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Characterization of Engineered PMMA-Doped Titanium dioxide Nanocomposite

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Abstract: ***TiO2-PMMA nanocomposite was prepared. The PMMA film was prepared by Chemical Bath Deposition. The TiO2 nanoparticles filler was added to the film with ratio of (0.1, 0.5 and 0.7) %. The mechanical properties (wear rate, applied load and sliding velocity) were done; the results show the capability to obtain a clear wear resistance at 0.5% of filler ratio. The optical properties of the prepared nanocomposite were studied, the result revealed the nonlinearity and limiting behavior.***

Keywords: Characterization, TiO2, Nano, PMMA

1. Introduction

Nano-scale composite materials containing titanium oxides are interesting because of their potential applications in mechanical and optical applications. A great deal of research effort has been focused on both synthesis of high-quality, transparent films consisting of polymer-TiO2 hybrid nanocomposites. The addition of inorganic spherical nanoparticles to polymers allows the modification of the polymers physical properties as well as the implementation of new features in the polymer matrix. The consumption of TiO2 increased in the last few years such as a photocatalyst, and thermo-mechanical stability [1]

The nonlinear-optical properties of such materials have also received attention. Polymer nanocomposites, consisting of inorganic nanocrystals (NCs) embedded in polymer matrix, are complex materials in which is possible to combine the properties of organic and inorganic materials in a unique compound for potential applications in many fields, such as optics, electronics, mechanics, chemical sensing and biology[2].

Organic–inorganic hybrid materials have attracted considerable attention due to their novel physical and chemical properties. Inorganic nanoparticles can be embedded in polymer matrix to form high refractive index nanocomposite [3].

Among the polymers, the PMMA is very interesting for optical applications as optical fibers, optical disks and lenses [2] PMMA is one of the most versatile polymeric materials for applications in various technological areas including optics and electro-optics [3].

Novel electronic and optical materials based on these nanohybrids have found applications in technologically demanding areas such as optical coatings, contact lenses, optical switches, high refractive index devices, optical waveguides and nonlinear optical devices [3].

One of most important application is for artificial teeth which are made up of polymeric materials, such as PMMA (poly-methyl-methacrylate). For practical applications these materials require significant wear resistance properties. Therefore researches have been going on to enhance the wear resistance properties employing different techniques for improved performances of these products. The addition of fillers nano-TiO2 increase the mechanical properties of polymers [4]

The aim of this work is to prepare (TiO2-PMMA) samples and to study the mechanical wear test, and study nonlinear optical properties such as nonlinear absorption and optical limiting behavior.

2. Experimental Procedure

The PMMA was prepared by chemical bath deposition -CBD- method, by dissolving 0.7 g of PMMA in 10 ml toluene to get the homogenous solution. The magnetic heater stirrer was used as a source of heating and to mix the solution. Titanium dioxide emulsion was prepared by dissolving different weights of TiO2 nanoparticles (0.1, 0.5 and 0.7 g) in 10 ml of toluene and stirred in magnetic stirred without heating for 2 hours. After preparing unmodified PMMA, the solution of TiO2 in toluene was added then mixed with heating the solution for 3 hours in order to avoid the molecular aggregation.

UV-VIS spectrometer was used to examine the films and compare them with unmodified PMMA. The nonlinear optical properties (nonlinear absorption coefficient as well as the optical limiting behavior) were done by z-scan technique. The z-scan system consist of Q-switched Nd:YAG laser with 100mJ energy pulses at 532nm focused onto the sample by using a lens with 10 cm focal length. The output laser pulses are monitored by energy meter (MellesGriot). The data collected were determined and graphed versus filler concentration.

3. Wear Test

The wear tests were performed in air at room temperature versus both of sliding velocity and applied loads, respectively. The wear rates are calculated according to the following equation:

$$\text{Wear Rate (W.R)} = \Delta W/SD \quad (1)$$

Where: ΔW: is the weight loss of the specimen before and after the wear test (gm), ΔW=W1-W2. SD: is the sliding distance (cm). [12,13]

$$SD = 2\,\pi Nrt \quad (2)$$

Where (t): is the sliding time (min). The sliding velocity is evaluated from the relationship:-

$$VS = (\pi DN)/60 \quad (3)$$

Where: D: disk diameter (cm). N: revolutions no. of the disc (rev. /min).

It is necessary to mention the following: all specimens were cleaned smoother for the test, the samples weight was measured before and after the test.

4. Results and Discussion

The absorption spectrum of the prepared sample films was detected. Fig. (1) showed the absorption of the TiO2-PMMA at different concentration. The behavior showed three viewed peaks which decreases according to the filler increased. All them are red shift. This is because the result of the excitation of electrons from the valence band to the conduction band of TiO2, is occurs at the wavelength of about 200–400 nm. The difference in absorption wavelength indicates a difference in the band gap of TiO2 with increasing loading of the inorganic phase.[3]

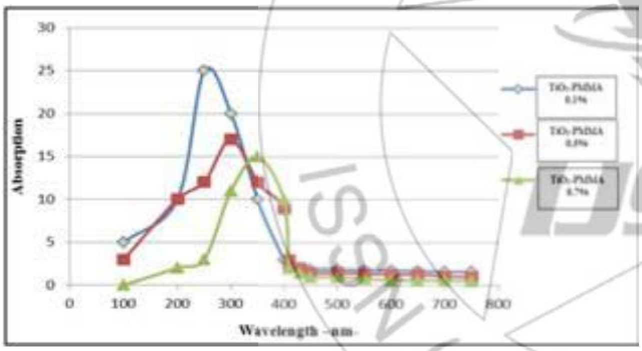

Figure 1: The absorption spectrum of the TiO2-PMMA with different concentration of TiO2

Fig. (2) Shows the nonlinear absorption coefficient behavior as a function of concentration. The figure showed the increasing of absorption coefficient with the ratio of filler , while it stops at 0.9. The nonlinear absorption behavior is due to the results of two photon absorption (TPA) [7].

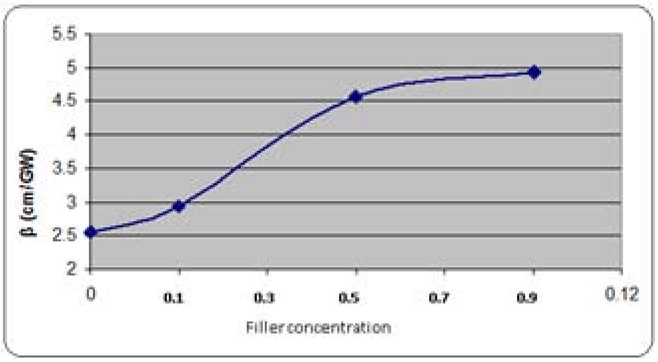

Figure 2: Variation of nonlinear absorption coefficient as a function of TiO2 concentration in PMMA

We tried to use the engineered composite as an optical limiter. Fig.(3). Shows the limiting behavior of TiO2-PMMA were performed by a Z-scan with nanosecond pulses at 532 nm, the output fluency was plotted versus the input fluence as measured for various input energy. The limiting energy was measured at various distances -Z- between the far-field of a Gaussian beam and the beam waist. The resulting data showed a linear behavior for low input fluence, the limiting occurs at approximately, 4.8 J/cm2 over which the sample may be damaged. This was attributed to enhance the Kerr effect and the two-photon absorption.

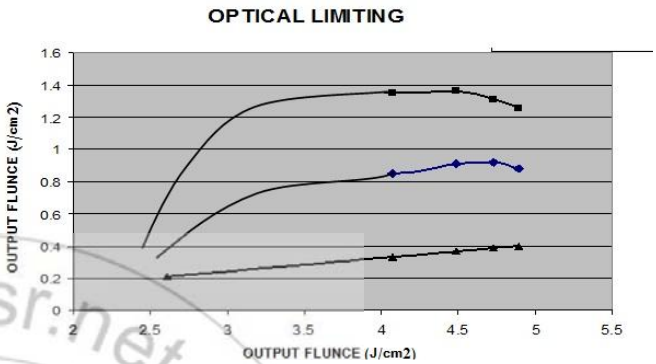

Figure 3: Optical limiting behavior of an open-aperture TiO2-PMMA at different TiO2 concentration

Fig. (4) and Fig.(5) respectively, showed the behavior of wear against applied load and sliding velocity. The two curves indicate a clear increasing of wear resistance at 0.5% filler concentration, which means the increase in hardening of the composite films. The main cause of the hardening is the distribution of TiO2 nanoparticles in the polymer matrix which decreases the dislocation movement that leads to increase in wear rate.

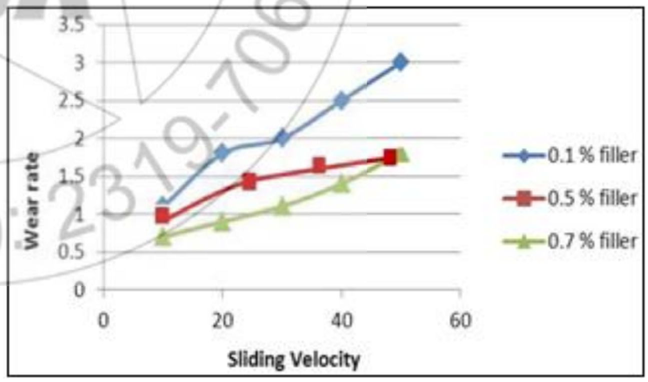

Figure 4: wear rate versus sliding velocity

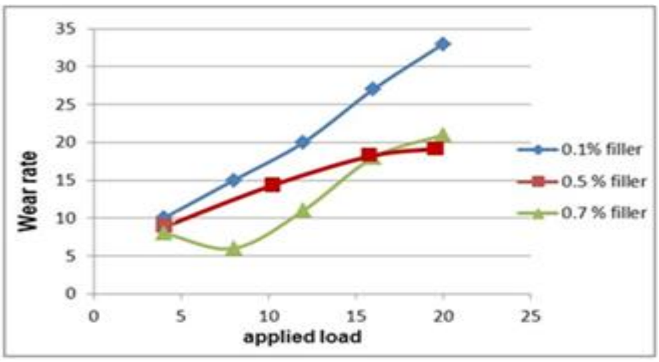

Figure 5: wear rate versus applied load

5. Conclusions

It can be conclude that TiO2-PMMA nanocomposite could be used as an optical limiter and revealed good wear resistance at 0.5% filler ratio.

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