Electromechanical Hardening in Lead-free Relaxor Composites

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Piezoelectric materials are generally classified as 'hard' and 'soft' based on the domain wall mobilities and the polarization response. When the A- or B- site cations are substituted with lower (higher) valence elements, the domain wall mobility is typically decreased (increased), resulting in hard (soft) type piezoelectrics. Hard type piezoelectrics are characterized by relatively lower ferroelectric and piezoelectric properties, high mechanical quality factors (Q_m) and low losses. Zhang *et al*. [1] recently demonstrated that the inclusion of semiconductor ZnO particles into the $0.94(Na_{1/2}Bi_{1/2})TiO_3$-$0.06BaTiO_3$ (NBT-6BT) matrix leads to an increase in the depolarization temperature. In the present study, we have extended this concept of the composite approach as an alternative to acceptor doping to induce a hardening effect. A two-fold increase in Q_m was observed for the composites with NBT-6BT. Akin to other hard piezoelectrics, a decrease in the saturation polarization and total strain was observed. The ac field dependent permittivity is used to establish a one-to-one correspondence between the increase in Q_m and the decrease in the domain wall mobility. The results are explained based on a clamping effect of ZnO that elastically restricts the ability for domain wall movement. The hardening effect is also achieved in composites with NBT-3BT and NBT-9BT. The composites of NBT-9BT exhibit a three-fold increase in Q_m. The results indicate possibilities of extending this approach to induce 'hardening' in other ferroelectric systems.

[1] J. Zhang, Z. Pan, F.-F. Guo, W.-C. Liu, H. Ning, Y.B. Chen, M.-H. Lu, B. Yang, J. Chen, S.-T. Zhang, X. Xing, J. Rödel, W. Cao, and Y.-F. Chen, Nat. Commun. 6, 6615 (2015).