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Studying the Effect of Kaolin Nano Particles on the Hydrophobicity Behavior of Polystyrene Nanofibers Prepared by Electrospinning Technique

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Abstract:

This project promotes the creation of a nanofiber fabric made of polystyrene nanofibers reinforced with locally produced kaolin nanoparticles. An electrospinning procedure was used to create the overlapping fibers. The kaolin particles employed in this study underwent an X-ray test, and the outcome matched that of the typical test. The AFM results demonstrated that the nano-kaolin has a high fineness (1.5 nanometers), good surface area, and a high tolerance factor 6, in addition to other desirable properties. Kaolin nanoparticles in various ratios were utilized to evaluate the effect of kaolin on the hydrophobic behavior of polystyrene nanofibers. The results showed that the produced nanofibers could self-clean since they were hydrophobic (could not absorb water) and had a contact angle of 87 degrees, which increased after adding kaolin nanoparticles (139 ^{o}) . This study also looked into how solution characteristics like solution concentration and viscosity affected the diameters of the resulting fibers. The impact of nano Kaolin concentrations on the diameters of the resulting fibers was examined for the ideal concentration (0.12 g/ml), which was achieved because free-bead nanofibers were produced. This concentration was previously determined with the stability of the other parameters. The findings demonstrated that as kaolin nanoparticle concentration rises, so do nanofiber diameters because rising solution viscosities increase the number of nanofibers reinforced with kaolin nanoparticles. Additionally, wetting angle rises until it reaches 139 degrees.

Key wards : PS nanofibers , Kaolin Nanoparticles , Electrospinning , Hydrophobic

Introduction:

Surfaces are split into two groups based on their water behavior: hydrophilic surfaces and hydrophobic surfaces [1]. Hydrophilic compounds have a contact angle of less than 90 degrees and can react with water to generate hydrogen bonds. [2] . Hydrophobic surfaces, on the other hand, do not interact with water and can break hydrogen bonds due to their greater than 90-degree contact angle. [3-4] and other extremely hydrophobic materials have a contact angle greater than 150 degrees [5-6]. Studies have actually focused their efforts on the study of super-hydrophobic materials and have made remarkable progress as a result of its various applications,

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such as corrosion reduction [7] , anti-friction [8], food packaging [9] self –cleaning and purification [10]. Nano composites are comprised of two materials: the reinforcement phase, which is measured in nanometers (10^{-9} m) [11], and the matrix phase, [12-13]. The goal of nanocomposites preparation is to improve some matrix phase features while also creating novel characteristics in the final nanocomposites [14], electrophoresis precipitation [15], chemical inscription [16], layer after layer self-assembly [17], chemical vapor deposition (CVD) [18] and electrospinning technique [19] are some of the methods used to manufacture hydrophobic nanocomposites materials. Electrospinning is an ideal technology for fabricating hydrophobic and hydrophilic substrates because of the numerous variables that may be used to modify the features of the final surfaces [20-22]. Kaolin clay, often known as white clay, is a layered silicate mineral rich in kaolinite. It has a high water resistance (hydrophobic materials) [23-24]. Clay minerals increase the thermal and mechanical characteristics of polymers [25-26]. There have been numerous studies on the use of electrospinning to create hydrophobic coatings. Jaafar et al. (2017) published a study on the electrospinning technique for the preparation of hydrophobic coatings on various substrates (glass, ceramic, and metal). Solutions containing of (Si) were used in various compositions for each solution, as well as nano Al_2O3 and nano TiO_2 to fabricate nanocomposites. All specimens had their contact angle, surface tension, viscosity, X-ray diffraction, and FTIR computed. After coating with 20% Si, metal substrates had a higher contact angle of around (110.173°) and ceramic and glass substrates had a hydrophobicity (20 percent Si). After coating with (20 percent Si/Al_2O_3) and (20 percent Si/TiO_2), SEM revealed the morphology of the surfaces and revealed that the specimens had good surface morphology. All of the findings were discussed [27]. Aldabbagh and Alshimary released a paper in 2017 about employing electrospinning to make Poly amide (PA-6) nanofiber coatings on aluminum surfaces at two different voltages (24 kV and 34 kV). Atomic force microscopes were used to examine the coating roughness and 3D structural characteristics. SEM microscopy and high-resolution optical microscopy were used to assess surface morphology (HROM). The shape drop analyzer was used to assess the contact angle for hydrophobic behavior, and FTIR analysis was used to look for changes in crystalline structure. The PA coating on the aluminum surface had a tight and twisted nanofiber structure with some beads across its morphology, according to the AFM pictures . The morphological beads of surface nanofibers are shown in SEM pictures. The electrochemical corrosion of aluminum without and with PA coating was investigated by immersing it in aerobic sodium chloride solutions containing 3.5 wt% sodium chloride (NaCl). The PA coatings have been observed to reduce corrosion currents and rates, as well as boost corrosion resistance for aluminum in the NaCl solution [28].

Experimental Part

Materials and Methods

Polystyrene (PS): $(C_8H_8)n$ with an average molecular weight of Mw 290,000 was acquired from Iran Petrochem Institute and has translucent white granules with a density of 1.05 g/mL at 25 °C. Tetra hydro furan (THF) was utilized as a solvent for PS with a boiling point of

66 degrees Celsius. It was obtained from Nandesari, Vadodara, India's (Qualikems Fine Chem. Pvt. Ltd). As a reinforcing material, kaolin nanoparticles were employed, which were manufactured from Sigma-Aldrich as a white powder with a granular size of around 40-75 nm.

The PS nanofibers were made with Iranian NANOAZMA equipment. A medical syringe was filled with polymer solution and connected to a syringe pump to keep a consistent flow of fluid through the needle during the electro spinning process. This needle was fitted with a positive HV electrode. The negative electrode of the HV was connected to a metallic collector, which in turn was connected to the earth.

Results and Discussion

Kaolin nanoparticles characterization

Figures 1a and 1b show XRD pictures of kaolin nanoparticles and AFM images of nano kaolin, respectively.

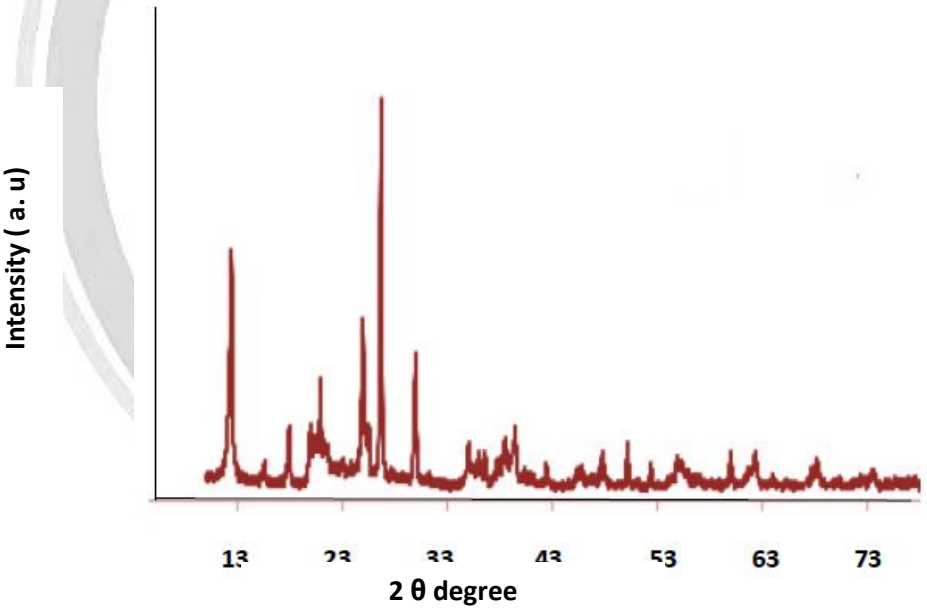

Figure 1.a XRD of Nano Kaolin

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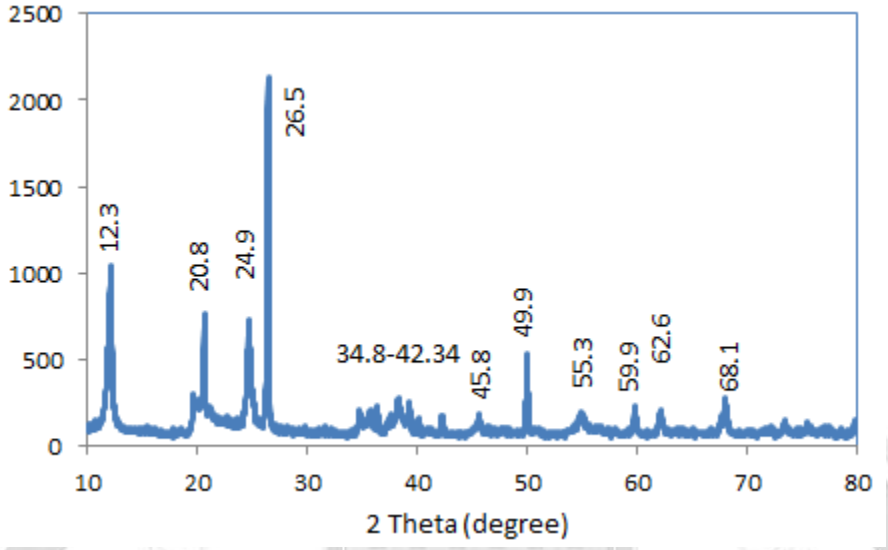

Figure 1.b Standardization of Kaolin Nanoparticles [29]

Figures 1a and 1b show that the x-ray spectra of the kaolin utilized in this work, which was analyzed using an x-ray spectrometer, and the spectrum examined by Aisha et al. [29] of Figure B exhibit excellent consistency. Highly pure nano kaolinite with diffraction intensities of kaolinite clay standard was revealed by the X-ray diffraction spectrum in Figure 1a,b, (JCPDS-No. 80-2186). By using the Debye-Scherer relation, the nano kaolinite particle was computed (Eq. 1).

$$D = K\lambda/\beta\cos\theta \quad \ldots(1)$$

Where D denotes the size of the copper hydroxide nanoparticles' crystallites, λ denotes the wavelength of the X-ray source used in X-ray diffractometry (0.1541 nm), β denotes the full width at half maximum of the diffraction peak, K denotes the Scherer constant, which ranges from 0.9 to 1, and θ denotes the Bragg angle. 20 nm was discovered to be the average size. [29].

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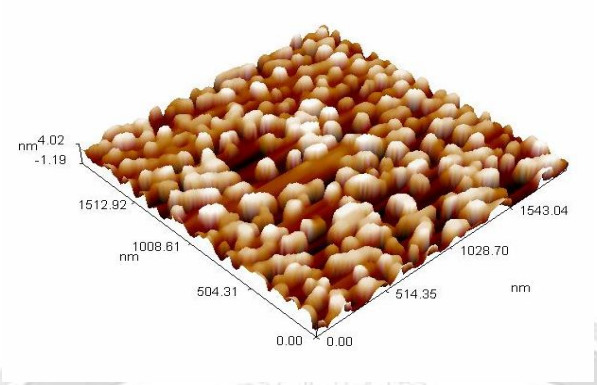

Figure 1.c AFM image of Nano Kaolin

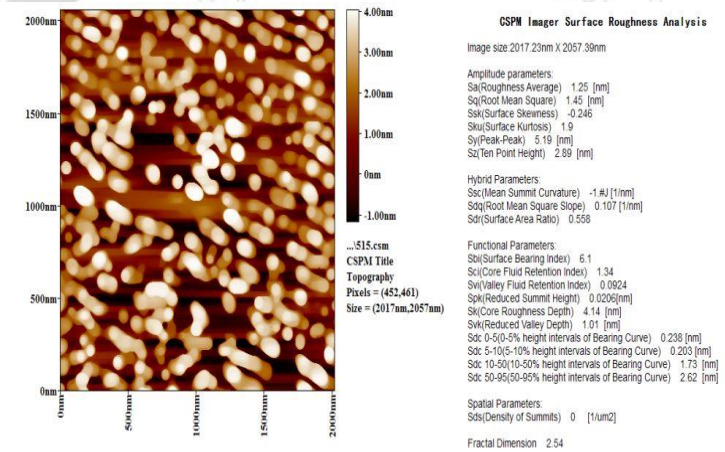

Figure 1.d Roughness Parameter of Kaolin Nanoparticles (Roughness Ava. 1.50 nm , bearing index (Sbi) = 6 , surface area = 0.6

Figure 1. Nano kaolin characterization forms a. XRD of used Nano Kaolin b. standard XRD of Nano kaolin c. AFM image of Nano kaolin d. Surface roughness of Nanokaolin

Figure 1c and 1d show that the surface roughness coefficients for kaolin nanoparticles show that they have a very low surface roughness of about 1.5 nm, indicating that they are very smooth, a surface area of 0.6, and a surface bearing index of 6, indicating good mechanical properties and a high bearing capacity. This is congruent with data found by the researcher Fadzil et al. [30] As shown in figure 1a, the primary peaks of Iraqi kaolin chemical compositions are MgO 1.47 percent, Fe_2O_3 5.69 percent, SiO_2 56.98 percent, Al_2O_3 14.96 percent, and CaO 4.64 percent, according to the Iraqi Geological Survey's standard chart. Figure 1.b shows the AFM images of Kaolin Nano particles.

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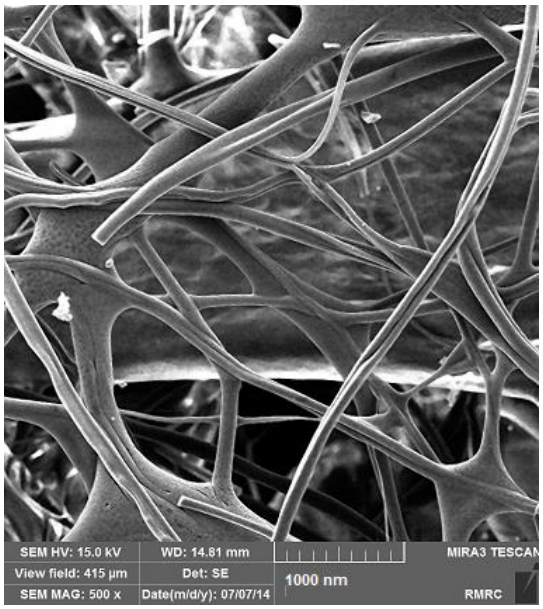
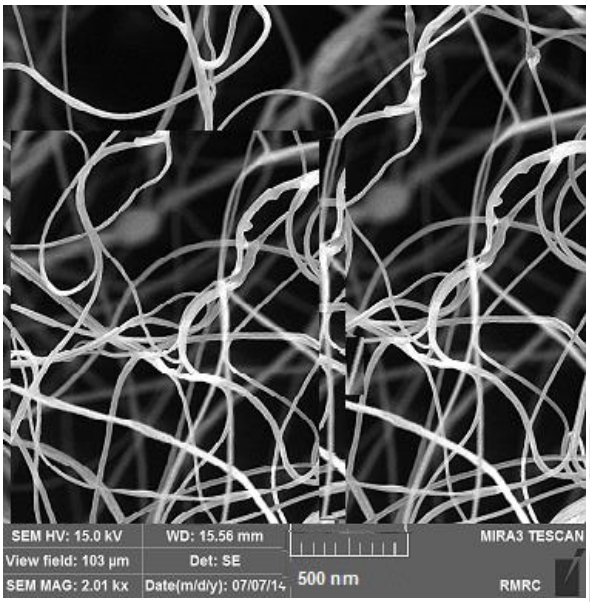
Morphology of Nanofibers by SEM Images

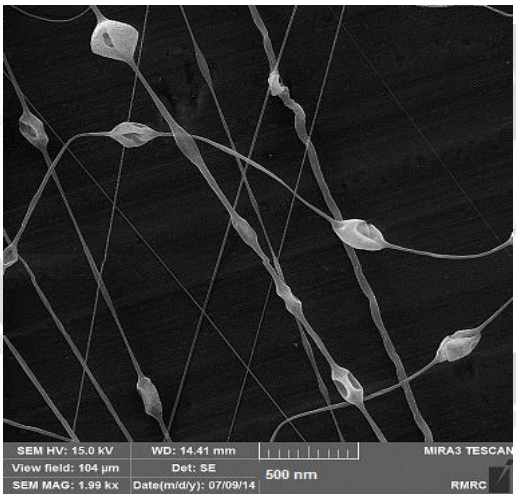
Figures 2a-c show SEM images of nanofibers generated with various PS/THF solution concentrations.



a. 0.14 w/v con. (150 nm)



b. 0.12 w/v con. (100 nm D)



c. 0.1 w/v con. (beads nanofibers)

Figure 2. SEM images of PS Nanofibers under 20 kV voltage , 1 ml/hr feed rate, 20 cm electrospinning distance , 600 rpm rotate collector speed and a. 0.14 con b. 0.12 con. C. 0.1 con.

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As can be seen in the previous figures, the diameter of nanofibers increases as the concentration of solutions increases. We utilize 0.1 con w/v Leads to make beaded nanofibers since the electrospinning process is unstable because to the low concentration and viscosity of the solution. While increasing the concentration to 0.12 w/v results in free bead nanofibers with a larger diameter due to increased solution viscosity and electrospinning process stability. Increasing the concentration to 0.14 w/v also results in the production of free beads with larger diameter nanofibers due to the increased viscosity of the solution, which results in more denes of polymer chains and stronger cohesive forces between them, resulting in larger nanofiber diameters.[31]

The sample with a concentration of 0.12 is the best for producing homogenous, free beads and smooth nanofiber shape.

The SEM pictures of the best sample of PS nano fibers reinforced with varied ratios of kaolin nanoparticles are shown in Figures 3 a-c.

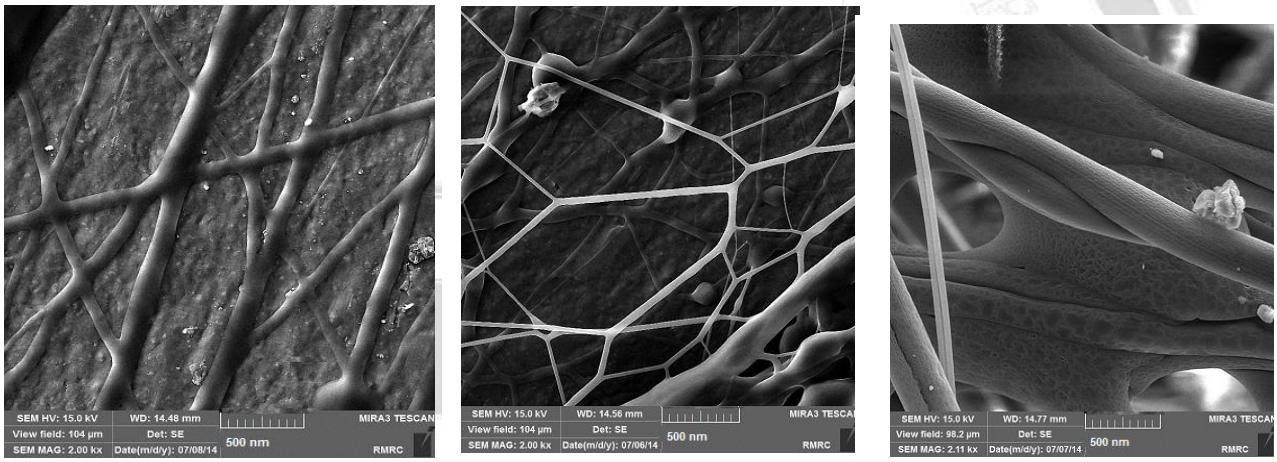

Figure 3. SEM images of PS Nanofibers reinforced by different ratios of Kaolin nanoparticles under 20 kV voltage , 1 ml/hr feed rate, 20 cm electrospinning distance , 600 rpm rotate collector speed and 0.12 w/v con a. 0.001 ppm. KNP, b. 0.002 ppm KNP c. 0.003 ppm. KNP

Note that from figs 3 a-c the adding of nano kaolin leads to increase the nanofibers diameter due to increasing the viscosity of solution which as a result to increase the shear resistance of solution that caused by prevent the mobility of polymer chains. Due to agglomeration of nanoparticles, there are some apparent nodules through the PS enhanced with 0.003 ppm kaolin nanoparticles sample [32]

Contact angle and Hydrophobicity

Figure 4 a-d show the contact angle of pure PS nanofibers and PS nanofibers reinforced with different ratios of kaolin nanoparticles .

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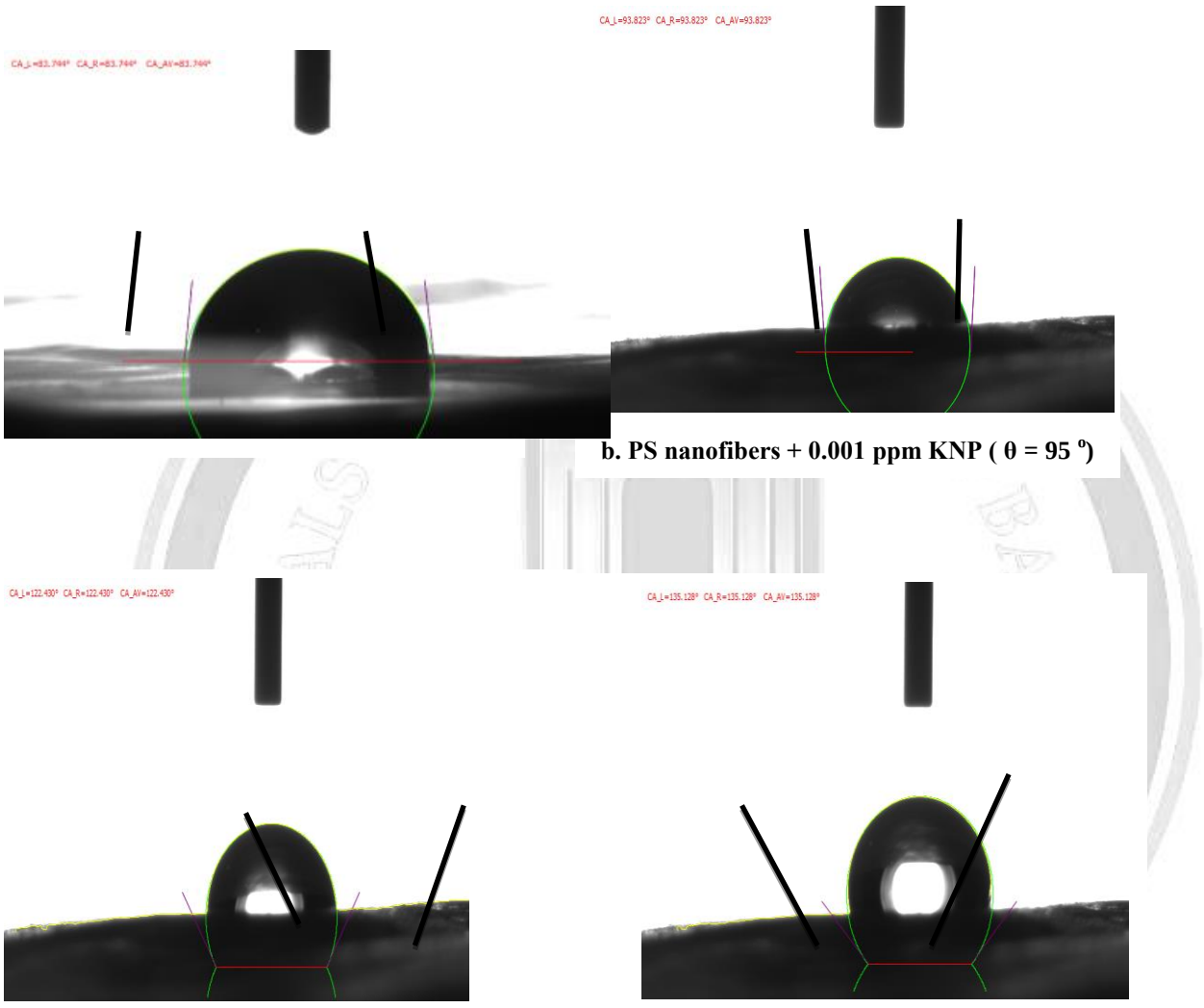

b. PS nanofibers + 0.001 ppm KNP (θ = 95 °)

c. PS nanofibers + 0.002 ppm KNP (θ = 122 °)

d. PS nanofibers + 0.002 ppm KNP (θ = 139 °)

Figures 4 . contact angle of pure PS nanofibers and it's nano composites

Figures 4 a-d show that the contact angle of pure polystyrene nanofibers increases from 81 ° to 139 ° for PS nanofibers reinforced with 0.003 ppm of kaolin nanoparticles. This is due to the hydrophobicity of kaolin nanoparticles, which prevents hydrogen bonds from forming and repels water.[33]

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Wettability of nanofibers

Figure 5 depicts the wettability behavior of PS nanofibers and polystyrene nanofibers reinforced with 0.003 ppm kaolin nanoparticles based on the contact angle and wetting time.

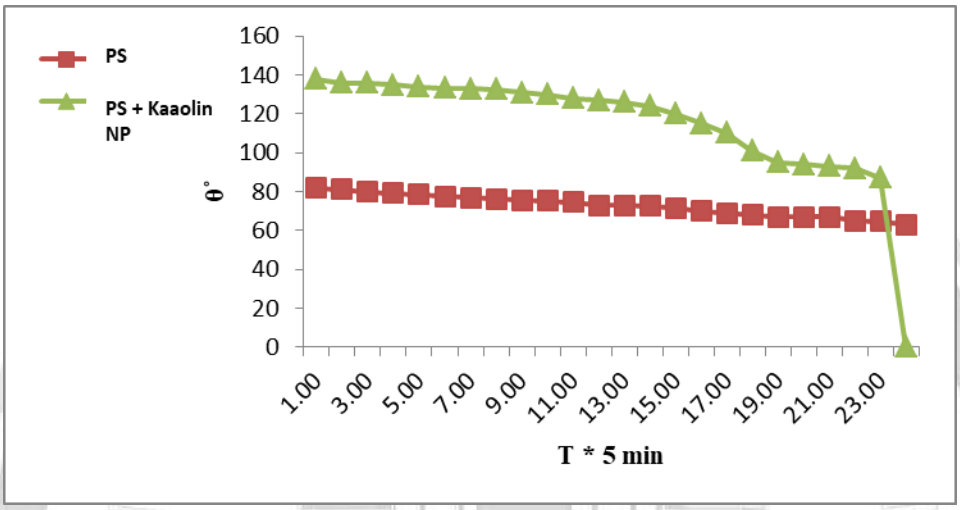

Figure 5. relationship between contact angle and time

Figure 5 depicts the flatness of the drop's balling after 115 minutes on the tissue's surface. We discovered that increasing the flatness of the drop on the surface of the polystyrene nanofibers reduced the hydrophobic behavior of the polystyrene nanofibers by decreasing the contact angle from 81 degrees at the start of the fall to 63 degrees after 115 minutes. The balling of the drop diminishes as the stability time on the tissue surface increases, as it drops from 139 degrees to 87 degrees after 115 minutes with the addition of kaolin. This is due to the presence of kaolin nanoparticles, which reduce the formation of hydrogen bonds. This signifies that the tissue's wettability reduces while its hydrophobic behavior rises. This indicates that the time it takes a pure polystyrene fabric to wet is shorter than the time it takes a fabric with kaolin nanoparticles to wet. [34] The hydrophilic nature of the polystyrene nano fiber generated for this investigation and its transformation into a hydrophobic nature after adding kaolin nanoparticles are indicated by the fact that the wetting angle of polystyrene is less than that of polystyrene reinforced with kaolin nanoparticles.

Conclusions:

As a result of this study, it can be said that protective layer a polystyrene fabric made using the electrospinning technique with kaolin particles increases the fabric's hydrophobic behavior while lowering its wettability because the kaolin nanofiber fabric takes longer to become wet than a fabric without them. Self-cleaning surfaces, liquid filtration, and protective

clothing are just a few of the many applications for electro spinning technique's hydrophobic surfaces with strong mechanical qualities.

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الخلاصة :

يهدف هذا البحث الى دراسة تاثير دقائق الكاؤولين النانوية على نسيج من الألياف النانوية المصنوع من ألياف البوليسترين النانوية. تم استخدام طريقة الغزل الكهربائي لإنشاء الالياف النانوية المسلحة بدقائق الكاؤولين . خضعت جسيمات الكاؤولين المستخدمة في هذه الدراسة لاختبار الأشعة السينية ، وكانت النتيجة مطابقة للاختبار النموذجي . أظهرت نتائج AFM أن الكاؤولين النانوي تتمتع بنعومة عالية عالية (١.٥ نانومتر) ، ومساحة سطح جيدة ، وعامل تحمل عالي (٦) ، بالإضافة إلى خصائص أخرى مرغوبة. تم استخدام جزيئات الكاؤولين النانوية بنسب مختلفة لمعرفة تأثير الكاؤولين على السلوك الكاره للماء لألياف البوليسترين النانوية. أظهرت النتائج أن الألياف النانوية المنتجة يمكن أن تمتلك خاصية التنظيف الذاتي لأنها كارهة للماء (لا تستطيع امتصاص الماء) ولها زاوية تلامس تبلغ ٨٧ درجة ، والتي زادت بعد إضافة جسيمات الكاولين النانوية (١٣٩ درجة). تمت دراسة تأثير معاملات المحلول ، مثل تركيز المحلول ، واللزوجة على أقطار الألياف الناتجة في هذه الدراسة. تم تحديد التركيز النموذجي لمحلول البولي ستايرين وكان 0.12 g/ml باستقرار المعلمات الأخرى، حيث كانت الالياف الناتجة باقطار ملائمة بحدود ١٠٠ نانومتر وخالية من الفقاعات ، تم فحص تأثير زيادة تركيز دقائق الكاؤولين على اقطار الالياف النانوية الناتجة .

اثبتت النتائج ان قطر الالياف النانوية يزداد عند زيادة تركيز دقائق الكاؤولين النانوية حيث تزداد لزوجة المحاليل بزيادة تركيز دقائق الكاؤولين النانوية مع ثبوت باقي العوامل ، وأظهرت النتائج أنه عند زيادة تركيز جزيئات الكاؤولين النانوية تزداد زاوية الترطيب حتى تصل إلى ١٣٩ درجة.

الكلمات الدالة: الياف البولي ستايرين النانوية، نانو كاؤولين، الغزل الكهربائي، هايدروفوبك.

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