

## Effect of UV radiation on dielectric properties of PU/nano-TiO<sub>2</sub> composites

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### Abstract

The dielectric constant of most polymers is very low; the addition of TiO<sub>2</sub> particles into the polymers provides an attractive and promising way to reach a high dielectric constant. Polymer-based materials with a high dielectric constant show great potential for energy storage applications. Four samples were prepared, one of them was polyurethane (PU) and the other were PU with different weight percent (wt %) of TiO<sub>2</sub> (0.1, 0.2, 0.3) powder AFM test was used to distinguish the nanoparticles. The result shows that the most shape of these nanoparticles are spherical and the roughness average is 0.798 nm. The dielectric properties were measured for all samples before and after the exposure to the UV radiation. The result illustrates that the dielectric constant decreased and the dielectric loss increased, the amount of decrease in the dielectric constant decreases with the increasing of the TiO<sub>2</sub> concentration that added to the PU and decreasing in the amount of dielectric loss.

### Key words

Polyurethane, TiO<sub>2</sub>, the UV radiation, nanocomposites.

### Article info.

Received: Oct. 2016

Accepted: Dec. 2016

Published: Jun. 2017

## تأثير الأشعة فوق البنفسجية على خواص العزل لمركب البوليمر/ثاني أكسيد التيتانيوم

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### الخلاصة

معظم البوليمرات لها ثابت عزل منخفض جدا و إضافة دقائق ثاني أكسيد التيتانيوم إليها توفر وسيلة واعدة للحصول على ثابت عزل عالي، المواد ذات الأساس البوليمري التي ثابت عزلها عالي تظهر قدرة عالية في تطبيقات تخزين الطاقة. فقد تم تحضير أربع عينات واحدة منها بولي يوريثان فقط والبقية كانت بولي يوريثان مضافا إليها نسب وزنية مختلفة من مادة ثاني أكسيد التيتانيوم (0.1، 0.2، 0.3) حيث استخدم فحص AFM لتمييز طبيعة جسيماتها والنتيجة كانت معدل الخشونة 0.798 نانومتر والجسيمات كانت كروية الشكل، وعرضت جميع العينات للأشعة فوق بنفسجية ثم تم قياس خواص العزل قبل التشعيع وبعده، وكانت النتيجة انخفاض ثابت العزل الكهربائي وازدياد فقد العزل، ويقل مقدار انخفاض ثابت العزل عند زيادة تركيز مادة ثاني أكسيد التيتانيوم المضافة للبوليمر وبالتالي يورثان وكذلك تقل قيمة فقد العزل.

### Introduction

Polymer composites filled with ceramic particles have received considerable attention in the past decade. Favourable features include a high dielectric constant, low dielectric loss making them promising candidates for embedded capacitors used in passive technology [1, 2].

Dielectric materials have storing ability to large amounts of electrical energy which are desirable for many power devices. Polyurethane elastomer is material that offers the elasticity of rubber combined with good mechanical properties, toughness and durability [1]. PU composites are used in various applications such as sensors

and cables [3]. Titanium dioxide is an inorganic filler having large permittivity and used for insulating material in a dielectric for capacitors [4, 5]. Polyurethane is a polar polymer having relatively high permittivity, so it used as a capacitor for electronic applications. A tailor-made capacitor with controlled dielectric properties can also be obtained using PU as a matrix filled with electro-ceramics, such as titania (TiO<sub>2</sub>) having a high dielectric constant [6]. The present investigation deals with the development of a dielectric material using PU as the base matrix with different concentrations of TiO<sub>2</sub> as a filler, and the UV effect on dielectric properties.

**Experimental**

The cast technique was used to prepare three sample of polyurethane one of them was pure and the other

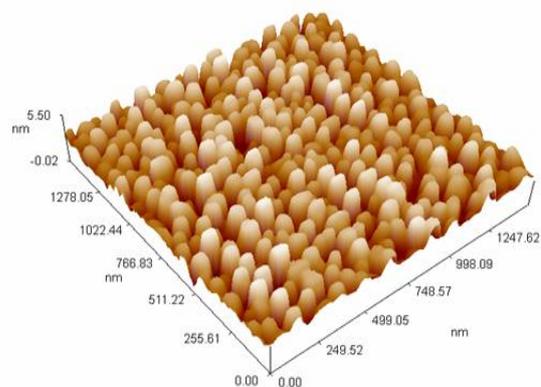
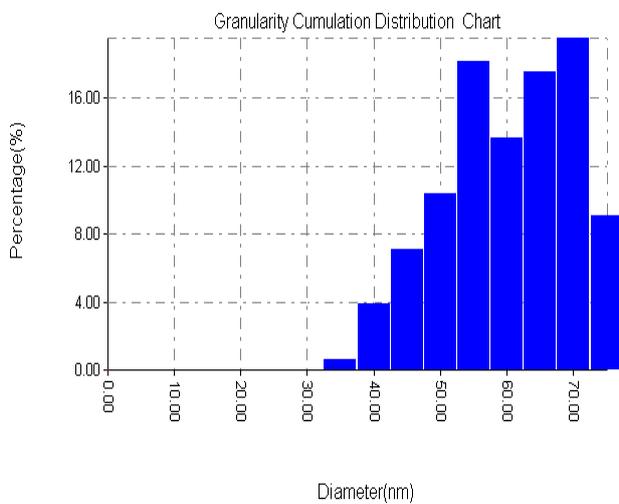
were polyurethane with additives three volume fractions of TiO<sub>2</sub> nanoparticales (0.1, 0.2 and 0.3). Dielectric properties of these composites were measured using a precision LCR meter (Agilent impedance analyzer American origin). All measurements were carried out over the frequency range (50Hz–5MHz). Measurements were performed before and after irradiation by UV Source.

**Results and discussion**

AFM was performed to measure the average diameter of TiO<sub>2</sub> nanoparticles by using AA3000 Scanning Probe Microscope by: Angstrom Advanced Inc. It is found that the average diameter was 57.57 nm which is agreed with data sheet of TiO<sub>2</sub> as tabulated in Table 1. Fig. 1 shows the percentage and particle diameter of TiO<sub>2</sub> nanoparticles.

**Table 1: Diameter, volume (%), and Cumulation (%) of Tio<sub>2</sub> nanoparticles.**

Diameter(nm)<	Volume(%)	Cumulation(%)	Diameter(nm)<	Volume(%)	Cumulation(%)	Diameter(nm)<	Volume(%)	Cumulation(%)
35.00	0.65	0.65	50.00	10.39	22.08	65.00	17.53	71.43
40.00	3.90	4.55	55.00	18.18	40.26	70.00	19.48	90.91
45.00	7.14	11.69	60.00	13.64	53.90	75.00	9.09	100.00



**Fig.1: Addition percentage (%) vs. diameter of TiO<sub>2</sub> nanoparticles.**

Dielectric constant ( $\epsilon'$ ) and dielectric loss ( $\epsilon''$ ) vs. frequency for different PU–TiO<sub>2</sub> composites are presented in Fig. 2 and Fig. 3, respectively. There is a large change in both dielectric constant and loss factor with a change in frequency and filler loading. Moreover, at any particular frequency, the dielectric constant is increased with an increase in titania

content. This is mainly because of the higher dielectric constant of filler compared to the matrix polymer. The dielectric constant of all the composites is increased significantly with a decrease in frequency. This is mainly because of the increased contributions of interfacial dipolar polarization at a lower frequency range.

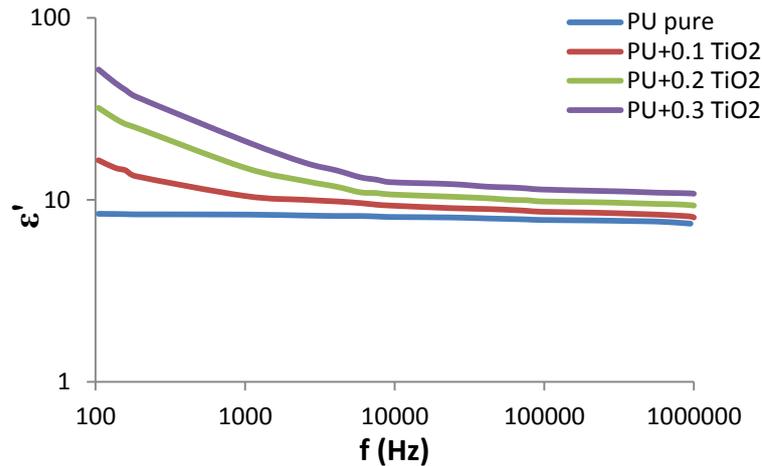


Fig. 2: Dielectric constant vs. frequency for PU–TiO<sub>2</sub> composites at various filler loading.

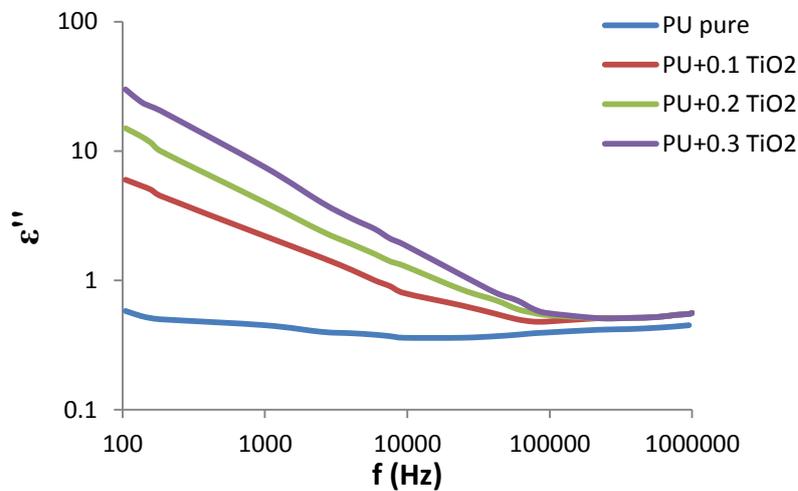


Fig. 3: Dielectric loss vs. frequency for PU–TiO<sub>2</sub> composites at various filler loading.

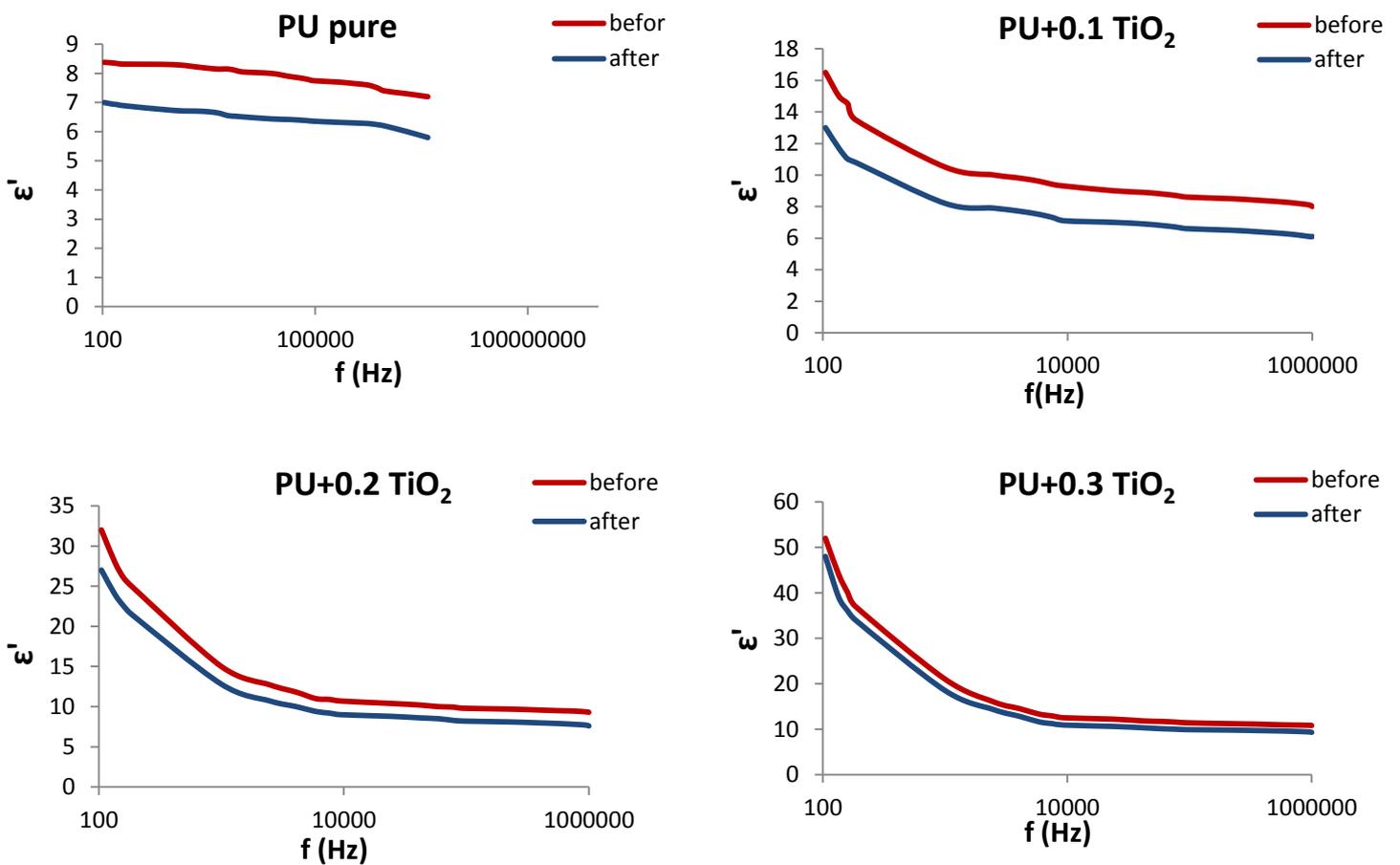
Over the frequency range (100–10<sup>3</sup>) Hz, it can be noticed that the dielectric constant increases dramatically as the frequency is lowered. This indicates the existence of strong interfacial polarization over this frequency region. Similar to the dielectric constant at any particular frequency, dielectric loss is also

increased with an increase in TiO<sub>2</sub> content, as shown in the Fig. 3.

The reaction of pure polymer film under UV irradiation occurs via the absorption of photons by the PU molecule to create the excited states which leads to the chain scission. After UV exposure, the dielectric constant decreased and dielectric loss increased

for all samples. The bonds between the atoms in many polymers have dissociation energies that are very similar to the quantum energy present in UV radiation, therefore this quantum energy capable of breaking the bonds in the polymer chains to generate a cascade of reaction, oxygen radicals, hydroperoxide units, carbonyl group formation and chain cleavage occur, as a result the polarization groups reduced and dielectric constant decreased and dielectric loss increased

as a function of frequency [7]. Therefore, in (PU-TiO<sub>2</sub>) samples observe that the amount of decrease in the dielectric constant decreases with increasing the concentration of TiO<sub>2</sub> that added to the PU as shown in Fig. 4 because of TiO<sub>2</sub> nanoparticles that add to facilitates the absorption of photons from UV, degradation is reduced because the reduction in the number of active photons and this also leads to decrease the dielectric loss as shown in Fig. 5.



**Fig. 4:** Variation of dielectric constant as a function of frequency before and after UV irradiation for PU and (PU-TiO<sub>2</sub>) composite.

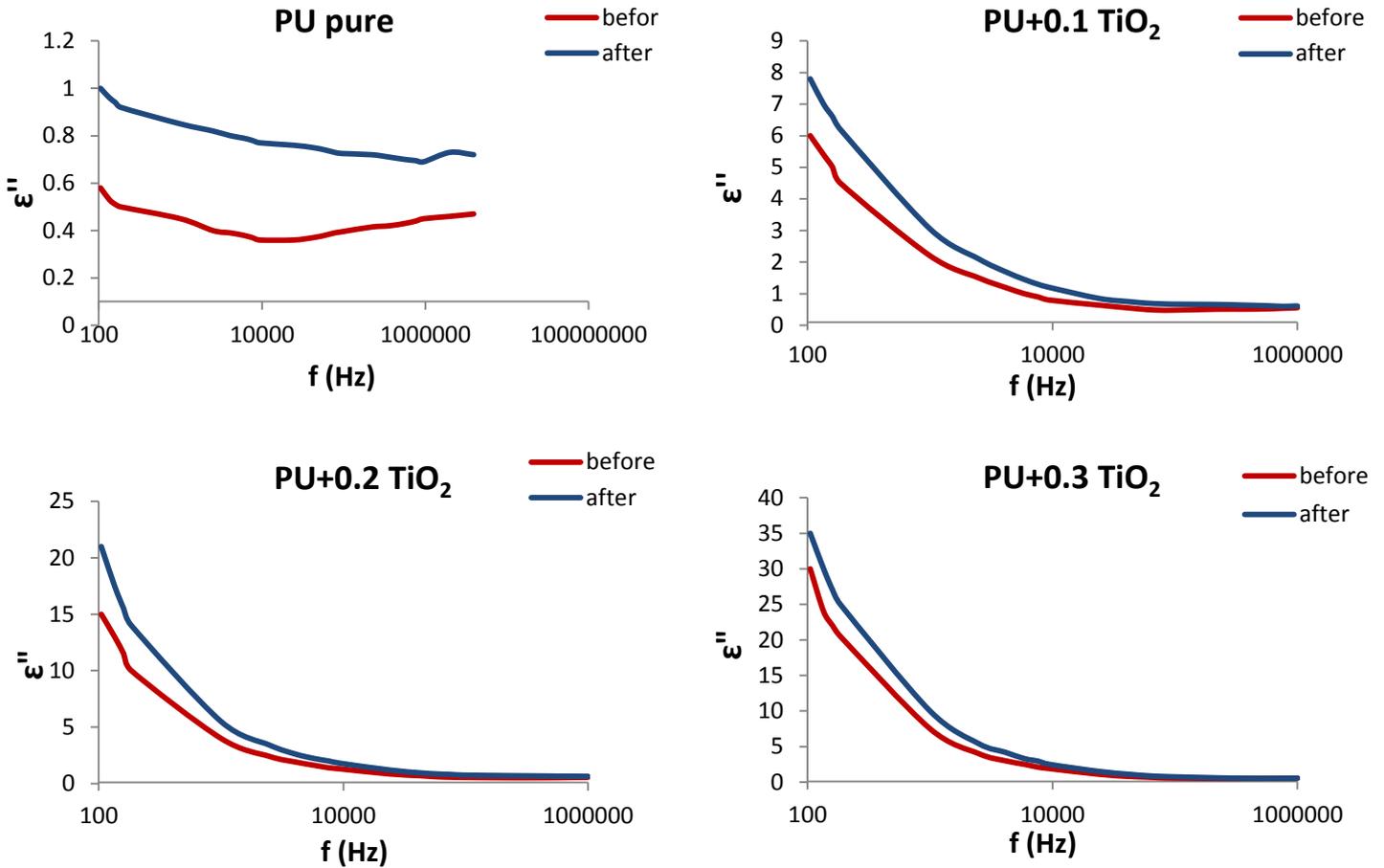


Fig. 5: Variation of dielectric loss as a function of frequency before and after UV irradiation for PU and (PU-TiO<sub>2</sub>) composite.

### Conclusions

Dielectric constant decreases after UV exposure, while the dielectric loss increases in all the samples, the amount of decrease in the dielectric constant decreases with the increasing of the  $\text{TiO}_2$  concentration that added to the PU and decreasing in the amount of increase in dielectric loss. Thus, we have developed a simple way for raising the dielectric performance of (PU-TiO<sub>2</sub>) nano-composites to resist ultraviolet radiation.

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