Valveless Microfluidic Flow Control Using Planar Fresnel Type GHz Ultrasonic Transducers

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Background, Motivation and Objective

Micropumps are key components in controlled delivery of chemical and microbiological samples in microanalytical systems. Various micropump technologies employing external electrical, magnetic and acoustic energy sources have been reported. However, acoustic based devices are advantageous as they perform contactless fluidic flow control without any restriction on the physical properties of the fluids. Traditional acoustic pumps based on SAW or membrane-based transducers use bubbles to efficiently generate streaming, require high voltages to operate, and the fluid is placed on the same side of the transducers necessitating considerable chip area to isolate electrical interconnects from the fluidic sample. We devised a planar CMOS compatible Fresnel type transducer that focuses GHz sonic wave through silicon. With higher frequency, attenuation in fluids increases, enhancing streaming forces. Further, the fluid is placed on the opposite side of the transducer enabling easier integration of transducer array and fluidics.

Statement of Contribution/Methods

A four-element linear array of Fresnel type transducers (Fig.1a, b) was fabricated using planar CMOS compatible materials such as AlN and Si. The Fresnel type transducer of outermost radius 165µm emanates bulk acoustic waves that propagate through the silicon substrate and add in phase at the focus located on the opposite side of the substrate; where a receive transducer of 2µm radius is placed. A PDMS microchannel of 27µm height fabricated using soft lithography process, was attached such that the receive transducers of the array were enclosed. At the input port, water with 2µm radius polystyrene beads was input at a constant flow rate using an external syringe pump. The RF input to the transducers was pulsed using a switch, and alternate transducers were excited in phase to generate peristaltic motion.

Results/Discussion

The transducer's resonant frequency was determined using Polytec UHF vibrometer. The peak displacement at resonance for various input voltage amplitudes was measured (Fig. 1c). In our experiment, the transducer was pulsed with a 1.08GHz, 19dBm RF signal. The pulse repetition frequency was varied from 100kHz to 500kHz. Due to acoustic streaming in water, the flow rate of water was controlled in the channel. Fig. 1d shows the microfluidic pump and the flow in channel at different input conditions.

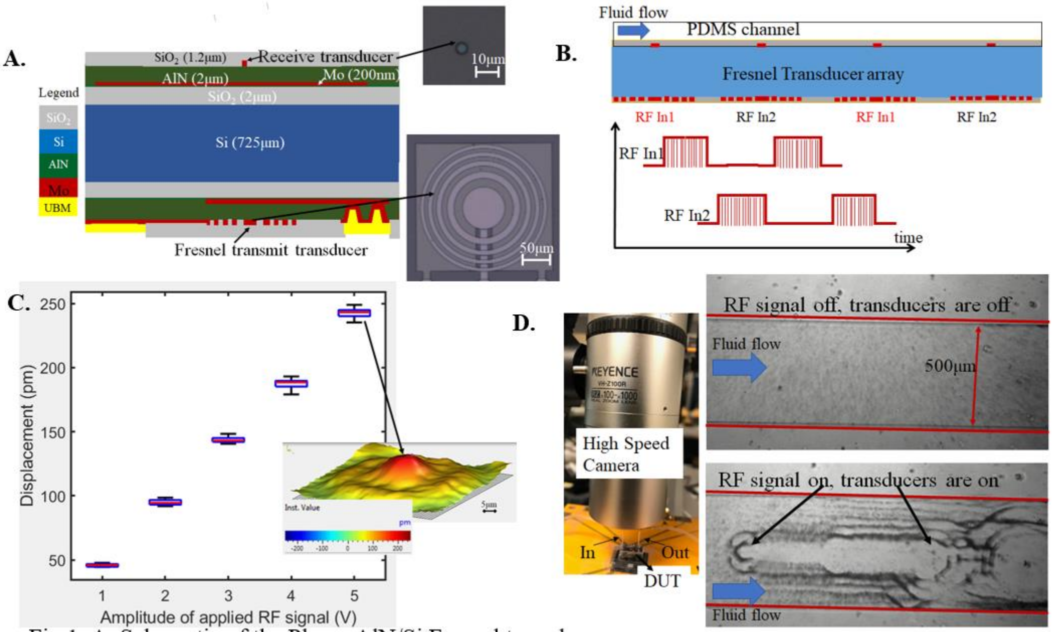

Fig.1: A. Schematic of the Planar AlN/Si Fresnel transducer with images of the fabricated devices; B. Pulsed RF excitation on alternate transducers; C. Peak displacement vs. applied RF input and 3D surface displacement plot ; D. Device under Keyence HS camera, focusing on the transducers underneath the channel