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RESEARCH ARTICLE - Physics

Nanofibers of PMMA/TiO_2 produced by electrospinning

Nadia M. Sallomi[1], Nuha Hussien Ali[2], Hiba S. Rasheed[3], Tariq J. Alwan[4]

[*1,3,4]Department of Physics, Collage of Education, University of Mustansiriyah, Baghdad, Iraq
[2]Register Office, Collage of Education, University of Mustansiriyah, Baghdad, Iraq
[*] Corresponding author E-mail: nadia.mehdi@uomustansiriyah.edu.iq

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Abstract

The method of electrospinning with a rotating cylinder collector was used to prepare PMM/TiO_2 nanofibers. The effect of the collector rotation speed on the diameters, morphology, and structural properties of the prepared PMM/TiO_2 nanofibers was studied, with the remaining parameters of the electrospinning system held constant. relied on the FE-SEM to study the diameters and regularity of the prepared nanofibers, which showed that the obtained nanofibers with diameters of 366 nm decreased to 127 nm and their regularity increased as the collector speed increased. The X-ray diffraction spectra showed that the prepared PMM/TiO_2 nanofibers have an amorphous structure and begin to transform into a polycrystalline structure with increasing collector speed. Functional groups identified through FTIR tests have been shown to not be affected by the increase in rotation speed, regularity, or decrease in the diameter of the prepared PMM/TiO_2 nanofibers.

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***Keywords**:* PMMA/TiO_2, Nanofibers, Electrospinning, Collector speeds.

1. Introduction

Electrospinning is a widely used technique in preparing fibers, and the diameter of the prepared fibers can reach several microns or even several nanometers. Because nanofibers prepared by electrospinning have the characteristics of high aspect ratio, large specific surface area, controllable pores and excellent mechanical properties, electrospinning has gradually become one of the most popular methods for fabricating nanofibers [1]. Electrospinning technology has not been widely known for long, but its history can be traced back to 1887. Charles F. Olad in his report that the “best line” was obtained from a viscous solution under the influence of an external electric field. Since the 1990s, due to the development and use of nanotechnology, electrospinning technology has also risen and achieved explosive development [2]. The electrospinning device is simple in configuration and consists of a high-voltage power supply, a driving pump, a syringe, a needle and a collector. During electrospinning, the positive electrode of the high-voltage power supply is connected to the needle, and the negative electrode is connected to the collector for grounding. During electrospinning, the solution or solute droplets are extruded from the needle by the syringe and impeller pump, charged under high pressure, and then stretched into fibers that are collected by the collector [2,3]. Polymethyl methacrylate PMMA is obtained by free radical polymerization of methyl methacrylate, PMMA is colorless and transparent. The light transmittance is the best among plastics. Also, it is Light weight, strong, high mechanical strength at room temperature, low water absorption, resistant to water and some dilute acids inorganic salts, resistance to long-chain alkanes and ethers, non-toxic, no flame when burning [4]. Manufacturing composite materials by using nanoparticles, although it is difficult to obtain a homogeneous distribution of particles in the base material, it is possible to obtain composite materials with broad properties in practical applications. These composites consist of one or more types of nanoparticles of different shapes and sizes immersed in the base material. They differ from traditional composites in the distribution of the added components, which are somewhat random and controlled. Accordingly, the nanocomposites are isotropic (properties in all directions) (Isotropic), and in this type of reinforcement, the particles distribute the load with the base material, and the reinforcement with the particles increases the stiffness of the base material, increases creep resistance, impact strength, and improves wear and fatigue resistance, in addition to giving the base material a specific property that achieves the required goal

[5],[6]. When the PMMA/TiO_2 nanocomposite is prepared as nanofibers, this gives that PMMA/TiO_2 distinctive mechanical properties such as hardness, tensile strength, etc., which qualifies it without competition for use as filters in purifying liquids or gases, in biomedicine, transplanting organs such as joints, transporting medicines in the body, and in military applications such as reducing air resistance. and other applications [7],[8], [9], [10]. In this research, will be manufacture PMMA/TiO_2 nanofibers and study the effect of collector rotation speed on their structural and morphology properties.

2. Experimental procedure

The pure polymethyl methacrylate PMMA polymer supplied by ICI (M_w = 35000) was dissolved in chloroform at a concentration of 3 wt%. The solution was stirred using a magnetic stirrer for 1 hour until the polymer was completely dissolved. Then add 0.3 g of TiO_2 nanoparticles supplied by MKnano (Mw = 81) to the PMMA solution under a stirrer for another 1 hour. The solution was then transferred to the ultrasonic bath to ensure the diffusion of TiO_2 nanoparticles in the PMMA solution. Place 3 ml of the PMMA/TiO_2 solution in the syringe of the electrospinning device; see ref [11], for more details about the electrospinning system. 20 KV applied a voltage between the needle and the collector that has a distance of 15 cm, metallic needles with 23 gauges (diameters), in addition to a rotating cylinder collector with different setting speeds (1800, 2000, and 2200 rpm). The structural properties of the prepared nanofibers were characterized by field emission scanning electron microscopy FE-SEM to evaluate the fiber diameter, morphology, and alignment. The FESEM was a Hitachi S-4160 SEM. X-ray diffraction examination was carried out using a Philips, and the characterization bonds for the functional gropes were measured by Fourier transform infrared FT-IR spectra (Shimadzu FTIR-8400S).

3. Results and discussions

Figure 1 shows scanning electron microscope images of PMMA/TiO_2 nanofibers under the influence of different collector speeds. Initially, it was observed that nanofibers were typically less than 500 nm in diameter and up to 10 microns in length, but at a collector speed of 1800 rpm, these fibers were unaligned and random, with the presence of bulges or knots. When increasing the collection speed to 2000 rpm, note the beginning of the appearance of regularity and alignment between the nanofibers, but they still contain knots or bulges. A clear and regular alignment of the nanofibers appears, and the knots disappear when increasing the collection speed to 2200 rpm. On the other hand, and from the Figure 1, there is a clear decrease in nanofiber diameters with increasing collector speed (366.13, 267.56 and 127.87 nm at 1800, 2000, 2200 rpm, respectively). The above situation can be explained as follows: at slower collector speeds, the nanofibers have less opportunity to be stretched by the rotational force. Insufficient stretching can cause nanofibers to be misaligned along the axis of rotation, resulting in irregular shapes or bulges due to uneven tension. Also, slower collector speeds mean that each segment of the nanofibers spends more time in the electric field before being deposited on the collector. This extended exposure can lead to variations in nanofibers thickness and the formation of bulges, as the polymer solution may accumulate in certain areas more than others. This is consistent with what Al-Abduljabbar et al 2023 [12] and Xue et al 2019[13]found about the effect of collector speed in electrospinning system on the formation of knots and diameters in the prepared nanofibers, it is also found that increasing the speed of the collector to a certain extent leads to the disappearance of knots and the regularity of the nanofibers, in addition to a decrease in their diameters.

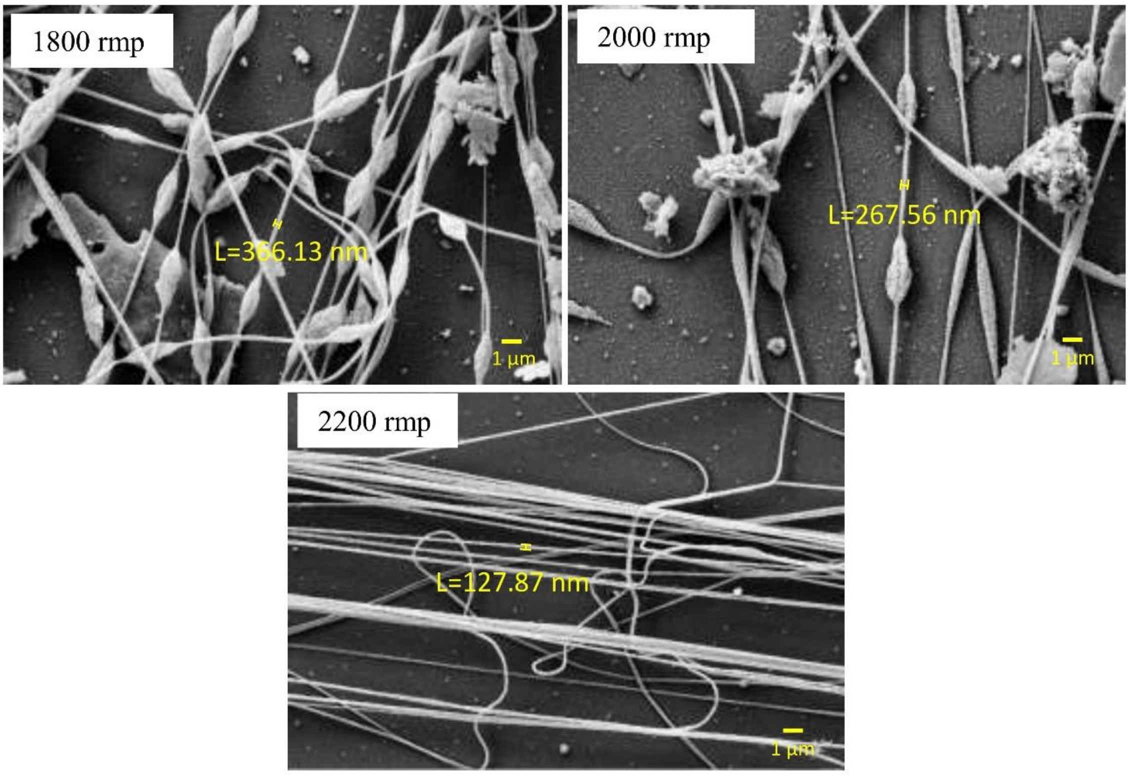

Fig. 1. FE-SEM images for the PMMA/TiO_2 nanofibers at different collector speed.

X-ray diffraction was used to study the crystallinity structure of the prepared PMMA/TiO_2 nanofibers. Figure 2 displays the X-ray diffraction patterns of the prepared PMMA/TiO_2 nanofibers and the effect of increasing the collector speed on them. At low speed, note that the samples have an amorphous structure and have a broad peak at $2\theta = 12.7^o$, this is a distinctive characteristic of polymethyl methacrylate and is consistent with previous literature [14], [15]. When the collector speed is increased to 2000 rpm, it is noticed that the broad peak becomes sharper, but it still indicates the amorphous structure of the samples. Raising the speed to 2200 rpm leads to a further improvement in the crystal structure through an increase in the sharpness of the broad peak as well as the appearance of a new peak at $2\theta = 24.84^o$ that matches the peaks characteristic of TiO_2. All of this indicates an improvement in the crystallinity structure with increasing collector speed. This is attributed to the of increased collector rotation rates provide enhanced alignment of the nanofibers in the electrospinning process. Enhanced alignment leads to a more organized and highly structured arrangement, which is seen in the x-ray diffraction patterns as more distinct and well-defined peaks. Moreover, increased collector rotation rates may effectively regulate the deposition of nanofibers on the collector, resulting in enhanced uniformity of nanofibers sizes. The presence of uniform nanofibers diameters enhances the regularity of the crystal structure [16], as shown in the X-ray diffraction investigation.

FTIR measurements were conducted to confirm the functional groups of the prepared samples and the effect of collector rotation speed on them, as shown in Figure 3. This figure shows the characteristic bands of the base material in the nanofibers (PMMA), and they are summarized in the table below. The functional groups summarized in the table above are similar and identical to the functional groups of the PMMA mentioned in much of the previous literature [17] [18] [19].

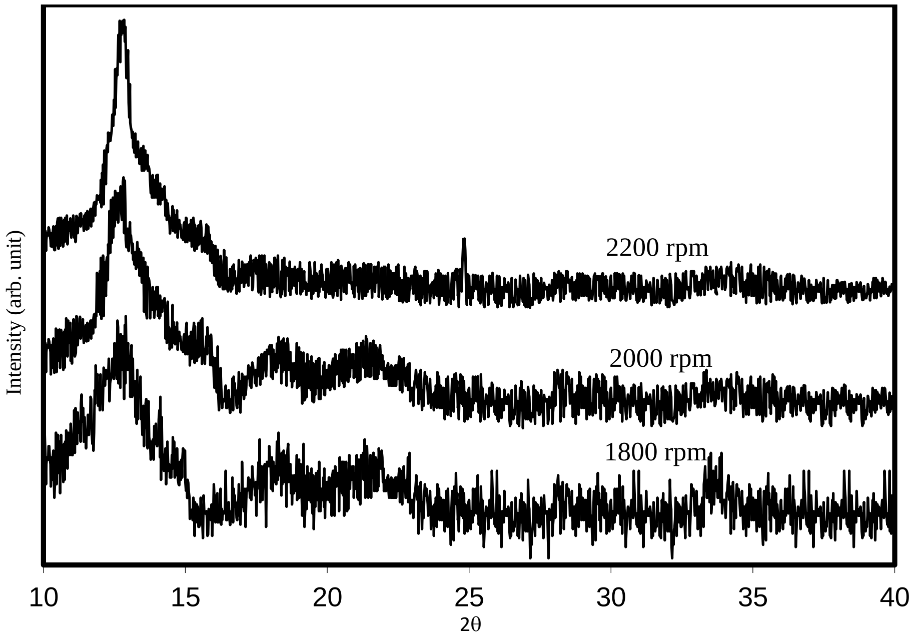

Fig. 2. The XRD spectra of the PMMA/TiO_2 nanofibers at different collector speeds.

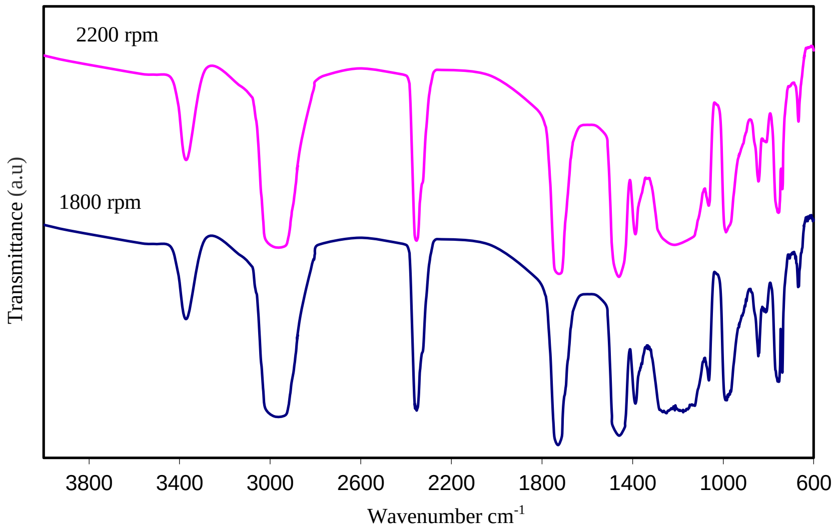

Fig.3. The FTIR spectra of of the PMMA/TiO_2 nanofibers at different collector speeds.

Table 1. The functional groups PMMA/TiO_2 nanofibers

Wavenumber cm^{-1}	Functional group
3000	C-H aliphatic
2361	C=H
1728	C=O
1459	C-H deformation
1392	C-O
995	C-H out of plane
846	C-H rock
3000	C-H aliphatic

It was also observed that bands at 769 cm^{-1} indicate the bonding of titanium into the nanofibers [20]. From the figure above, it is clear that increasing the rotation speed of the collector, the regularity of the fibers, and decreasing their diameters does not affect the functional groups for PMMA/TiO_2 nanofibers. That would be because the change in the physical dimensions of the nanofibers not involves chemical reactions that affect the functional groups of the PMMA/TiO_2 nanofibers [21].

4. Conclusions

From this study, concluded that the PMMA/TiO_2 compound can be successfully made into nanofibers using an electrospinning system. Increasing the speed of the system's rotating collector while adjusting the other parameters results in a decrease in the diameters of the prepared nanofibers, and becomes an alignment. The increase in collector speed improved the crystalline structure, with the best speed achieved being 2200 rpm, enabling the production of aligned nanofibers free of bulges and defects**.**

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