# High Q-factor Small Size Polymer Micro-ring Resonators for High-frequency Ultrasound Detection

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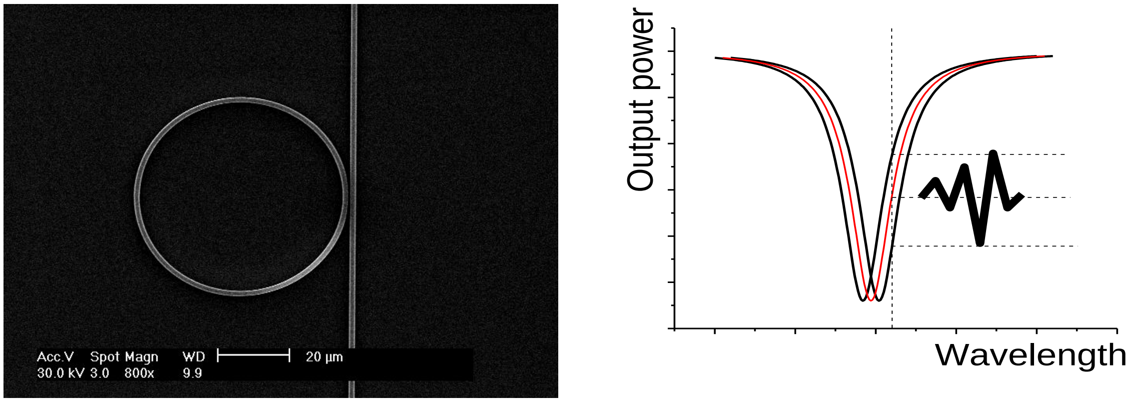
High resolution and high sensitivity ultrasound imaging at the frequency range of 30-100 MHz is capable of resolving structure almost down to cellular level. Developing such an imaging modality for clinical use could have a huge impact on medical diagnosis. High sensitivity detection is desirable for applications such as photo-acoustic imaging for early stage breast cancer detection. Optical detection of ultrasound can avoid the difficulties of realizing high-frequency two-dimensional arrays using piezoelectric technology, which include increased noise level in small elements and complexities of electrical interconnects and fabrication. We have developed polymer micro-ring resonators (SEM image in Fig. 1a) for optical detection of high frequency ultrasound that provides wide band and high sensitivity response [1]. The detection is based on the interaction of polymer waveguide with an incident acoustic wave. The pressure wave can cause strain and thus modulate the optical properties of the microring cavity. A sharp cavity resonance can amplify the optical response to transient acoustic pressure (Fig. 1b).

Our previous experiments were performed by using 100 μm diameter microrings [2]. Such element size will limit the device's spatial resolution in real imaging applications. Smaller size micro-rings are preferred in high spatial resolution 2D imaging system. But smaller size microring waveguide will suffer higher scattering loss that will reduce the device's resonance Q-factor and the sensitivity. The polymer microring resonators were fabricated by an imprinting technique [3]. Smooth sidewalls of the imprinted waveguide are very important to high Q-factor in small size microrings. We have developed a new process to fabricate the nanoimprint molds in Si rather in oxide. By using a thermal oxidation process followed by wet etching, we are able to significantly smooth the sidewall of the silicon mold. With such a mold, we have successfully fabricated the high Q-factor polymer micro-rings with 60 μm diameter. The SEM images in Fig. 2 demonstrate the benefit of the thermal oxidation process in achieving smooth sidewalls.

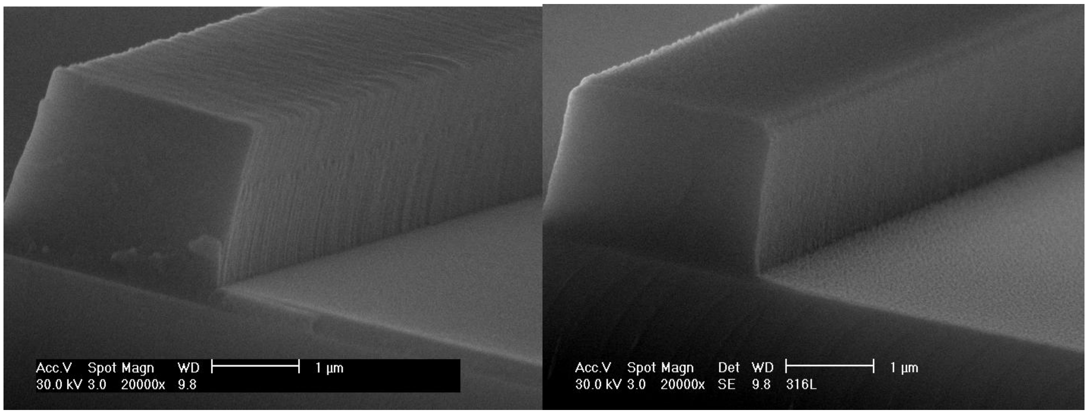
The fabricated device was characterized in a photoacoustic experimental setup (Fig. 3a), in which the ultrasound wave is generated by the thermal expansion of a polymer bead when absorbing the energy from a short laser pulse. The generated ultrasound waveform measured by the micro-ring is shown in the Fig. 3b. More detailed experimental results will be presented at the conference.

[1] S.-W. Huang, S.-L. Chen, T. Ling, A. Maxwell, M. O'Donnell, L. J. Guo and S. Askenazi, *Appl. Phys. Lett*. 92, 193509 (2008)
[2] A. Maxwell, S.-W. Huang, T. Ling, J.-S. Kim, S. Ashkenazi, and L. J. Guo, *IEEE J. Special Topics in Quantum Electronics*, 14, 191 (2008)
[3] C.Y. Chao, L.J. Guo, *J. Vac. Sci. Technol*. B, Vol. 20, No. 6, (2002)



(a) (b)

Fig.1. (a) SEM picture of a polymer micro-ring resonator with 60 µm diameter. (b) Principle of ultrasound detection. Phase modulation caused by acoustic pressure is transformed into amplitude modulation of device’s optical output power.



(a) (b)

Fig. 2. SEM images of (a) polymer waveguide imprinted by silicon mold without thermal oxidation process, and (b) waveguide imprinted by silicon mold with thermal oxidation process.

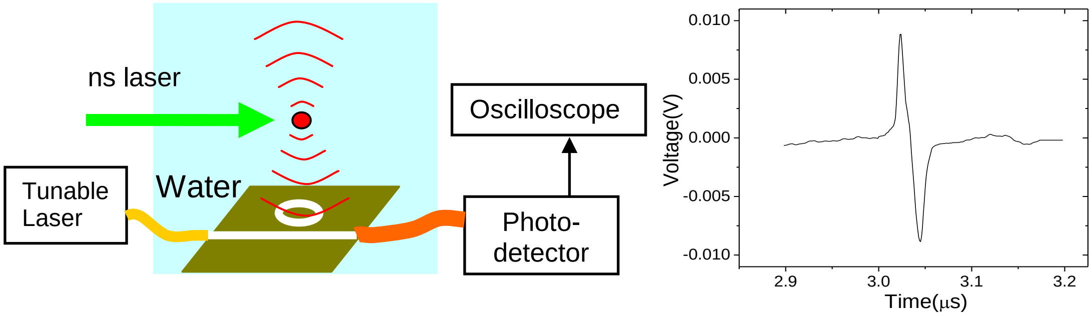


Fig. 3. (a) Schematic of photoacoustic experimental setup. (b) Single-shot acoustic waveform measured by the polymer micro-ring resonator with 60 µm diameter.