
Graphene 2018: Surface modified barium titanate for optimal dielectric properties in polymer-ceramic nanocomposite films-Kimberly Cook-Chennault-Rutgers University, USA**Abstract**

High permittivity polymer-ceramic nanocomposite dielectric films leverage the ease of flexibility and processing of polymers and functional properties of ceramic fillers. Thus, they could be applied to advanced embedded energy storage devices for printed wired electrical boards. The incompatibility of the two constituent materials, hydrophilic ceramic filler and hydrophobic epoxy limits the filler concentration and therefore, dielectric properties of these materials. Use of surfactants and core-shell processing of composite fillers is traditionally used to achieve electrostatic and steric stabilization for adequate ceramic particle distribution. This work aims to understand the role of surfactant concentration in establishing meaningful interfacial layers between the epoxy and ceramic filler particles by observing particle surface morphology, dielectric permittivity and device dissipation factors. A comprehensive study of nanocomposites that were comprised of non-treated and surface treated barium titanate (BT) embedded within an epoxy matrix was performed. The surface treatments were performed with ethanol and 3-glycidyloxypropyltrimethoxysilan, where the best distribution, highest value of permittivity (~ 48.03) and the lowest value of loss (~ 0.136) were observed for the samples that were fabricated using 0.5 volume fraction of BaTiO₃ and 0.02 volume fraction of silane coupling agent.

A scalable processing route for fabrication of polymer-based dielectric nanocomposite films has been developed by spray deposition and in situ polymerization of monomer-nanoparticle dispersions. Polydiacrylate-BaTiO₃ films with filler loadings of 10vol% to 30vol% and controlled thickness of 5–30 μ m were achieved by optimizing spray conditions of spray liquid flow rate, atomizing gas pressure and substrate traverse speed and temperature. Microstructural investigations confirmed well-dispersed BaTiO₃ nanoparticles embedded in the polydiacrylate matrix. Dielectric constants of ~ 39 at 10kHz, excessive breakdown strengths of >100 kV/mm and low leakage currents of 10^{-9} to 10^{-8} A/cm² above 1000V, and thermal stability up to 150°C had been attained for PTPGDA-30 vol%BaTiO₃ films. The low-cost, atmospheric spray deposition technique developed in this work has plausible for larger-scale manufacture of dielectric nanocomposite motion pictures for energy capacitor and different applications.

Conventional dielectric substances based totally on ceramics have been extensively used considering the discovery of barium titanate (BaTiO₃, $\kappa \sim 3,000$), due to their giant dielectric consistent (or permittivity, ϵ_r or κ).(Arit, Hennings et al. 1985; Fujishima 2000; Ihlefeld, Laughlin et al. 2005) These ABO₃ kind metal oxides have a perovskite

structure and can showcase spontaneous polarization underneath zero-field due to the displacement of the core atom, B, along the crystalline axis c, as shown in Figure 1.3. However, these substances have many restrictions such as a excessive temperature requirement in processing, large leakage cutting-edge under tremendously small applied bias, and low dielectric strength (~ 2 V/ μm) that limits running voltage.

The crystalline shape of ABO_3 perovskite. (1) Non-ferroelectric phase (cubic phase), A: octahedral web sites on every face, B: middle atom, and oxygen atoms in every corner. (2) Perovskite shape below an applied electric field where the middle atom is displaced alongside the crystalline axis c (tetragonal phase). A ferroelectric material tends to keep this displacement exhibiting a spontaneous polarization even after turning off the external field. The orientation of this polarization can be switched with the aid of applying reasonable magnitude of external field. It can be additionally eliminated when the thermal energy ($k_B T_c$, k_B = Boltzman constant, T_c = Curie temperature) is sufficiently high or when a coercive discipline is applied.

On the other hand, polymeric materials such as bi-axially oriented polypropylene (BOPP) showcase very excessive dielectric strengths (~ 640 V/ μm) with facile low temperature processability. The development of without difficulty processable materials with desired properties often not solely comes from synthesizing novel materials, however also from combining existing materials. A composite cloth is a combination of two or more component substances behaving like one fabric system with blended homes of more than one constituents. Thus the idea of mixing high permittivity ceramic particles with polymers has been 11 added to make easily processable, excessive permittivity,

low leakage, and excessive breakdown strength materials. Recently, some outcomes based on this thinking have been demonstrated, but the homes received are appropriate only for some limited applications. Thus, breakthroughs in processing these composite materials are required to fulfill the increasing demand for excessive overall performance materials, e.g. higher capacitance densities and breakdown strengths, in cutting-edge electronics.

Analytical theories describing the high-quality permittivity of a composite device having a 0-3 connectivity predict that the high quality permittivity increases both with growing quantity fraction of the lively section (high permittivity fillers) or with increasing permittivity of the passive section (host polymer). One frequently used mannequin to describe dielectric composite structures used to be developed by using Jayasundere and Smith, as proven in Equation The details about one of a kind fashions will be described. Two example calculation effects the usage of this equation for nice permittivity of nanocomposites are proven in Therefore, excessive volume fractions of high permittivity fillers in high permittivity polymer hosts are the key aspects to gain excessive permittivity polymer/ceramic composites.

Polymer/ceramic composite materials have discovered many functions so far as a dielectric components, however contemporary lookup is directed to the use of a lot smaller particles (nanoparticles) as the miniaturization and integration of electronic factors require similar or better overall performance from lots smaller place and/or extent of materials.

Simple mixing of nanoparticles in a polymer host usually results in poor exceptional and inhomogeneous films, normally due to the agglomeration of the nanoparticles. (Gilbert, Schuman et al. 2005) As defined in the previous section, large quantity fractions of the excessive permittivity nanoparticles are proper to enlarge the fine permittivity of nanocomposites. Increasing the quantity fraction of the nanoparticles increases the interfacial area of nanoparticles in the system. The processing and reaching high nice nanocomposite Thin motion pictures with high nanoparticle quantity fractions will become even more difficult except manipulate of the nanoparticle interfaces. Therefore, techniques to chemical change of the nanoparticle surfaces are tremendously desirable.

Chemically editing the surface of nanoparticles has many workable advantages: i) capping of the nanoparticle surface with a chemical modifier, or ligand, can successfully suppress nanoparticle aggregation, which is the first hassle to be solved in order to accomplish homogeneous nanocomposites, the compatibility of visitor substances (nanoparticle filler) in host substances (polymer) can be expanded by means of altering the shape of a chemical modifier in accordance to that of surrounding media, iii) different favored chemical performance can be tailor-made for in addition processing, studies, and different applications, and as soon as the surface modification chemistry is established, it can be effortlessly utilized to other comparable systems.

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