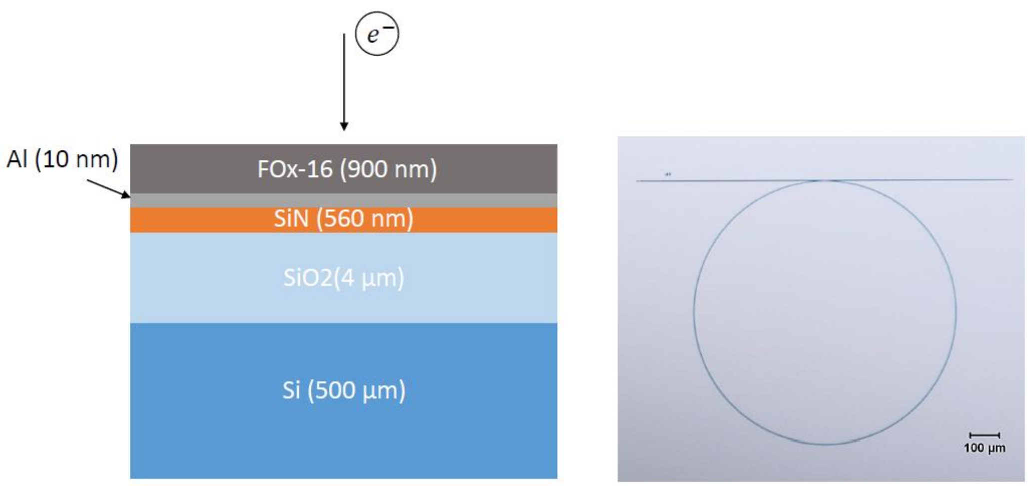

Figure 2: Schematic during the electron beam exposure (left) and optical micrograph of the developed resist pattern (right)