Processing of Al₂O₃/SrTiO₃/PDMS Composites With Low Dielectric Loss

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Abstract. Polydimethylsiloxane (PDMS) is widely used in the electrical and electronic industries due to its excellent electrical insulation and biocompatible characteristics. However, the dielectric constant of pure PDMS is very low which restricts its applications. Herein, we report a series of PDMS/Al₂O₃/strontium titanate (ST) composites with high dielectric constant and low loss prepared by a simple experimental method. The composites exhibit high dielectric constant (relative dielectric constant is 4) after the composites are coated with insulated Al₂O₃ particles, and the dielectric constant gets further improved for composites with ST particles (dielectric constant reaches 15.5); a lower dielectric loss (tanδ = 0.05) is also found at the same time which makes co-filler composites suitable for electrical insulation products, and makes the experimental method more interesting in modern teaching.

1 Introduction

Due to the excellent insulation, light-weight and easy transportation and installation, polymeric insulators have attracted more attention, and they are increasingly replacing the traditional ceramic insulators [1]. However, they still have some inherent disadvantages, hindering their application in fields of electrical and electronic industries. To overcome these defects, ceramic fillers have been incorporated into the polymer matrix. Among the polymeric insulators, PDMS has one superior attribution on the electrical and electronic industries because of its superior or comparable physical, electrical and chemical properties as compared to traditional ceramic and glass-based insulators [2–4]. However, the apparent disadvantages of the pure silicon rubber is low dielectric constant [5–6], which limits its application as flexible dielectric materials. Previous studies report that inorganic fillers and
ceramics dispersed in the polymers are able to enhance dielectric properties.

Al₂O₃ and ST have remarkable electrical resistivity and high dielectric constants, respectively [⁷]. The co-filled system of tow kind of inorganic fillers is more useful when some researches display the effect of materials’ dielectric properties improved are not obvious. The dielectric properties of PDMS co-filled with Al₂O₃ and ST have not been reported so far. Here present is an investigation of the combined effect from such fillers on dielectric properties of PDMS composites, and an unexpected increase of dielectric constant are obtained by using conventional hot-press method, which be frequently applied in teaching experiment of polymer materials lessons, and make the classic experiment more interesting in modern teaching.

2 Experimental
2.1 Materials
PDMS(parts: A and B) used in present by Shenzhen Hong Ye Jie Technology Co (Shenzhen, China), Aluminum oxide used as a filler was 99.99% metals basis by Aladdin Industrial Co (Shanghai, China), Strontium titanate used as a high dielectric properties filler by Nantong Auxin Electronic Technology Co (Jiangsu, China).

2.2 Samples preparations
Part A and Part B of the PDMS were mixed at a volume ratio of 1: 1 for 10min at room temperature. Then, Al₂O₃ and ST mix with PDMS for 10min respectively. The composites were prepared by a simple heating and curing processes at about 70~80°C for 5h. Finally, the samples were silvered by silver-paint.

2.3 Characterizations
The measurement of dielectric constant and dielectric loss were carried out using a LCR Spectrum Analyzer (Frequency range is 10²~10⁶ Hz).

3 Result and Discussion
3.1 The dielectric properties of Al₂O₃/PDMS and ST/ PDMS composites
The dielectric constants and dielectric loss of Al₂O₃/PDMS composites were showed in Fig.1(a), Fig.1(b) respectively. Fig.1(c) and Fig.1 (b) respectively display dielectric constants and dielectric loss of ST/PDMS composites.
Figure.1 The dielectric constants and dielectric loss of Al₂O₃/PDMS composites (a, b) and ST/PDMS composites(c, d)

Evaluation of dielectric properties of Al₂O₃/PDMS and ST/PDMS composites yielded obvious results (Fig.1). Although the dielectric constant of pure PDMS is as low as 1.8 at 100 Hz, the addition of a series of fillers display excellent dielectric constants and low dielectric loss: the highest value of Al₂O₃/PDMS and ST/PDMS reaches 5 and 9 at 100Hz, respectively, at 15vol% Al₂O₃ and 20vol% ST, at the same time, the dielectric loss of tow composites was below 0.05 from low frequency to high frequency. The results showed the addition of Al₂O₃ or ST both improve material’s dielectric constant, and it is obvious that ST/PDMS composites had more higher dielectric constant than Al₂O₃/PDMS composites. At the same times, dielectric loss of materials with numerous ST were unstable when the frequency was blow 1000 Hz. So to overcome tow fillers’ disadvantages and improve the dielectric constant further, Al₂O₃ and ST has been add into PDMS together.

3.2 The dielectric properties of Al₂O₃/ST/PDMS composites

The ternary composites’ dielectric constants and dielectric loss were showed in Fig.2(a) and 2(b), respectively.

Figure.2 The dielectric constants and dielectric loss of Al₂O₃/ST/PDMS composites (a, b)

The test of dielectric properties of Al₂O₃/ST/PDMS composites yielded remarkable results. Al₂O₃/ST co-filled system(15vol% Al₂O₃ and 20vol%ST) obtain a the highest value (13)that was seven times than pure PDMS and dielectric loss did not increased and more stable compare with pure PDMS. This result display Al₂O₃/ ST co-filled system is more effective than the only one filler in enhancement of
dielectric constant.

4 Conclusion
A series of \( \text{Al}_2\text{O}_3/\text{PDMS, ST/PDMS and Al}_2\text{O}_3/\text{ST/PDMS composites} \) exhibit outstanding dielectric properties and low dielectric loss owing to the \( \text{Al}_2\text{O}_3 \) and ST have remarkable electrical resistivity and high dielectric constants. The highest value of materials’ dielectric constant reach 13 at 100Hz and the dielectric loss (0.05) does not obviously increase at the same time. The results display that \( \text{Al}_2\text{O}_3/ \text{ST co-filled system} \) obviously enhance dielectric properties of composites.

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