

that the as-grown films are highly epitaxial with excellent single crystal quality. The high temperature electrical properties of the films have been systematically investigated with traditional four-probe dc and ac-resistance measurement techniques and by two-probe ac impedance spectroscopy. Activation energies and diffusivities for these materials have been derived from the ac and dc-resistance measurements at different temperatures, or the Arrhenius plot— $\ln(\sigma)$ versus $(1/T)$. For instance, the activation energy of $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_3$ thin films on YSZ was determined to be 1.3 eV. The oxygen diffusivities in nano columnar structures of these materials have been also investigated. Various high temperature transport phenomena have been observed from these systems. The nano domain structures might play a key role in the oxygen conduction in the solid state fuel cell devices. Details will be discussed in the talk.

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Magnetoelectricity of multiferroic composites

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Differently from magnetoelectric (ME) crystal families (e.g. Cr_2O_3 and phosphates) to which the ME effect is intrinsic, multiferroic composites such as ferrite/piezoelectric ceramic composites exhibit extrinsic ME effect which is known as a ‘product property’ resulting from the interaction between the ferrite and piezoelectric ceramic phases, and the extrinsic ME effect is a ‘ $0 + 0 > 0$ composite effect’, since neither phase is magnetoelectric. In this article, based on the expressions derived by using a physics-based Green’s function technique, we review the extrinsic ME effect in a few piezoelectric/magnetostrictive composites including laminated and particulate composites.

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Hot spot phenomenon in ceramic rod and its application

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The present authors found a phenomenon that a local area of $\text{LnBa}_2\text{Cu}_3\text{O}_{7-\delta}$ (Ln: rare-earth element) ceramic rod glows with orange when a voltage over a certain value is applied to the rod at room temperature. The glowing area

migrates toward the negative electrodes. We named the area hot spot. The rod with the hot spot shows various functional characteristics. After the hot spot appearance, the current through the rod remains constant with increasing voltage, showing a prospective application for a constant current generator without any active component. The current depends on the oxygen partial pressure in the ambient atmosphere, which provides an oxygen sensor without any heating system. The current is sensitive to the gas flow around the hot spot, resulting in a sensitive flowmeter. Under low oxygen partial pressure, the current vibrates in the form of damped sinusoidal oscillation, which can be used as a low-frequency generator. In this presentation, firstly, we show the mechanism of the hot spot appearance from the view point of heat balance in the ceramics. Secondly, the mechanism of the hot spot migration is discussed from ionic conduction. The hot spot is considered to appear in the ceramics with positive temperature coefficient of resistivity (PTCR). New application field may be created from the related researches.

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Preparation and dielectric property of perovskite artificial superlattices

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Barium titanate (BTO)/strontium titanate (STO) artificial superlattices were fabricated by molecular beam epitaxy (MBE) process. Dielectric properties were measured for superlattice films on pure STO substrates using planar interdigital electrodes. Superlattice films were so thin (32 nm) that fine planar electrodes were necessary to reduce the penetration of electric flux into the substrate. Interdigital electrodes with the interdigital width of 5 μm were formed by electron beam lithography. Dielectric permittivity of superlattices was determined from admittance data using an electro-magnetic field analysis. It was found that the dielectric permittivity changed with the structure of superlattices and the highest permittivity was obtained for $[(\text{BTO})_{10}/(\text{STO})_{10}]_4$ superlattice from 1 to 110 MHz. The refractive index of the superlattice films was measured with a spectroscopic ellipsometry. The refractive index of the superlattices changed with their structures and those of $[(\text{BTO})_{10}/(\text{STO})_{10}]_4$ superlattices were larger than other superlattices. This indicated that the superlattice structure affected not only on the ionic polarization but also on the electronic structure or chemical bonding nature in the superlattices.

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Electronic and structural properties of ferroelectric $\text{SrBi}_2\text{Ta}_2\text{O}_9$ thin films and its Schottky junction by photoelectron spectroscopies

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Electronic and structural properties such as Fermi level, density-of-states and chemical bonds of ferroelectric $\text{SrBi}_2\text{Ta}_2\text{O}_9$ (SBT) thin films have been characterized by UV-photoyield spectroscopy (PYS) and X-ray photoelectron spectroscopy (XPS), and band diagrams of its Schottky junction have been studied.

Electronic structure of ferroelectric thin film is very important to obtain good ferroelectricity and high insulation which are closely related to polarization switching phenomena in 1T1C FeRAM capacitor and also memory retention characteristics in ferroelectric gate FET memory. SBT thin film is used widely for the memory application, and so its electronic structure has been investigated. XPS spectra of Au and SBT film show that band bending of 0.5 eV happens at their junction. UV-PYS spectrum of the SBT film shows that its work function is 5.90 eV after the deposition and decreases to 5.56 eV by O_2 annealing. This change increases the hole barrier height from 1.80 to 2.14 eV, so induces reduction of the current through metal-SBT junction, and coincides well that leakage current of SBT film capacitor was reduced after the O_2 annealing. Moreover, this reduction improves the memory retention time of capacitance of the MFIS structure, which is hopeful to realize ferroelectric gate FET memory. Ar^+ bombardment effect on electronic structure of the SBT film has been studied by XPS to clarify mechanism of the improvement of the barrier height and the current conduction. The $\text{Bi}4f$ XPS signal mainly shows oxide state on the surface, but after Ar^+ bombardment reduces contribution of the oxide and enhances contribution of the metallic. On the other hand, ratio of the oxide contribution to the metallic changes little in the signal of $\text{Ta}4d$ and $\text{Sr}3d$. The density of states corresponding to $(\text{Bi}_2\text{O}_2)^{2+}$ layer decreases with Ar^+ bombardment time. These results suggest that Bi_2O_2 layer is easily damaged and deoxidized by the Ar^+ bombardment. Therefore, the O_2 annealing is considered to improve insufficient oxidation of $(\text{Bi}_2\text{O}_2)^{2+}$ layer which might exist in the as-deposited SBT film.

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Low temperature processing of PZT-based thin films

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The usually reported crystallization temperatures of the perovskite phase for lead zirconate titanate (PZT) thin films prepared by chemical solution deposition (CSD) method are around 600 °C. It is a continuous challenge to lower the crystallization temperature in order to decrease the possibility of either interface reaction of PbO with the substrate or PbO evaporation and to be able to use substrates and/or electrodes that are stable below 500 °C.

It is generally accepted that the activation energy for nucleation of the perovskite phase is considerably higher than that for growth. Further, the crystallization temperature of PZT solid solution decreases with decreasing Zr/Ti ratio.

By careful control of solution chemistry and annealing conditions, Ti-rich PZT and PLZT films were successfully processed at temperatures as low as 400 °C. The crystallization of these films is characterized by rapid nucleation and rapid growth. The microstructure and corresponding ferroelectric properties are controlled by thermal treatment. Films with thickness below 100 nm can be processed as well. The maximum value of $\text{Pr} = 33 \mu\text{C}/\text{cm}^2$ and $\text{Ec} = 99 \text{ kV}/\text{cm}$ of PZT30/70 films were obtained.

The Zr-rich PZT and PLZT compositions require a lead titanate (PT) seeding layer for further crystallization at a temperature of 400 °C. The growth of the perovskite phase is diffusion controlled and, as a consequence, slow. The step of conversion of amorphous to crystalline phase depends on the amount of PbO excess in starting composition. The results are discussed in terms of sublimation of PbO as well as incorporation of lead on to B sites of perovskite lattice.

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Composition–structure–properties studies on bismuth layered ferroelectric thin films

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By both alternating the structure of layered ferroelectrics $\text{A}_{m-3}\text{Bi}_4\text{Ti}_m\text{O}_{3m+3}$ ($m = 3, 4, 5, 6$, and SBTi_m) and partially substituting A site of perovskite cell by lanthanide elements, the composition–structure–property relationship of these ferroelectrics were studied. The thin films were prepared by pulse laser deposition (PLD). With the capacitor structures of $\text{Pt}/\text{SBTi}_m/\text{Pt}/\text{TiO}_2/\text{SiO}_2/\text{Si}$, these films show excellent fatigue properties ($>10^{11}$). The feasibility of the family in optimizing ferroelectric properties was established. Epitaxial heterostructures of $\text{SBTi}_m/\text{SrTiO}_3$ were