Monolithic ultrasonic integrated circuits

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Ultrasonography based on traditional bulk piezoelectric transducers has been established as an inexpensive and safe medical imaging modality. By borrowing techniques from the microelectronics industry, the performance of the ultrasound transducer can be dramatically improved and new applications become feasible. Dr. Arman Hajati and his co-workers from Fujifilm Dimatix (FDMX), Santa Clara CA, have developed a high performance ultrasound transducer technology. This novel transducer technology is based on an array of three-dimensional micromachined semi-ellipsoidal piezoelectric domes made of the high-quality PZNT thin film developed at FDMX. This work is published in the journal *Applied Physics Letters* on November 11, 2013.

Thin-film processing techniques have enabled highly-customizable integrated circuits (IC) containing hundreds to billions of components with complex and powerful functionalities in various fields. Electronics, photonics and sensors have benefited from large-scale integration technologies and have enabled solutions which were not imaginable with discrete circuits. Nevertheless, acoustic devices have not benefited from this trend of integration. FDMX is proposing an acoustic analog of a monolithic microwave integrated circuit (MMIC) as the alternative in which various micromachined acoustic resonators can be coupled to synthesize the desired acoustic frequency response.

"We have built a musical instrument by building these tiny domes which act like the strings of a guitar or a harp," says Hajati, the principal investigator and the lead author of the paper. "Each dome gives you an acoustic note defined by its tension and size, again just like the strings of

guitar or harp! We can compose a very rich melody by putting these extremely high pitch notes (ultrasound) together."

Analogous to IC technology, a monolithic integrated ultrasonic circuit (MUIC) is tailored by lithography with four main advantages over bulk piezoelectric transducers: ease of integration, performance, customization, and miniaturization capability. Three dimensional semi-ellipsoidal piezoelectric membranes were introduced as the highly customizable building block of the MUIC. The testing results of five different devices which were fabricated on the same wafer were presented to demonstrate the performance and customization capability of this technology.

MUIC can be implemented as a desirable solution in various medical imaging and therapeutic applications. Exploiting its small form-factor, high sensitivity, low voltage level and low impedance well matched to micro-coaxial cables, the transducer can be incorporated into various high performance miniaturized ultrasound catheters such as EUS, TEE, ICE and Intravascular Ultrasound (IVUS) catheters. Besides in-vivo imaging, this new technology can enable high performance, low-power, low-voltage and portable 3D/4D sonography and an affordable 3D Ultrasound Stethoscope. Furthermore, it is well suited as a miniaturized electronically-steering phased-array probe for HIFU ultrasound endotherapy. Finally, the MUIC can be easily integrated with other functionalities such as low-voltage CMOS electronics, optical components and other MEMS and sensor technologies using 3D Wafer-Level-Packaging (WLP) techniques, enabling unforeseen applications.

More information: Arman Hajati, Dimitre Latev, Deane Gardner, Mats Ottosson, Darren Imai, Marc Torrey, Martin Schoeppler, Monolithic Ultrasonic Integrated Circuits based on Micromachined Semi-Ellipsoidal Piezoelectric Domes. *Applied Physics Letters*, 103(20), 2013. dx.doi.org/10.1063/1.4831988

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