Process and Microstructure to Achieve High Dielectric Constant in Ceramic-Glass Composites for Energy Storage Applications

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$BaTiO_3$ ceramics have been extensively studied. Although $BaTiO_3$ ceramics exhibit a high dielectric constant, the low electric breakdown strength limits their applications. In recent years, due to the interest in non-lead materials, $BaTiO_3$-based materials once again become an interesting topic for the dielectric research. To improve the breakdown strength of $BaTiO_3$ based dielectrics for varying applications, composite approaches are widely used. Glass-ceramic composite is one of the effective approaches since these composites have a low porosity and exhibit a high stability[1]. Additionally, by using proper glass composition, the dielectric loss of material could be reduced[2]. However, due to the low dielectric constant of glass, the dielectric constant of the $BaTiO_3$ based glass-ceramic composites is usually lower than that of pure $BaTiO_3$ ceramics.

To increase the dielectric constant of $BaTiO_3$ based glass-ceramic composites, a process to increase the dielectric constant of $BaTiO_3$ is used. That is, the $BaTiO_3$ particles with an average size of 200 nm were pretreated at 950 °C in vacuum to induce vacancies. The pretreated $BaTiO_3$ nanoparticles were, then, coated by a layer of SiO_2. By a wet chemical process, the reaction between tetraethylorthosilicate (TEOS) and H_2O was utilized according to stöber process[3]. The 2.5, 5, 10, 15 and 20 wt% of SiO_2 were coated on $BaTiO_3$ by adjusting the amount of chemicals. The nanoparticles were pressed to form green body disks and then sintered at 1230 °C in air for 5 hours to get final ceramic pellets.

The dielectric properties of prepared $BaTiO_3$ based composites were shown in Figure 1. As shown in Figure 1 (a) and (b), the dielectric constant of the composites can reach more than 3,000 with a low loss of about 0.03. By the testing of changes of dielectric properties in the temperature range of -50 °C to 140 °C, the properties are much more stable compare with changing environment temperatures. From the P-E hysteresis loops of $BaTiO_3$ based composites in Figure 1 (c), the linearity of P-E loop are increased with increasing SiO_2 content. The energy density calculated from P-E loop of 2.5 wt% composites reached a maximum value of 1.66 J/cm^3, which are higher then the $BaTiO_3$ based composites reported previously[1].

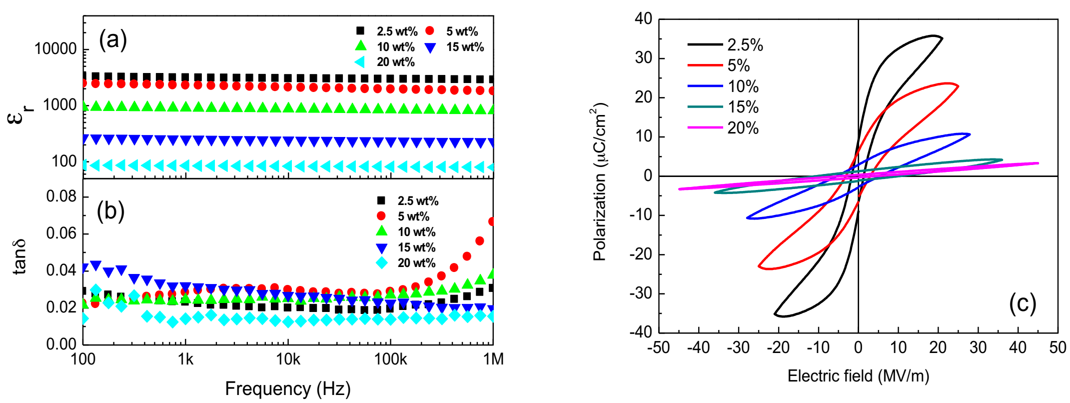

Figure 1 The (a) dielectric constant, (b) loss and (c)P-E hysteresis loops of $BaTiO_3$ based composites against different SiO_2 content.

Reference

1. Gorzkowski E P, Pan M J, Bender B, et al. Glass-ceramics of barium strontium titanate for high energy density capacitors[J]. Journal of electroceramics, 2007, 18(3-4): 269-276.
2. Wang X, Zhang Y, Song X, et al. Glass additive in barium titanate ceramics and its influence on electrical breakdown strength in relation with energy storage properties[J]. Journal of the European Ceramic Society, 2012, 32(3): 559-567.
3. Stöber W, Fink A, Bohn E. Controlled growth of monodisperse silica spheres in the micron size range[J]. Journal of colloid and interface science, 1968, 26(1): 62-69.