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ORIGINAL PAPER

Enhanced dielectric constant of acrylonitrile–butadiene rubber/barium titanate composites with mechanical reinforcement by nanosilica

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Abstract Acrylonitrile–butadiene rubber (NBR), a synthetic rubber having C≡N dipoles, was chosen as a polymer matrix with a higher dielectric constant than other non-polar rubber like silicone rubber or ethylene–propylene–diene monomer. Barium titanate ($BaTiO_3$), as a ferroelectric material, with a high dielectric constant and low dielectric loss was selected as a main filler to further enhance the dielectric constant of NBR. An effective silane coupling agent (KH845-4), selected from five types of silane coupling agents with different characteristic functional groups, was used to modify the surface of $BaTiO_3$ particles to enhance its interfacial adhesion to the matrix. Fourier transform infrared spectroscopy (FTIR) was used to verify the successful modification. The addition of $BaTiO_3$ obviously enhanced the dielectric constants. In particular, an uncommon pattern of dielectric loss has been displayed and analyzed in this paper. Nevertheless, the reinforcing effect of mechanical strength of the NBR/treated $BaTiO_3$ composites is limited. On this basis, the addition of nanosilica (SiO_2), replacing part of NBR, improved the mechanical strength. Confirmed by scanning electron microscopy (SEM), the SiO_2 and treated $BaTiO_3$ particles were dispersed well in the NBR matrix. The tensile strength was increased from 4.33 to 6.12 MPa when SiO_2 accounted for 4%. Moreover, the curing characterizations, crosslinking density, resistivity, and oil resistance were evaluated. This composite material can be used in manufacturing electronic devices, which are subjected to oily environments for a long time.

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Keywords Acrylonitrile–butadiene rubber · Barium titanate · Dielectric constant · Surface modification · Nanosilica

Introduction

Inorganic dielectric materials have been developed for several decades because of their high dielectric constant and low dielectric loss. They can be used for many applications such as base-plate materials, multi-layer ceramic capacitors (MLCCs), and resonators or filters in microwave communication. Nevertheless, these inorganic materials, particularly ceramic materials, are limited by their low breakdown strength and difficult processability [1, 2]. Therefore, many researchers have turned their attentions toward other materials including polymer materials [3, 4]. Compared with conventional ceramic dielectrics, polymer dielectrics have the main advantages such as light weight, excellent mechanical properties, chemical stability, and improved processability [5, 6]. Among the numerous polymer materials, elastomer materials have attracted more attention. Dielectric elastomers, with high actuated strain, can be designed for diverse applications like artificial muscle in bionic applications, valves, and actuators [7, 8].

Unfortunately, most polymer materials possess relatively low dielectric permittivity values despite some polar polymers like acrylonitrile–butadiene rubber (NBR) having permanent dipole moments. In electronic devices industry, greater functionality at smaller size is an essential requirement, which requires the dielectric materials for efficiency improvement and reliability [9]. If the dielectric constant of a dielectric material is 4 times higher than that of the other, its size can be reduced to a half the size of the other [10, 11]. One of the basic methods to improve the dielectric