High Frequency Sensors and Actuators for Ultrasonic Imaging and Sensing

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Primary CNF Tools Used: Olympus BX-51 Fluorescence Microscope, Zygo Optical Profilometer, VersaLaser Engraver, Harrick Plasma Generator

Abstract:

Geegah, Inc., specializes in developing ultrasonic imagers that are compatible with complementary metal-oxide-semiconductor (CMOS) technology and operate at gigahertz (GHz) frequencies. These imagers are designed with an array of transducers made with thin film of aluminum nitride (AlN), each measuring $50 \times 50\ \mu$m. The acquisition of high-resolution images consisting of 128×128 pixels can be performed at a sampling rate up to 20 fps. Geegah's technology finds applications in diverse fields. It can be used in agriculture for soil imaging [1] and nematode detection [2]. It also enables the monitoring of fluid flow and mixing [3] of colorless liquids in opaque substrate microfluidic channels. Other applications currently being explored include lens imaging [4], microbes and biofilm analysis, water quality sensing, tissue imaging [5], and skin analysis. While the imaging chips are manufactured in a commercial CMOS foundry, early packaging of these systems was done in CNF. Furthermore, other packaging and analysis tasks performed in CNF include fabrication and bonding of Polydimethylsiloxane (PDMS) microfluidic channels on Geegah chips, fluorescence imaging to validate biofilm growths, and height profile analysis of thin films on imaging surface.

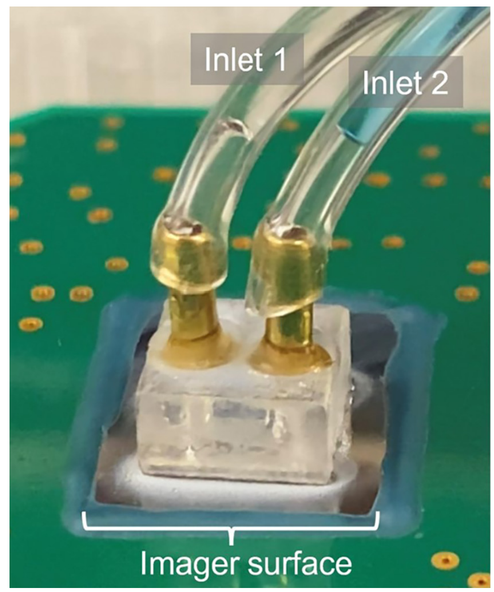

Figure 1: Ultrasonic imager with a microfluidic chip attached to the sensing surface.

Summary of Research:

Microfluidic channels on-chip enable real-time visualization of fluid flow and mixing based on the acoustic impedance differences between the liquids. This enables monitoring photo-sensitive liquids in dark, transparent fluids without the aid of color dyes, and visualization of fluids inside opaque microfluidic channels. The device that consists of a semi-transparent microfluidic channel bonded on the imager chip is shown in Figure 1. Various shapes of channels were patterned on PDMS molds using the VersaLaser Engraver and plasma bonded to the silicon surface using Harrick Plasma Generator. This device is then used to visualize mixing of two transparent liquids, alcohol and water, as shown in Figure 2. Note the benefit of acoustical approach when it comes to imaging of optically transparent liquids as the captured contrast stems from the acoustical impedance differences, not from the differences in optical properties.

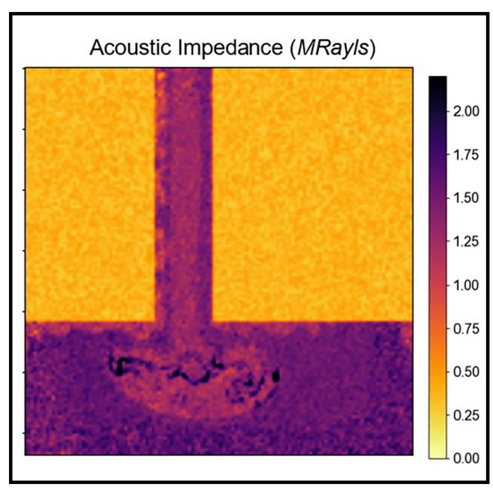

Figure 2: Acoustic impedance map showing jet of ethanol (99%) mixing with water in microfluidic channel captured at 1.853 GHz.

Conclusions and Future Steps:

Overall, various applications have been demonstrated using the GHz ultrasound imaging technology, including but not limited to microfluidics monitoring, biofilm tracking, soil sensing, and tissue imaging. The visualization of structures/layers, in addition to the measurement of acoustic impedance, enables the exploration of various biological and chemical processes using this novel chip. In the future, various patterned PDMS structures as well as other substrates will be attached and tested on the Geegah imager. Furthermore, chemical reactions forming precipitates along with exothermic and endothermic reactions will be monitored using GHz ultrasound imaging.

References:

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[4] Hwang, J., Baskota, A., Davaji, B., Kuo, J., and Lal, A. (2022, October). Gigahertz Metamaterial Ultrasonic Lens Characterization Using GHz CMOS Integrated Ultrasonic Micro Imager. In 2022 IEEE International Ultrasonics Symposium (IUS) (pp. 1-4).

[5] Baskota, A., Kuo, J., Ardanuç, S., and Lal, A. (2023). Compact GHz Ultrasonic Micro-Imager for Cells and Tissues. Microscopy and Microanalysis, 29(Supplement_1), 1116-1117. https://doi.org/10.1093/micmic/ozad067.572.