Short Course on October 7, 2012

Title: **Piezoelectric Fundamentals – Materials and Transducers**

Instructors: **Susan Trolier-McKinstry** Materials Research Lab, Penn State University, **Sandy Cochran** Institute for Medical Science and Technology, University of Dundee, **Christine Démoré** Institute for Medical Science and Technology, University of Dundee

Course Description

Piezoelectric ultrasound transducers are crucial in most contemporary ultrasound systems, with applications including biomedical therapy and imaging, nondestructive evaluation, and underwater sonar. This course covers topics that provide a strong foundation of understanding of the fundamentals of piezoelectric materials and their use in ultrasound transducers, and an informed appreciation of more advanced subjects in this state of the art technology. The course is divided into two sections.

Ceramic, single crystal, polymer and foam piezoelectric materials are introduced in the first section, along with the mathematical descriptions for them and their behavior, and an explanation of the physics underlying these descriptions. The nature of different materials is presented with particular reference to the phase diagram and to domain structures. This allows the behaviour of existing materials to be understood, as well as the possibility to predict the behaviour of new materials according to their composition and structure. New materials such as binary, ternary and doped ternary single crystals are compared with those in use since the 1950s, and lead free materials are considered for the future.

In the second section, the operating principles of transducers based on piezoelectric materials are described with reference to wave propagation within and external to the transducer. Electrical impedance spectroscopy is introduced for both material characterisation and transducer performance prediction, along with ultrasound transmission and reception techniques. Different types of the one-dimensional model are presented, along with a summary of the capabilities of finite element analysis. These lead into descriptions of external electrical circuitry, including the latest integrated electronic implementations, with a particular focus on how electronics and signal processing can compensate for particular aspects of material behavior and transducer structure.

Throughout the course, practical demonstrations and modeling will be utilised to illustrate the concepts under discussion, including materials characterisation and analysis with electrical impedance spectroscopy, differences between established and new materials, and how the designs of different components within the transducer translate into practical behavior.

Susan Trolier-McKinstry is a professor of ceramic science and engineering and director of the W. M. Keck Smart Materials Integration Laboratory at the Pennsylvania State University. Her main research interests include dielectric and piezoelectric thin films, the development of texture in bulk ceramic piezoelectrics, and spectroscopic ellipsometry. She obtained B.S., M.S., and Ph.D. degrees in Ceramic Science at Penn State, and upon graduation, joined the faculty there. She has held several international visiting appointments and is a fellow or member of several learned societies. She is past-president of Keramos and the Ceramics Education Council, and co-chairs the committee revising the IEEE Standard on Ferroelectricity. She is the recipient of many awards and is particularly proud that 17 people she has advised/co-advised hold faculty positions around the world.

Sandy Cochran is a professor of biophysical science and engineering, Team Leader in Medical Ultrasound, and Deputy Director of the Institute for Medical Science and Technology at the University of Dundee, Scotland. He received his B.Sc. degree in electronics in 1986, Ph.D. for work on ultrasonic arrays in 1990, and MBA in 2001, all from the University of Strathclyde. His present research interests are focused on medical ultrasound devices, with applications in diagnosis and imaging, and therapy. He also maintains an interest in relevant materials, fabrication techniques and systems design for medical and life sciences applications. He is a fellow or member of various learned societies and is a co-author on more than 200 papers and conference presentations.

Christine Démoré is the senior research staff member within the Medical Ultrasound team at the Institute for Medical Science and Technology, University of Dundee, Scotland. She received a B.Sc.E. degree in Engineering Physics and a Ph.D. in Physics from Queens University, Kingston, Canada in 2000 and 2006 respectively. Her research activities have been focused on the design, simulation, fabrication and characterisation of ultrasound transducers and arrays for medical imaging and life science applications. Presently, she is working on devices for ultrasonic manipulation of small particles and on high resolution imaging. She is an Associate Editor of IEEE UFFC and a member of various societies.

Conference website: http://ewh.ieee.org/conf/ius_2012

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