Solid State Phenomena
ISSN: 1662-9779, Vol. 355, pp 141-152
doi:10.4028/p-n7l0Ve

Submitted: 2023-06-21
Revised: 2023-09-27
Accepted: 2023-10-19
Online: 2024-02-15

Confinement of the Permittivity Enhancing Fillers in Bacterial Cellulose for Dielectric Elastomer Applications

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Keywords: Bacterial cellulose (BC), confinement, dielectric elastomer, polydimethylsiloxane (PDMS), silicone oil, titanium dioxide

Abstract. The electromechanical performances of dielectric elastomers were investigated after the incorporation of the confined permittivity enhancing fillers in bacteria cellulose (BC) into polydimethylsiloxane (PDMS) films. The purpose of this study is to investigate the capability of BC as a confinement matrix for the permittivity enhancing fillers to overcome the low relative permittivity and at the same time to increase the softness of the PDMS films. The metal oxide and silicone oil were confined in BC before being physically mixed with PDMS at different percentages. The results showed that the confined TiO_2-BC increased the relative permittivity and at the same time maintained the softness of the PDMS films to some extent. In addition to that, by adding confined silicone oil-BC into the PDMS films, this PDMS based dielectric elastomer (DE) becomes even softer.

Introduction

Dielectric elastomer (DE) is essentially a compliant capacitor, where the dielectric medium is an elastomeric film with low elastic stiffness coated on both sides by compliant electrodes. The applied voltage onto the DE will decrease its thickness and increase the surface area [1]. Due to these properties, DE can be developed for various applications such as soft actuators, sensors, and generators [2]. Polydimethylsiloxane (PDMS) is one type of elastomer that is widely researched as a dielectric elastomer due to its great mechanical properties. Silicone elastomer has superior properties which are reliable, quick response and have high efficiency making it a promising dielectric elastomer material [3]. PDMS are also inert, resist toward water and stable at low and high temperatures.
Despite PDMS's great mechanical properties, PDMS possess relatively low dielectric permittivity compared to other elastomers. Low dielectric permittivity indicates that PDMS requires a high electric field to actuate. One of the methods to counter this drawback is by introducing filler to the PDMS elastomer matrix. Filler was proven to improve the electromechanical responses at smaller voltage, increasing the dielectric constant and also decreasing the elastic modulus of DE [4]–[6].
There are two main types of fillers: hard and soft fillers. Hard fillers are solid composites such as ceramic or conductive fillers. Some of the ceramic fillers that are studied are TiO_2, ZnO [7], $BaTiO_3$ [8] and boron nitride (BN). Soft fillers are liquid fillers such as glycerol [9] and silicone oil. Both fillers can affect the mechanical and electrical properties of DE.
Bacterial Cellulose (BC) is pure cellulose that is produced by the fermentation of sugar by bacteria called *Acetobacter xylinum*. *Nata de coco* is also bacterial cellulose produced through coconut water fermentation using *Acetobacter xylinum* [10]. A study conducted by Potivara & Phisalaphong (2019) stated that BC possesses the ability to store water, excellent biodegradability, high crystallinity, and