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Design of polymer-based PMUT array for multi-frequency Ultrasound imaging

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Background, Motivation and Objective

Portable multi-frequency ultrasound (MF-US) imaging has the potential to provide long-term monitoring with high resolution images of deep penetration depth, paving the way for expedited diagnosis, follow-up and treatment. Piezoelectric micromachined ultrasound transducer (PMUT) arrays can achieve this due to their high density, low-cost and low-energy consumption as compared to traditional bulk piezoelectric (BP) transducers. However, their multi-frequency properties remain unclear. In this paper, we demonstrated the design and characterization of multi-frequency polymer-based PMUT array intended for novel imaging applications.

Statement of Contribution/Methods

PMUT devices are designed and thereafter fabricated using polymer-based large area technology [1]. A 15 µm polyimide layer is deposited on top of circular microcavities with diameter of 400 µm . These membranes are actuated by 500 nm polyvinylidene fluoride (PVDF) sandwiched between two conductive layers as shown in Fig. 1a, 1b and 1c. Finally, a thin layer of Parylene coating is deposited on the surface to make the devices immersible for imaging applications. A 36 ×16 row-column PMUT array is actuated in parallel by 5-cycle 27 Vpp pulses between the top-row and bottom-column electrodes. To characterize the PMUT array, the resonance frequencies and membrane mode shapes of discrete devices at different locations of PMUT array are measured in air using a laser Doppler vibrometer (LDV). In water, resonance frequencies are again characterized by LDV and the transmitted pressure field of the whole PMUT array is measured using a hydrophone mapping system. Moreover, the pulse-echo signal reflected by 12 cm depth water surface is captured using a US pulser.

Results/Discussion

The membrane mode shapes (M01, M02, M03) are characterized and the cross-section profiles of PMUT devices (D = 400 µm) are plotted in Fig. 1d. As shown in Fig. 1e, the resonance frequencies averaged across the array for each mode shape are measured as 0.5 MHz (M01), 2 MHz (M02) and 4MHz (M03) in air. In water, the frequencies are shifted into 0.2 MHz (M01), 1.1 MHz (M02) and 2.7 MHz (M03) with membrane velocity peaked at the second mode-M02. Based on these results, the PMUT array is selected to be driven by 1.1 MHz at M02 in water and the pressure intensity is characterized as 3170 Pa at the depth of 20 mm using the drive as mentioned above (see Fig. 1f). In addition, the pulse-echo signal of PMUT array is received as 0.04 mV per driven voltage. Instead of integrating multiple single-frequency BP transducers, the proposed PMUT array is promising to achieve multi-frequency imaging in a portable manner.

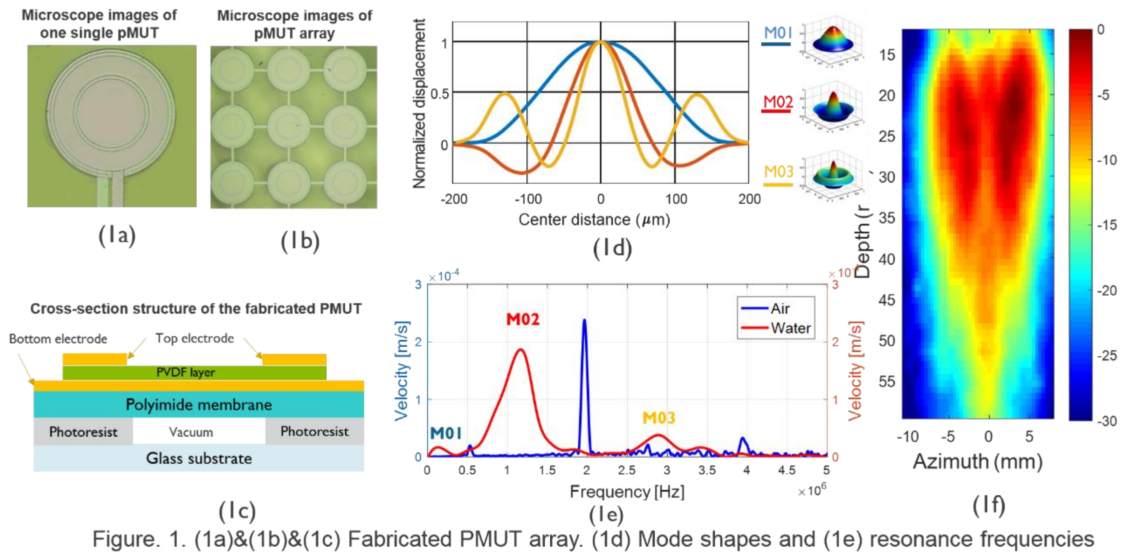

Figure. 1. (1a)&(1b)&(1c) Fabricated PMUT array. (1d) Mode shapes and (1e) resonance frequencies characterization in air and in water. (1f) Pressure mapping of a 36 x 16 PMUT array at mode 2 (M02).

[1] Huang, C. H., et al. "Design, modelling, and characterization of display compatible pMUT device." EuroSimE, (pp. 1-4). IEEE, 2018.