Effect of complex doping on microstructural and electrical properties of PZT ceramics

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Lead zirconate titanate ($PbZr_xTi_{1-x}O_3$ or PZT) ceramics are the most widely studied and technologically important ferroelectric materials. Especially, the solid solution composition located near the rhombohedral-tetragonal morphotropic phase boundary (MPB) possesses eminent piezoelectric characteristics. In particular, compositionally modified lead zirconate titanate (doped-PZT) ceramics with their improved electrical properties are widely utilized in the dielectric and piezoelectric applications.

In general, with the amount of dopant content, the compositional modification (doping) by single dopant leads the drastic variations of electrical properties of the PZT ceramics. Since the properties are also changed by impurities in raw materials, it is difficult to reproduce and optimize the electrical performances. In the present study, to improve the reproducibility and to enhance the electrical properties of the MPB-PZT ceramics, a complex doping with two or more metal elements including both softners and/or hardeners is adopted. Compositionally modified PZT [doped with softeners, i.e., La^{+3} and Nb^{+5}, and both the softeners, i.e., La^{+3} and/or Nb^{+5}, and hardeners, i.e., Fe^{+3} and /or Mn^{+2}] were prepared by the conventional solid-state reaction process.

The prepared PZT ceramics modified with complex soft dopants of La^{+3} and Nb^{+5} showed that the piezoelectric properties were enhanced and stable with the compositional variations, e.g., the amount of dopants contents or the raw materials with low purities, which made it possible to establish the higher reliability and reproducibility of the piezoelectric performances. Unlike single (soft or hard) element doping, the complex doping of both the soft and hard ions caused various compensation effects for the piezoelectric properties of the PZT ceramics. The improved piezoelectric properties, i.e., enhanced Q_m with remaining higher K_p were obtained in the PZT composition doped with La^{+3} and Fe^{+3}.