Low-loss dielectric ceramics with filled-type tungsten bronze structure were investigated in the $BaO–Ln_2O_3–TiO_2–Ta_2O_5$ (Ln = La, Nd, and Sm) systems, and the typical compounds $Ba_3Ln_3Ti_5Ta_5O_{30}$, $Ba_4Ln_2Ti_4Ta_6O_{30}$, and $Ba_5LnTi_3Ta_7O_{30}$ were synthesized and characterized. The present ceramics indicated high dielectric constant ε (103–175) and low dielectric loss $\tan\delta$ (in the order of 10^{-5} to 10^{-3} at 1 MHz). Meanwhile, the temperature coefficient of dielectric constant τ_ε varied from −728 to −2500 ppm/°C with increasing Ba and Ta and decreasing Ln and Ti concentration. The present ceramics are promising candidates for high-ε and low-loss dielectric materials, and the suppression of τ_ε should be the primary issue in the future work. Among the present ceramics, the Sm-based system indicated the highest dielectric constant combined with the highest dielectric loss and the largest temperature coefficient of dielectric constant, while the La-based system showed the lowest dielectric loss and the smallest temperature coefficient of dielectric constant.

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Frequency agile materials for tunable microwave electronics

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There are interesting developments in the area of microwave dielectrics which require wide range of dielectric permittivity single crystals, ceramics or composites. The emphasis of the research is to improve materials and develop component and subsystems for frequency agile communications and remote sensing that utilizes the field variable properties of ferroelectrics, paraelectrics, ferrites or other novel materials. The goal of the current research is to develop miniature devices with significant agility at appreciable lower loss than the state of the art. Such approach will provide the ability to tune the bandwidth and frequency of RF filters and antennas and subsequently will result in improved performance of RF systems for communications to remote sensing.

This talk will overview the wide range of dielectrics available for such applications and will also provide the spectrum of potential materials choices which earlier were not considered suitable for designing microwave devices.

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Calcite microcrystals in the pineal gland of the human brain: second harmonic generators and possible piezoelectric transducers

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A new form of biomineralization in the pineal gland of the human brain has been studied. It consists of small crystals that are less than 20 μm in length and that are completely distinct from the often-observed mulberry-type hydroxyapatite concretions. Cubic, hexagonal and cylindrical morphologies have been identified using scanning electron microscopy. Energy dispersive spectroscopy, selected-area electron diffraction and near infrared Raman spectroscopy established that the crystals were calcite. Experiments at the European Synchrotron Radiation Facility (ESRF) to study the biomineralization showed the presence of sulfur originating from both sugars and proteins. Other studies at the ESRF furnished information on the complex texture crystallization of the calcite. With the exception of the otoconia structure of the inner ear, this is the only known non-pathological occurrence of calcite in the human body. The calcite microcrystals are believed to be responsible for the previously observed second harmonic generation (SHG) in pineal tissue sections. There is a strong possibility that the complex twinned structure of the crystals may lower their symmetry and permit the existence of a piezoelectric effect.

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Bismuth-based pyrochlore and related ceramics for microwave application

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Bismuth-based pyrochlore and related materials are a group of ceramics with very low sintering temperatures in the range of 850–1000 °C. The dielectric constant of the ceramics is in the range of 40–100 with very low temperature coefficient in the range of lower than ±30 ppm/°C. The dielectric loss at high frequencies is in the order of 10^{-4}. The Q factor of the ceramics in microwave GHz frequencies is in the order of 10^2–10^4. $Bi_2O_3–ZnO–Nb_2O_5$, $Bi_2O_3–ZnO–Ta_2O_5$, $Bi_2O_3–ZnO–Sb_2O_5$ systems are studied systematically. Effect of substitution and co-substitution of ZnO and Nb_2O_5 by equal-valence and alien-valence cations for the BZN materials and the effect of chemical deviation of the stoichiometric composition on the dielectric behaviors and structures are presented. Discussion on the structure, defects, and property relationship of the materials are given in this presentation. A new understanding of the superior microwave behaviors of the bismuth pyrochlore structure is to be discussed.

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Piezoelectric transducer arrays

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Our research group has been involved in piezoelectric transducers for thirty years and has developed several well-known designs. We hold the original patents on the 1–3 piezocomposites and the commercially successful moonie transducers. This talk describes more recent work on flat transducer arrays constructed from miniature flextensional transducers (cymbals) and small piezoelectric hollow spheres (BBs) embedded in polyurethane matrices. Several modifications were developed with the aid of computer modeling including the double-dipper (high pressure capability), the double-driver (cardioid beam patterns), and smart caps made from shape memory alloys (adjustable resonant frequency). Applications for the cymbal-based designs include deployable arrays for undersea surveillance and transdermal insulin delivery for the treatment of diabetes. The higher-frequency BBs are used as miniature hydrophones and in the treatment of localized cancer.

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Progress prospects and problems in advanced materials for dielectric piezoelectric and electro-optic applications

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Dielectric applications still provide major driving force for research and development on oxide electro-ceramics to serve this substantial market. Current excellent progress in dielectric/electrode systems for co-fired base metal electrode multilayer ceramic capacitors will be discussed. Research on switchable dielectrics for high power systems and frequency agile field tunable dielectric for microwave filter needs will be briefly outlined. In non-volatile random access memories (FeRAMS) ferroelectric thin films on silicon continue to make good progress. Low count, low power, low-cost memories for smart cards using bismuth oxide Aurivillius phase ferroelectrics are now in production. Fatigue and imprint problems for lead zirconate titanate (PZT) based films for high density memories appear to have been solved, whilst very new ultra high ($100\,uc/cm^2$) polarization switching has recently been demonstrated in $BiFeO_3$ epitaxial films. The clamant but highly intractable problems of ultra-thin higher permittivity gate dielectrics for sub micron field effect transistors (FETs) will be briefly outlined.

In piezoelectric and electrostrictive materials for elastic strain sensing and actuation, material systems with wide new ranges of elastic stiffness are being introduced. In the ultra-soft category exceptional sensitivity polymer foam electret sensors from VTT in Finland and soft electrostrictior actuators from SRI in the USA will be considered. Of intermediate stiffness are the irradiated PVDF:TrFE copolymers and the newer terpolymers from Penn State which provide excellent energy density. In stiff high strain/high coupling materials, oriented single crystals in the lead magnesium niobate: lead titanate (PMN:PT) and lead zinc niobate: lead titanate (PZN:PT) systems provide unique capability for sonar and ultra sonic tomography systems. The newer bismuth ferrate based systems which promise wider ferroelectric range at the polable morphotropic phase boundary compositions will be briefly introduced.

For the very widely used lithium niobate, lithium tantalite families of electro-optic crystals recent work has highlighted the profound effect on ferroelectric switching of oxide stoichiometry, where electrical coercivity is reduced by orders of magnitude in properly stoichiometric crystals. All the most widely used crystals are of the more easily grown congruently melting non-stoichiometric composition. The observed massive changes in switching makes us nervous in that much of our understanding of domain switching has come from research on similarly non-stoichiometric mixed oxide systems.

New researches on multi-ferroic systems are at last showing promise of interesting high coupling ferroelectric: ferromagnets in both single phase and composite systems, opening the possibility for completely new areas of application.

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The new frontier of vacuum microelectronics—diamond and carbon derived cold cathodes

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Chemical vapor deposited diamond or related carbon are excellent cathode materials for vacuum microelectronics because of their low electron affinity and excellent mechanical and chemical properties. However, the “direct” usage of diamond or other forms of carbon emitters leads to non-uniform emitter microstructures, uncontrolled randomly scattered emission sites, and inconsistent emission behaviors. Consequently, practical engineering design and