Dirbtinių morfotropinių fazių sandūrų beieškant: $BaTiO_3$-$KNbO_3$ kompozitų dielektrinė spektroskopija

In search for artificial MPBs: dielectric spectroscopy of $BaTiO_3$-$KNbO_3$ composites

Maksim Ivanov[1], Sergejus Balčiūnas[1], Jūras Banys[1], Satoshi Wada[2]
[1]Vilniaus universitetas, Fizikos fakultetas, Saulėtekio al. 9, LT-10222 Vilnius
[2]Interdisciplinary Graduate School of Medical and Engineering, University of Yamanashi, Kofu,Yamanashi 400-8510, Japan
maksim.ivanov@ff.vu.lt

High piezoelectric activity is of high demand for various applications. The desired properties are most often observed in solid solutions displaying the so-called Morphotropic Phase Boundary (MPB), when two different lattice structures are of similar energy, thus extrinsic stimulus leads to easy deformation. The co-existence of the phases is often observed in a broad temperature range, thus the electromechanical properties are enhanced in a region much broader than the ferroelectric phase transition, making the MPB the main feature to look for in a piezoelectric.

However, not all solid solutions exhibit the MPB, especially if lead-free materials are considered. There has been a substantial effort to engineer a lead-free piezoelectric material, which would be competitive with PZT, but the results are average at best. As a result artificial MPBs are of high interest, and they can be formed in ferroelectric composites with epitaxial interfaces between the phases. $BaTiO_3$ (BT) and $KNbO_3$ (KN) were selected as the starting members, as they are both lead-free ferroelectrics and have dissimilar lattice structures at room temperature. Furthermore, their solid solution does not form a MPB. Creating epitaxial interfaces with KN inside BT structure creates stresses that increases domain wall count and, as a result, enhanced piezoelectric coefficient can be expected in analogy with the conventional MPB materials.

Polyhedron BT particles (around 300nm) were pressed into low-density ceramics using a uniaxial press, then porous BT structure was heated up to 1000°C for 2 hours. KNBT composites were prepared by the solvothermal method. KN was epitaxially deposited into sintered and non-sintered BT structure forming 0.18KN-0.82BT (0.18KNBT) and 0.5KN-0.5BT (0.5KNBT) composites respectively.

Dielectric measurements were performed in 100 – 500 K temperature and 10^2 – 10^{11} Hz frequency range. The specimen was polished and washed in acetone bath then parallel electrodes were made using silver paste. In frequency range from 100 to 10^6 Hz the complex impedance was measured using HP 4284A precision LCR meter. To obtain higher frequencies (10^6-10^9Hz) the coaxial line was terminated by a flat capacitor - reflection and phase were measured using Agilent 8714ET RF network analyser. For highest frequencies, dielectric rods were made. The sample was placed in waveguide system then reflection and transmission was measured using Elmika scalar network analyser R2400. Dielectric permittivity was obtained by solving optimization problem. All measurements were performed during cooling cycle at 1K/min rate.

In this presentation dielectric properties of BT-KN with different KN molar ratios will be presented. It was found, that the piezoelectric effect gives a significant contribution to the total dielectric permittivity. The main mechanism is piezoelectric coupling of the external field to intrinsic mechanical resonators formed by the aggregates in the necking structure of BT. The contribution is so big, that it might be useful in real-life devices, if the permittivity can be engineered to have a higher value with less frequency dependence. Impact of KN on the piezoelectricity of the strained BT was obtained from the piezoelectric contribution and compared with the pure material. Furthermore, the spontaneous polarisation of the movable domains was estimated based on the dielectric data, and it seems to be dependent on the strain induced by KN layer.

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Literature

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