High Frequency Sensors and Actuators for Ultrasonic Imaging

CNF Project Number: 2876-20

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Primary CNF Tools Used: SÜSS MA6 Contact Aligner, PT740 Reactive Ion Etcher,
E-Beam Evaporators, PECVD Deposition Tools

Abstract:

Geegah develops CMOS compatible ultrasonic imaging for fast and high-resolution environmental sensing; thanks to the high excitation frequencies (>1GHz) and lack of mechanical scanners that are typical to many commercial scanning acoustic microscopes. Using ultrasonic transducers made from aluminum nitride (AlN) deposited on top of CMOS, Geegah demonstrated imaging worms in soil, drying blood droplets, 3-D printed ink, fingerprints, and bacteria colony growth at frame rates more than 6Hz with 128 × 128 pixel arrays [1-3]. While the imaging chips are manufactured in a commercial CMOS foundry, early packaging of these systems were done in CNF.

For some applications that require imaging of soft materials or sensing over long distances in liquid, high acoustic impedance of AlN and large acoustic absorption due to high frequency of operation are not desired. To be used in this complementary set of applications, Geegah has been developing PVDF-TrFE spin-on piezoelectric films in CNF. These transducers are expected to operate at frequencies from 20 MHz to 600 MHz and are being fabricated using a three-mask process.

Summary of Research:

Planar ultrasonic transducers realized on silicon substrate emit ultrasonic waves through the piezoelectric effect. Amplitudes and nature of these waves are a function of the elastic properties of the transducer stackup as well as the frequency and amplitude of excitation. These ultrasonic waves can be used for imaging and sensing through pulse-echo operation where one transducer transmits and the other or the same transducer receives. Time-of-flight and amplitude of the received pulse in this process is used for sensing or imaging. Crystalline nature of the silicon substrate helps by providing a low acoustic loss medium as these waves propagate through the substrate.

The PVDF-TrFE is a much softer material than both silicon and AlN, and hence it is commonly used in biomedical sensing applications. Figure 1 shows the 3-mask process we developed to fabricate PVDF-TrFE transducers. The process starts with PECVD SiO_2 deposition on blank silicon wafer to serve as an insulation material. Then bottom electrode material, aluminum, is evaporated and patterned using the first mask and wet etching. Next, off-the shelf PVDF-TrFE powder is dissolved in a solvent and spun on the wafer to get thicknesses varying from 1.5 to 2.5 µm. The film thickness vs. spin-speed characterization curve is given in Figure 2. Following vacuum annealing and curing, the piezoelectric film is patterned using the second mask and an oxygen plasma etcher. Due to the reaction of standard photoresist removal solutions with the PVDF-TrFE film, a double exposure photoresist strip step is followed. Finally, a top metal layer is evaporated and patterned using the last mask.

Figure 3 shows the picture of a 200 µm diameter transducer after the lithography for the top electrode. Next steps involve dicing As for the high frequency imaging applications, Figure 4 illustrates a typical ultrasonic image acquired using Geegah's imaging chip, which was wirebonded and packaged in CNF. Here, the sample imaged is conductive ink printed directly on the surface of the imager for use in quality control of additive manufacturing [4].

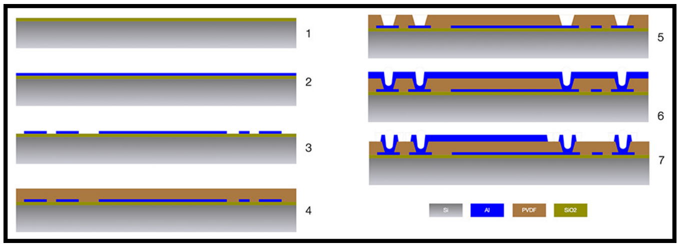

Figure 1: Process flow for the PVDF-TrFE ultrasonic transducer fabrication.

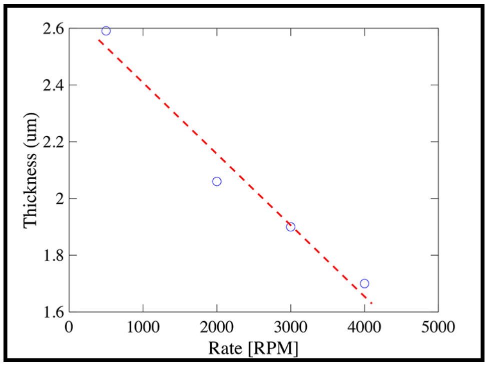

Figure 2: Characterization of the PVDF-TrFE thickness control using the spin-speed.

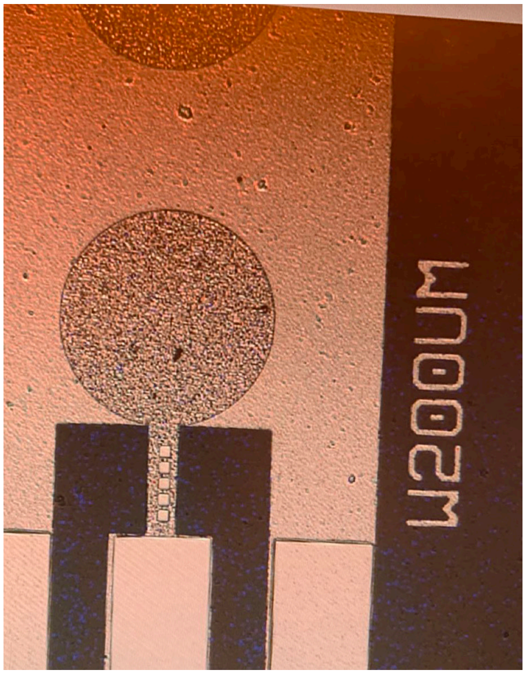

Figure 3: Picture of a fabricated 200 µm diameter device.

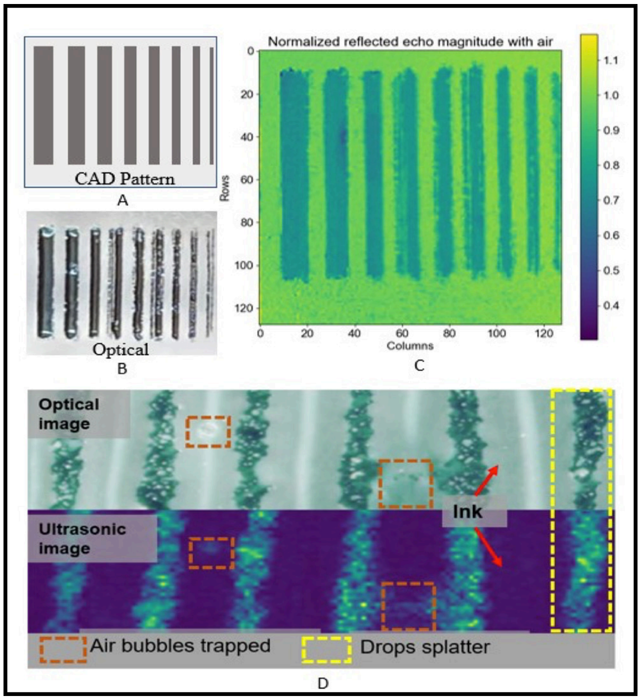

Figure 4: A) CAD pattern (grey area shows ink) for printed conductive ink lines. B) Optical image of the printed conductive ink on the imager surface. C) Ultrasonic image of the same ink patterns. D) Optical and ultrasonic images showing defects in the ink print pattern: air bubbles trapped within ink and tiny drops splattering between the ink lines [4].

In addition to imaging elastic properties, our results showed that the phase of the received echo carries signature of the temperature changes in the medium and sample.

Conclusions and Future Steps:

A PVDF-TrFE ultrasonic transducer is being developed to enhance imaging for materials with lower acoustic impedances or through longer fluidic coupling mediums. The three-mask process flow is close to completion and devices will be ready for testing following dicing and polarization. This process is expected to complement the high-frequency ultrasonic imaging capabilities and work with softer materials at lower excitation frequencies.

References:

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