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Development of Optically Transparent Ultrasound Transducers for Combined Ultrasound and Photoacoustic Imaging

Sunghun Park[1], Sungwoo Kang[1], Jin Ho Chang[1,2], [1]Electronic Engineering, Sogang University, Seoul, 04107, Republic of Korea, [2]Biomedical Engineering, Sogang University, Seoul, 04107, Republic of Korea

Background, Motivation and Objective

Photoacoustic microscopy (PAM) is capable of providing functional images with high spatial and contrast resolutions, for which a laser delivery module and an ultrasound (US) transducer should be integrated. Both optical and acoustic mirrors have been used to deliver light into the target and receive photoacoustic (PA) signals from the target at the cost of signal loss. Ring transducers have also been employed despite lowered spatial resolution and complicated fabrication process because irradiated light can pass through the opening at the center of the transducers. Such integration methods were invented due to the optical opacity of US transducers. Here, we report a recently developed optically transparent US transducer for PAM (see Fig. 1(a)).

Statement of Contribution/Methods

The developed transducer consisted of lithium niobate ($LiNbO_3$) as an active material and epoxy for both backing and acoustic lens that are all optically transparent. ITO (Indium Tin Oxide) was deposited on both surfaces of the LiNbO3 as electrodes, which is also optically transparent. The thickness of the LiNbO3 was determined to be 280 µm, so that the transducer had a center frequency of 11 MHz; its size was 7 by 7 mm^2. The backing block was designed to be easily combined with an optical fiber buddle (Fig. 1(b)). To achieve sufficient spatial resolution for PAM, an acoustic lens was designed for a focal length of 11 mm; F-number was 1.11.

Results/Discussion

From a pulse-echo response test, it was found that the developed transducer had a center frequency of 11.21 MHz and a focal length of 11 mm. The lateral beam width was 190 µm at the focal depth, and depth of focus was measured as 1.4 mm. A fluence of 1.51 mJ was decreased to 0.13 mJ after passing through the transducer. The ability of the transducer to produce combined US and PA images was verified through the experiment with a vascular mimicking phantom. Silicone tubes with a diameter of 1 mm were filled with either blue or red ink. Nd:YAG laser pulses with wavelengths of 750 and 850 nm and US were sequentially delivered to the phantom to obtain both spectroscopic PA and US images. The combined US and PA images exhibited the ability of the developed optically transparent transducer to distinguish between two types of the optical absorbers in the PA images as well as to provide structural information in the US images.