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Editorial

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Piezoelectrics are multifunctional materials widely used in industry, transportation, medicine, communications and science. Examples include high frequency transducers for medical ultrasonic imaging, pressure sensors in the process industry, underwater transducers, active elements for controlling position in scanning systems, filters and resonators in communication devices, and fuel-injection actuators in cars. Piezoelectric materials are employed as ceramics, ceramic-polymer composites, films, single crystals and polymers, in sizes from a few nanometers to tens of centimeters. New applications, especially in the medical field and the broad field of micro-technology, are emerging every year. On the fundamental level, one is approaching the state where it will be possible to predict new materials with desired properties using ab initio calculations.

Despite the considerable progress achieved in developing new materials and applications, piezoelectric materials still present many challenges in processing, environmental impact, suitability for applications under extreme conditions, characterization and understanding of the multitude of mechanisms that contribute to the piezoelectric response. This Special issue on *Advances in Piezoelectrics* focuses on some of the important challenges facing materials scientists, chemists, physicists, applied researchers and users in the field.

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The piezoelectric effect in ferroelectric materials is controlled by intrinsic (lattice) and extrinsic (domain wall related) contributions. The latter are responsible for the effects of weak field hysteresis, nonlinearity, frequency dispersion, fatigue, creep and aging, undesired in most advanced applications. Four papers discuss these fundamental issues. The effects of crystal and domain wall structure on piezoelectric response are addressed by Reaney; this study is based on an in-depth investigation of several ferroelectric materials by transmission electron microscopy. The domain wall displacement in ferroelectrics can be controlled by aliovalent dopants, resulting in hard and soft piezoelectrics. However, the atomistic mechanisms of hardening and softening are not yet well understood. Results of a recent investigation of the defect chemistry of lead zirconate titanate ceramics by electron para-magnetic resonances spectroscopy assisted by density-functional theory calculations are presented by Eichel. The article by Davis discusses the giant piezoelectric effect in relaxor ferroelectric single crystals and the role that a monoclinic phase may have on the attractive piezoelectric properties in these materials. The domain wall contributions to the properties of ferroelectric thin films are discussed by Bassiri Gharb and colleagues. Important differences in behavior of bulk materials and thin films, which are of interest for micro-electro-mechanical systems (MEMS), are identified and discussed.

Efforts to tailor properties of piezoelectric materials require detailed understanding of the processes that take place on the microscopic level. Diffraction techniques and, in particular time-resolved techniques to characterize ferroelectrics in real-time under the application of cyclic electric fields, are discussed by Jones. Local piezoelectric response of polycrystalline piezoelectrics and nanosale characterization by piezoresponse force microscopy are discussed by Kholkin and colleagues.

Need for miniaturization and integration of the piezoelectric elements with other electrical and mechanical components have led, over the past decade, to the development of piezoelectric thick and thin films with an enormous potential for MEMS. The recent advances in processing and new devices based on screen-printed thick films are described by Torah and colleagues. The best piezoelectric materials contain about 60% of lead in weight, which can create considerable environmental problems. The search for high performance lead-free materials has become one of the most active fields in ferroelectric materials. The recent developments are critically discussed in the paper by Zhang and Shrout. One of the most important problems with inorganic piezoelectric materials for the high frequency medical and low frequency underwater applications, is acoustical impedance matching with biological tissues and water. Development of porous ceramics is a possible solution and is discussed by Levassort and colleagues. A more general review of piezoelectric materials for high frequency medical imaging applications is written by Zhou and colleagues.

Piezoelectrics can be combined with other materials into macroscopic composites to obtain new functionality. A current trend is to develop magnetoelectric composites where electric and magnetic properties are coupled by strain via magnetostrictive and piezoelectric effects. A review on the topic is written by Priya and colleagues. Finally, excellent electro-mechanical energy conversion of piezoelectric materials is used in energy harvesting applications. The recent developments are reviewed by Priya.

It is hoped that the reader will find this snapshot of current activities in the field of piezoelectric materials and their applications informative and interesting.