Introduction to the Special Issue on Micromachined Ultrasonic Transducers

Ultrasonic transducers have traditionally been implemented with crystals such as quartz, lithium niobate, lead zirconium titanate combinations, and others; or with capacitors but mostly in airborne ultrasound applications. With the advent and maturation of silicon micromachining, new possibilities for making ultrasonic transducers have emerged, both for piezoelectric based and capacitor based devices, and for both airborne and immersion applications.

Thin vibrating membranes of silicon, silicon nitride, alumina, diamond, and other materials can be easily made and vibrated with piezoelectric, capacitive, magnetic, thermal, and other types of driving mechanisms. More attention has been given to capacitive ultrasonic transducers because with the use of integrated circuit manufacturing techniques it is possible to make capacitors with sub-micron gaps where electric fields of over 10^8 V/m can be sustained. The merit of such a high electric field is that it results in transducers where the electromechanical coupling coefficient can get close to unity, and thus be very competitive with the best piezoelectric materials. Added to this advantage is the broad bandwidth resulting from using over-damped membranes in immersion applications, the control afforded by integrated circuit manufacturing techniques in making single element, 1-dimension, 1.5-dimension, and 2-dimension arrays, and the ease of integration of the transducers with electronic circuits.

The last ten years have seen a tremendous rise in the research and development of the micromachined ultrasonic transducers as evidenced by the number of papers on the topic in conferences and scientific journals. Another evidence of the growth in the field is the development of research activities in the topic in most countries around the world. In Europe for instance, European community funding has enabled research and collaboration between groups in various countries. Such activities seem to be on a course of continuing growth towards adoption of the technology, at least for some niche applications. Presently, there is commitment from major medical ultrasound imaging companies to provide commercial products with these transducers, in the very near future.

This special issue attempts to offer a number of publications that span a comprehensive list of topics of interest in the development of the micromachined transducer. A lot of good development in modeling and implementation has taken place in 10 years, but more, much more needs to be done to bring about a complete understanding of these devices. It is hoped that this issue will help encourage more research and development in this field to help realize the full potential of the micromachined ultrasonic transducers.

Prof. B. (Pierre) T. Khuri-Yakub, Guest Editor
E. L. Ginzton Laboratory, room 11
Stanford University
Stanford, CA 94305-4088

Butrus T. Khuri-Yakub (S'70–S'73–M'76–SM'87–F'95) was born in Beirut, Lebanon. He received the B.S. degree in 1970 from the American University of Beirut, the M.S. degree in 1972 from Dartmouth College, Hanover, NH, and the Ph.D. degree in 1975 from Stanford University, Stanford, CA, all in electrical engineering.

He joined the research staff at the E. L. Ginzton Laboratory of Stanford University in 1976 as a research associate. He was promoted to a senior research associate in 1978 and to a professor of electrical engineering (research) in 1982. He has served on many university committees in the School of Engineering and the Department of Electrical Engineering at Stanford University. Presently, he is the Deputy Director of the E. L. Ginzton Laboratory.

Dr. Khuri-Yakub has been teaching at both the graduate and undergraduate levels for over 15 years. His current research interests include in situ acoustic sensors (temperature, film thickness, resist cure, etc.) for monitoring and control of integrated circuits manufacturing processes, micromachining silicon to make acoustic materials and devices such as airborne and water immersion ultrasonic transducers and arrays, and fluid ejectors, and in the field of ultrasonic nondestructive evaluation and acoustic imaging and microscopy.

Dr. Khuri-Yakub is a fellow of the IEEE, a senior member of the Acoustical Society of America, and a member of Tau Beta Pi. He is associate editor of *Research in Nondestructive Evaluation,* a Journal of the American Society for Nondestructive Testing. He has authored over 300 publications and has been principal inventor or coinventor of 52 issued patents. He received the Stanford University School of Engineering Distinguished Advisor Award, June 1987, and the Medal of the City of Bordeaux for contributions to NDE, 1983.