Effect of Adding Methyl Orange Dye on Optical Properties of Polymethyl Methacrylate Polymer

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Abstract
This study investigated the effect of methyl orange dye on some optical properties of polymethyl methacrylate (PMMA) polymer films prepared by the casting method. Absorbance, transmittance, reflectance, extinction coefficient, and reflection coefficient were studied. It was found that these parameters changed with the addition of methyl orange dye to the polymer.

Keywords: PMMA polymer; Methyl orange dye; Optical properties; Spectroscopic characteristics
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1. Introduction

The doping of PMMA (polymethyl methacrylate) polymer with organic dyes holds significant importance across various scientific and technological domains [1]. This process fundamentally alters the optical properties of the otherwise transparent polymer, enabling its use in advanced applications [2]. One primary significance lies in the development of organic light-emitting diodes (OLEDs) and flexible displays. Doped PMMA can serve as a host matrix for emissive organic dyes, providing a robust and flexible platform for light generation. This leads to devices that are lightweight, thin, and can be conformed to various shapes, opening possibilities for wearable electronics and novel display technologies. Furthermore, this doping is crucial for optical sensors and biosensors. Organic dyes exhibit unique spectroscopic properties, such as fluorescence, which can be tuned by their environment or interactions with specific analytes [3]. Incorporating these dyes into PMMA creates stable, transparent sensing platforms where changes in fluorescence intensity or wavelength can signal the presence or concentration of a target substance. This is particularly valuable in medical diagnostics, environmental monitoring, and chemical analysis.

Another key area is laser technology and photonics [4]. Doped PMMA can be engineered to create solid-state dye lasers, offering tunable laser emission over a broad spectrum [5]. The polymer matrix provides mechanical stability and ease of fabrication, making them attractive for compact and cost-effective laser systems used in spectroscopy, telecommunications, and industrial processing.

Finally, the ability to control the color and light-filtering properties of PMMA through dye doping is vital for decorative and architectural applications, as well as optical filters and lenses [6]. This allows for the creation of aesthetically pleasing and functionally specific materials that can manipulate light for various purposes, from enhancing visual appeal to precisely controlling light transmission in optical instruments. In essence, doping PMMA with organic dyes transforms a basic polymer into a versatile material with advanced functionalities, driving innovation in diverse high-tech fields [7].

Polymer membranes play a significant role in the development of several areas of scientific research, particularly in the field of detectors and sensors. In recent years, polymer membranes impregnated with organic dyes have become a central topic of scientific research, given the optical properties offered by organic dyes such as methyl red, methyl orange, and methyl blue [8,9]. Using polymers as a matrix to contain the dye offers significant opportunities for developing new applications in diverse fields [10]. This work aims to enhance the optical properties of polymer materials and improve their optical performance by distributing and diffusing the dye across the polymer chains [11-15].

2. Materials and Method

A mixture of polymethyl methacrylate (PMMA) and methyl orange dye was used to dissolve the dye in chloroform. Pure polymer films impregnated with the dye at a weight percentage of 6% were prepared using the casting method. The thickness of the films was in the range of 30±0.05 μm by using micrometer and the average area was 2.5x2.5 cm^2. The absorbance and transmittance measurements were carried out using a Shimadzu UV/VIS-160A double beam spectrophotometer in the wavelength range (190-1100) nm.

3. Results and Discussion

The study of the optical absorption spectrum is one of the most productive methods in developing and understanding the structure and optical energy gap of polymers. The UV-VI-NIR absorbance spectra of pure PMMA as well as methyl orange dye doped

PMMA are shown in Fig. (1). It was found that the absorption edge shifts towards lower energies. Furthermore, the transmittance was found to decrease with doping by methyl orange dye as shown in Fig. (2).

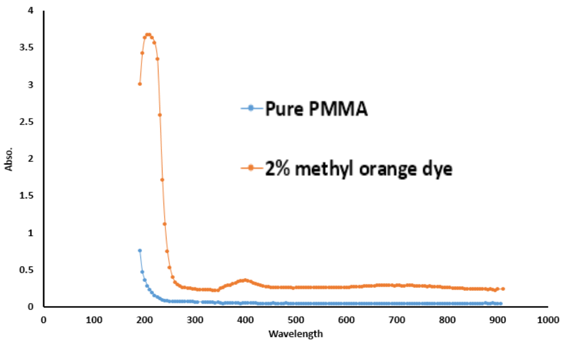

Fig. (1) Absorption spectra of PMMA:methyl orange dye as a function of wavelength

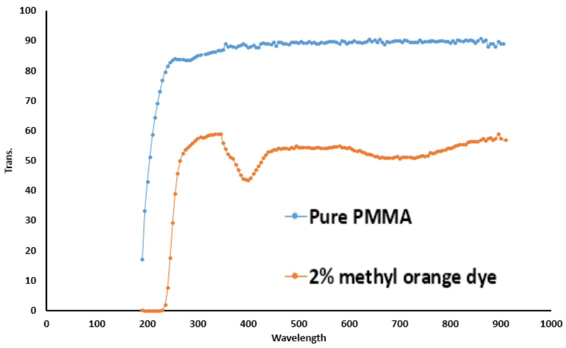

Fig. (2) Transmission spectra of PMMA:methyl orange dye as a function of wavelength

The following relation could be use for calculating the absorption coefficient (α) [4]:

$$\alpha = \frac{2.303A}{t} \qquad (1)$$

where A is the absorbance and t is the film thickness

Figure (3) shows the reflectance spectra for all the prepared samples.

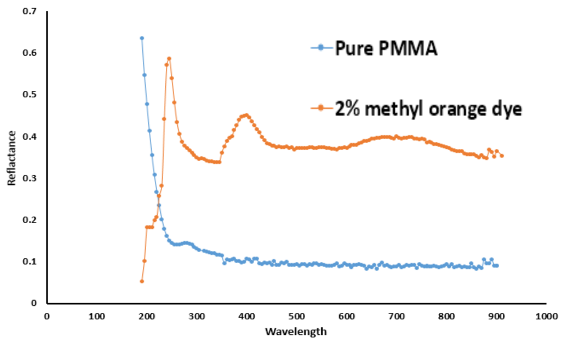

Fig. (3) Reflection spectra of PMMA:methyl orange dye as a function of wavelength

The refractive index (n_0) of the films can be determined from the following equation [8]:

$$n_0 = \left(\frac{1+R}{1-R}\right) + \sqrt{\frac{4R}{(1-R)^2} - k_0^2} \qquad (2)$$

where R is the reflectance and k_0 is the extinction coefficient

The extinction coefficient (k_0) represents the imaginary part of complex refractive index and it can be defined as the amount of energy losing as a result of interaction between the light and the charge of medium [10].

From Fig. (4), the behavior of extinction coefficient is increases with increasing red methyl concentration because it is directly proportional to the absorption coefficient as see in relation [11]:

$$k_0 = \frac{\alpha\lambda}{4\pi} \qquad (3)$$

where λ is the wavelength of the incident photon

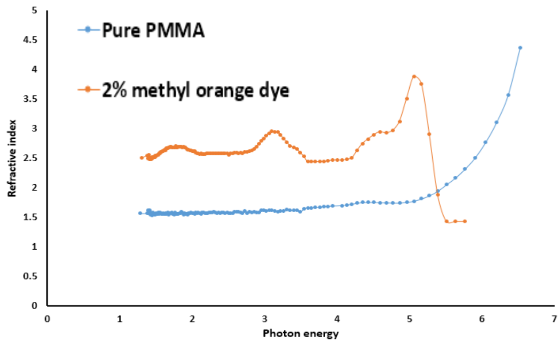

Fig. (4) Extinction coefficient of PMMA:methyl orange dye as a function of photon energy

Figure (5) shows the variation of refractive index (n_0) with photon energy, for all samples refractive index is behavior similar to reflectance. This figure reveals a tendency for an increase in refractive index with doping. The variation of refractive index in investigated frequency range shows that some interactions take places between photons and electrons. Refractive index changes with variation of the wavelength of the incident light beam are due to these interactions [9].

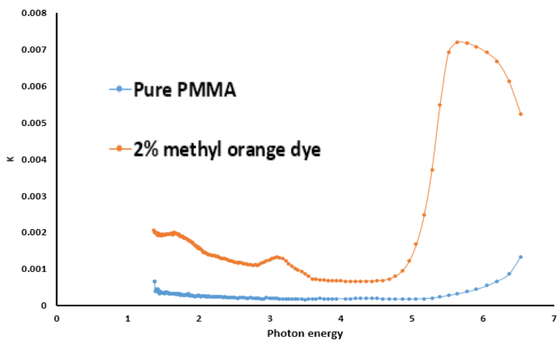

Fig. (5) Refractive index of PMMA:methyl orange dye as a function of photon energy

4. Conclusions

Based on the experimental results obtained from this work, it can be concluded that the doping process decreases the transmittance and the refractive index and extinction coefficient constant increase with doping.

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