

Characterization of Electret Based on Inorganic-organic Nanocomposite Using Fluoropolymer and Silica Nanoparticles

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Abstract. An A novel electret based on inorganic-organic nano composite using fluoropolymer and silica nanoparticles was developed in this study. CYTOP® is used to fabricate the nanocomposite electret, which is one of fluoropolymer. Three kinds of silica nanoparticles dispersed in methyl ethyl ketone were employed. Each type of nanoparticles was mixed in the CYTOP or stuck between three layers of CYTOP. Then, negative charge was implanted by corona discharge method. The initial surface potential of the nanocomposite electret was higher than that of a control electret made of pure CYTOP. Additionally, time stability of those was also better than that of control electret. However, above mentioned properties of the mix-typed electret was worse than that of stuck-typed electret, because of discharging through aggregates composed of the nanoparticles.

1. Introduction

Recently, vibrating energy harvesters (VEHs), which generate electrical power from ambient vibration, have attracted much attention [1-5], because it is prospective power supply for wireless sensors [1, 2]. Since main frequency of ambient vibration is usually on the order of a few to several tens of hertz, electret-based electrostatic VEH are more suitable as power generator using ambient vibration than magnet-based VEHs and piezoelectric-based VEHs [3]. Electret is dielectric material of which surface potential is stable based on electrical charges trapped in itself. Previously, many type of electret-based VEH were developed. We also developed an electret-based VEH consists of a fixed electret on bade electrode and a vertically vibrated counter electrode with high dielectric constant (high- k) plate [4, 5]. Theoretical output electrical power of electret-based VHE is generally proportional to square of surface potential of electret. Therefore, improvement of surface potential of electret is important to enhance output of electret-based VEH. Conventionally, fluorocarbon polymers [1-5] were frequently used as electret in VEHs because they keep higher concentration of electrical charge than other materials. CYTOP® is famous fluorocarbon polymer as an electret, of which surface potential and its time stability are better than other fluorocarbon polymer [6]. In previous work, we demonstrate that surface potential of an electret made of organic-inorganic nanocomposite materials, in which BaTiO₃ nano-particles are mixed in CYTOP, is higher than that made of pure CYTOP. In this study, it was investigated the surface potential of electrets made of CYTOP based nanocomposite materials when the silica nanoparticles is mixed in CYTOP.



2. Fabrication of nano/micro textured electret

In this study, CYTOP (provided by Asahi Glass Co. Ltd., Model: CTL-809-M) solved by a fluorinated organic solve materials, and three kinds of silica nanoparticles (provided by Nissan Chemical Industries, Ltd., Model: MEK-AC-2140Z, MEK-AC-4130Y, MEK-AC-5130Z) dispersed in methyl ethyl ketone (MEK) were employed. Grain sizes of the nanoparticles are shown in Table 1.

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Additionally, two types of electret structures were employed, one of which is “mix-typed electret,” and the other of which is “stack-typed electret.” In fabrication of the mix-typed electret, CYTOP and silica nanoparticles are mixed by hand, followed by dispersion of the mixed particles using ultrasonic homogenizer (NIHONSEIKI KAISHA LTD., model:US-150T). Then, the mixture was spin coated on a thermal oxidized silicon substrate, and baked to form an electret. The thickness of CYTOP layer and SiO₂ layer are 5.4 μm and 0.8 μm , respectively. In fabrication of the stack-typed electret, CYTOP were spin-coated in three separate times (Thickness of each layer is 1.7 μm , total thickness is 5.4 μm). The nanoparticles dispersed in MEK were coated between the CYTOP layers. Schematic of the electret sample is shown in Fig. 1. After fabricating the two types of electrets, negative charge was implanted into the electrets by corona discharge method as shown in Fig. 2.

Table 1. Specification of Silica nano-particles

Model ID	SiO ₂ Ratio (w%)	Dispersion medium	Diameter of particles (nm)
MEK-AC-2140Z	40	methyl ethyl ketone	10 – 20 (typically 20)
MEK-AC-4130Y	30	methyl ethyl ketone	40 – 50 (typically 50)
MEK-AC-5130Z	40	methyl ethyl ketone	70 – 100 (typically 70)

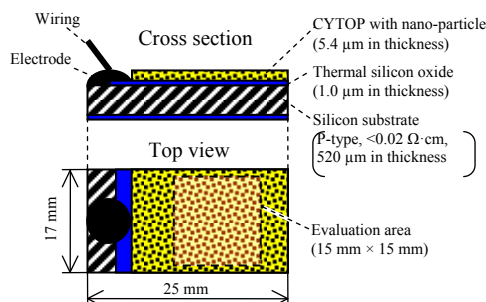


Figure 1. Fluoropolymer (CYTOP) electret with silica nano-particles which is fabricated on the thermal oxidation layer of a low-resistive silicon substrate (SiO₂). The Si substrate also acts as a lower electrode for the electret.

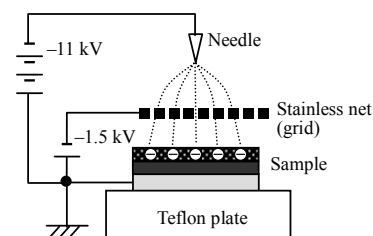


Figure 2. Schematic of setup for corona discharge to implant electron to the fabricated nanocomposite film.

3. Measurement results and discussion

The initial surface potential of CYTOP mixed or stacked with silica nanoparticles was higher than that of a control electret made of pure CYTOP (5.4 μm in thickness). Additionally, time stability of those was also better than that of control electret, as shown in Figs. 3 and 4. Particularly, above mentioned properties of the stack-typed electret was better than that of CYTOP mixed with BaTiO₃ nanoparticles which was reported at PowerMEMS2014 [8]. As a result of the observation of mix-typed electret by an SEM, it was found that there are many projections which may be derived from aggregate of

nanoparticles. We consider that aggregates of nanoparticles were formed in nanocomposite when the CYTOP and the silica nanoparticles were mixed, and implanted charges were discharged through the aggregates, as shown in Fig.5.

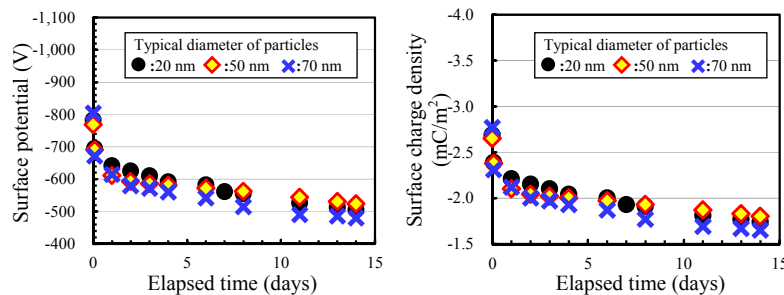


Figure 3. Time degradation of surface potential of electrets made of mixture of CYTOP and silica nano-particles.

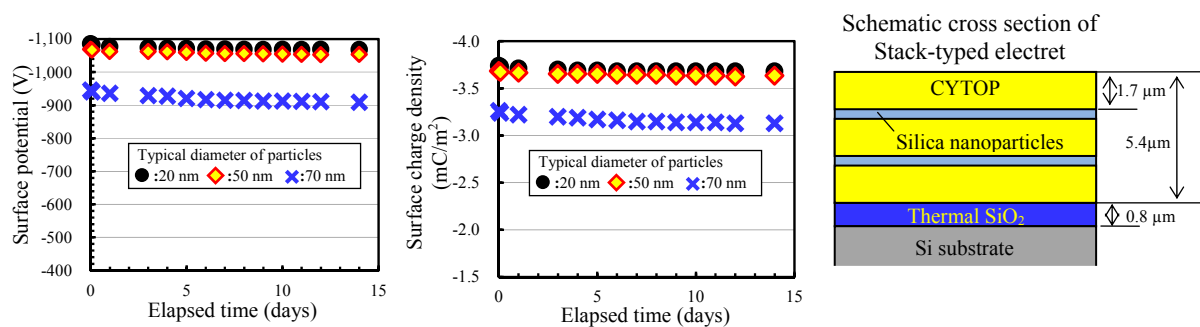


Figure 4. Time degradation of surface potential of electrets made of stacks of CYTOP and silica nano-particles.

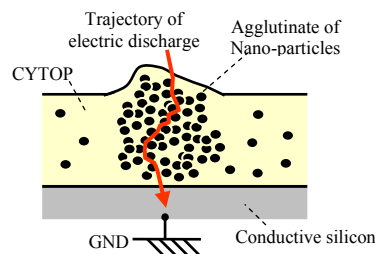


Figure 5. Schematic illustration describing how electric charge discharges through the aggregate of nano-particles.

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