Effects of SiO$_2$ Coating on the Dielectric and Ferroelectric Properties of BaTiO$_3$-SiO$_2$ Composites

Xu Lu$^{1,2}$*, Yang Tong$^1$, Hossein Talebinezhad$^1$, Jiachen Liu, Yancen Cai and Z.-Y Cheng$^1$

$^1$Materials Research and Education Center, Auburn University
Auburn, AL, USA, 36849
$^2$School of Materials Science and Engineering, Xi’an University of Technology
Jinhua South Road, Xi’an, China, 710048
*Xu Lu: luxur.y.1@gmail.com

In comparison with conventional ceramics, ceramic-glass composites have some advantages in application due to their novel properties, such as high breakdown strength and low dielectric loss. Ceramic-glass composites could be sintered from mixtures of ceramic and glass powders or core-shell like particles with ceramic core and glass shell. Chemical coating method is considered effective to prepare the core-shell like particles, which can be used as raw materials in the composites sintering process. In this paper, BaTiO$_3$-SiO$_2$ composites were fabricated. Firstly, core-shell like BaTiO$_3$-SiO$_2$ particles were fabricated by coating BaTiO$_3$ nano powders with a series of contents of amorphous SiO$_2$ (2.5, 5, 7.5, 10, 15 and 20 wt.%) through a wet chemical coating process named Stöber Method. Then, the as-prepared core-shell particles were used to fabricate BaTiO$_3$-SiO$_2$ composites by conventional ceramic process. Phase composition and microstructure of BaTiO$_3$-SiO$_2$ composites were characterized by X-ray diffraction (XRD) and Scanning electron microscopy (SEM). The dielectric properties in the frequency range from 100 Hz to 1 MHz and in the temperature range from -50 °C to 150 °C were determined using an HP 4294A LCR Meter assisted with an Espec ECT-2 temperature chamber. Ferroelectric hysteresis loops (P-E) and breakdown strength ($E_b$) were measured in silicone oil using a Radiant Precision-LC 100 system with H.V. Supply Amplifier at room temperature. The XRD patterns illustrate a typical tetragonal perovskite structure of the core-shell particles, which confirm an amorphous phase of coated SiO$_2$ layer. After sintering, a secondary phase, BaTiSiO$_5$, is obvious in the composites, which is caused by the interface reaction of BaTiO$_3$ core and SiO$_2$ shell. Furthermore, the content of BaTiSiO$_5$ phase increases with coating content of SiO$_2$. SEM results show that the porosity in composites could be removed by SiO$_2$, which can be attributed that SiO$_2$ works as sintering agent during the sintering process. The coated SiO$_2$ layer between BaTiO$_3$ cores could also acts as inhibitor in grain grown of BaTiO$_3$. It is found that dielectric constant decrease with increasing content of SiO$_2$ in composites and the dielectric constant peak associated with dielectric temperature dependence curve could be greatly suppressed accordingly. The P-E loop of composites gets slimmer and polarization decreases with increasing coating content of SiO$_2$, while the breakdown strength could be remarkable enhanced.