High-quality factor of micro ring resonator array using Nano-imprint lithography for photoacoustic tomography imaging applications

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Abstract

This study presents the fabrication and application of high-performance polymer-based micro ring resonators array with 40 elements tailored for ultrasound signal detection, in particular, to attempt photoacoustic tomography for the first time. Utilizing nanoimprint lithography (NIL), we developed a micro ring resonator array characterized by a high-quality factor and enhanced sensitivity utilizing the polymer's high photo-elastic coefficient. By employing a 3 wt% polystyrene solution, known for its refractive index of 1.577 at 780 nm, we achieved excellent optical transparency and significant photo-elastic responses. The thermal imprinting process was conducted with a Nanonex NX-2000 system to maintain consistent and uniform waveguide formation. By precisely increasing the radius of each micro ring, we achieved distinguishable resonant wavelengths within a free spectral range of 1.291 nm and a high-quality factor of 1.1073×10^5. To demonstrate the controllability of the micro ring array, we performed photoacoustic tomography that utilizes the acoustic-sensitive micro rings. The micro ring resonator array demonstrated an acoustic bandwidth of 173.5 MHz, an acoustic sensitivity of 121.8 μV/Pa at 10 MHz, and a noise equivalent pressure of 13.5 Pa. These parameters enabled the micro ring array to achieve photoacoustic images without translating the array device. We validated the feasibility of the array device in photoacoustic imaging by reconstructing images from complex structures, such as a mouse prostate. The reconstructed images showed a high correlation with actual biological contours and highlighted blood vessel regions. These results confirm the device's capability to capture high-resolution, low-noise photoacoustic images. Our research highlights the significant advantages of NIL-fabricated micro ring resonator arrays fabricated from polymer materials, demonstrating the potential for advanced applications in optical communications, integrated photonic systems, and biomedical imaging.

Figures

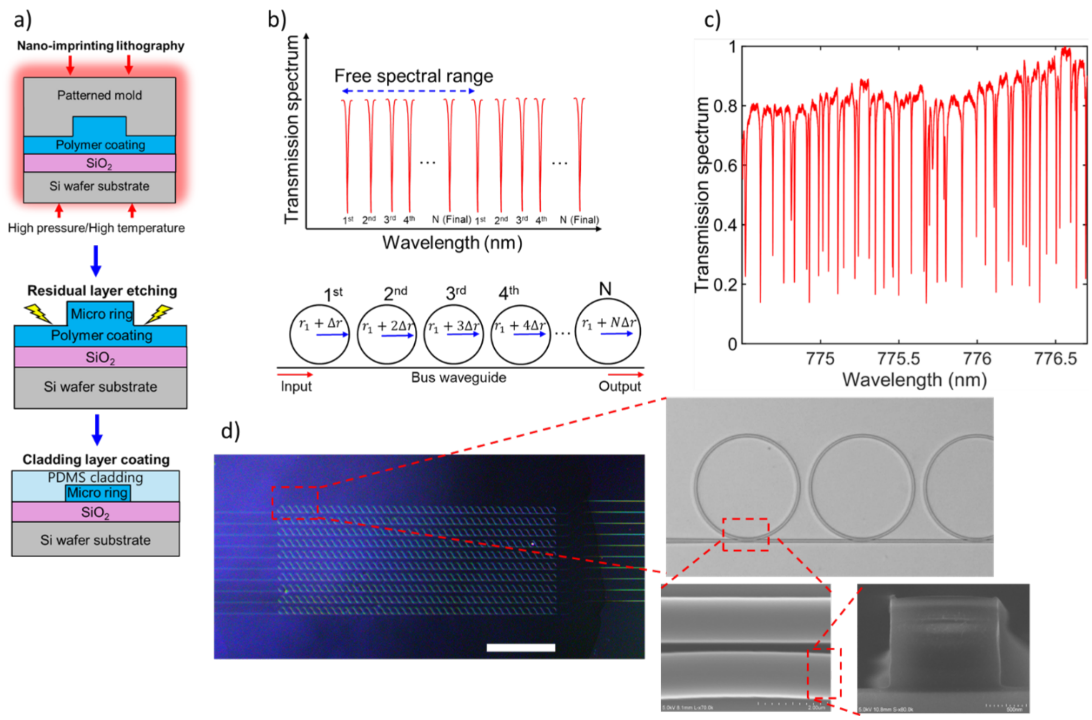

Figure 1. a) Schematic diagram of NIL fabrication processes. b) schematic diagram of this work for achieving micro ring resonator array. c) Transmittance spectrum of proposed micro-ring array and its photograph. d) Photograph of fabricated micro ring array with a different gap size of waveguides, and SEM images of gap between waveguides and cross view of waveguide.

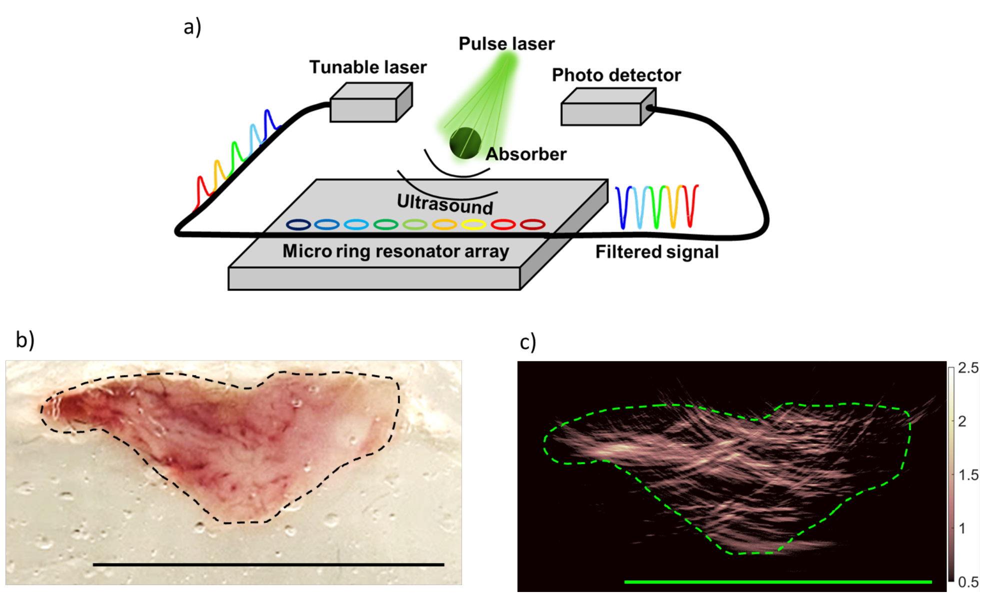

Figure 2. a) Schematic diagram of photoacoustic imaging. b) Photograph of mouse prostate and c) photoacoustic tomography image.