Effect of TiO_2 nanoparticle on Wicking Phenomenon in PAN Nanofiber Yarns

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Abstract Summary: In this research, different concentrations of PAN polymeric solutions with various percentages of TiO_2 nanoparticles were electrospun to investigate vertical wicking of PAN/TiO_2 nanofiber yarns. Results showed by the presence of nanoparticles in the nanofiber structure, the capillary rise increased, although by increasing concentrations of polymeric solutions and nanoparticles, capillary rises were statistically insignificant.

Keywords: PAN/TiO_2 Nanofiber Yarns, Electrospinning, Wicking, Nanoparticles, Capillary

Introduction: A spontaneous transport of a liquid into a fibrous system such as nanofiber yarns and mats by capillary forces is termed wicking. Capillary phenomenon is a function of liquid properties and nanofibrous structure properties such as radius of capillary space, pore size, pore size distribution, porosity, and surface chemical characteristics [1]. Recently, researchers have focused on using electrospun nanofibers for many applications due to their extremely high surface to volume ratio, highly porous structure with excellent pore interconnectivity. Nanofibers with specific characterizations of their structures show different capillary behaviour from normal spun or filament fibres [2]. The aim of this work is to study wicking behaviour in PAN/TiO2 electrospun nanofiber yarns. SEM images were taken and the nanofiber diameters were measured in different concentrations of PAN polymer solutions and Tio_2 nanoparticles.

Experimentation:
Materials: A kind of polyacrylonitrile (PAN) polymer with molecular weight (Mw) of 7000 was obtained from Iran Polyacryl Company. Anatas TiO2 nanoparticles with average nanometre sizes of 21 were purchased from Evonik Company, and Dimethylformamide (DMF) as solvent was provided from Merck Company. PAN/DMF polymer solutions with 11 %(w/v) and 15 %(w/v) concentrations were mixed with 0%, 1%, and 2% of TiO2 nanoparticles, respectively. The coloured liquid used for the wicking measurements was single-distillation water with 0.2% non-ionic detergent and 0.2 % red acid dye.
Electrospinning Set-up: A modified schematic set-up for electrospinning is shown in Figure 1(A). It consists of a high voltage-power supply, a conductive hemisphere, two syringe needles, a take up unit and a feeder unit. The hemisphere diameter was 8 cm. Electrospinning was done between two syringe needles with opposite voltages, and collected electrospun nanofibers on rotating hemisphere were pulled out by take-up roller [3]. PAN/TiO2 solutions were fed to the set-up via syringes with flow rate of 0.085 mL/h and the electrospinning was done at a voltage of 13 kV between two nozzles. The distance between two nozzles, and the distance between hemispherical neutral surface and nozzles tips were 19 and 4 cm, respectively. The distance between the hemispherical collector and take-up unit was 20 cm. Rotating speed of take-up unit was 0.088 rpm.
Capillary Tests: Figure 1(B) illustrates the apparatus designed for capillary height measurement schematically. The nanofiber yarn with 20cm length was placed to a coloured liquid reservoir vertically while, a Sony digital handy cam (DCR-PC115E) was used to make video films of the capillary rise. The nanofiber yarn wicking measurements were observed for 24 hours in standard conditions.

Result and discussion: The effect of polymer concentration on the PAN/TiO2 nanofiber yarns morphology was investigated for five different concentrations. Figure 1(C) shows a typical SEM image and histogram of PAN/TiO2 nanofibers at the polymer concentration of 15% (w/v) PAN/DMF and 2% (w/v) TiO2/DMF. Also, the average diameters of PAN/TiO2 nanofibers ranged from 172.94 to 591.525 nm was illustrated in Figure 2. Thus, Results showed by increasing concentrations of polymer solution and nanoparticles, nanofibers diameter increased.

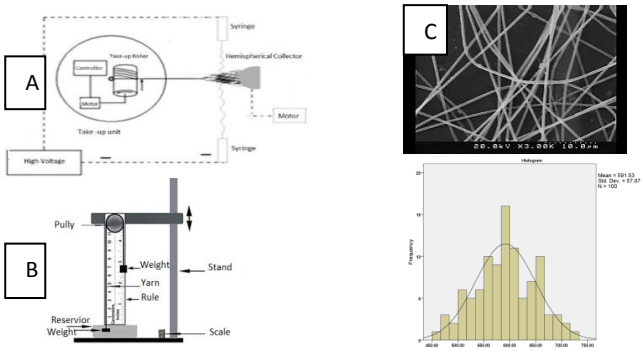

Fig.1.Electrospinning setup (A), Wicking apparatus (B), SEM and histograms of diameter (C).

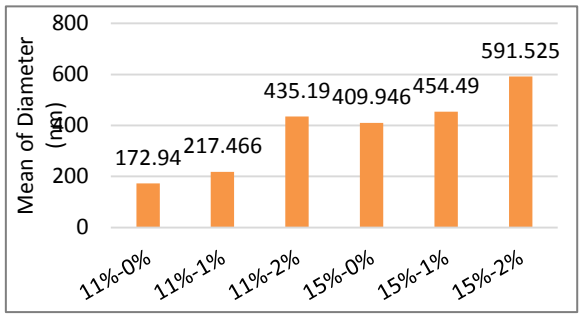

Fig.2. Average diameters of PAN/TiO2 nanofibers.

To analyse the kinetics of capillary flow in PAN/TiO2 nanofiber yarns, images taken during the capillary rise were processed to gain a set of points (t, h). Figure 3 (A) and 3 (B) show the effect of nanoparticles at 0%, 1%, and 2% concentrations on capillary rises of 11% PAN nanofiber yarn and 15% PAN nanofiber yarn, respectively. Figure 4 (A) and 4 (B) show the variations of height square as a function of time for 2 samples of PAN/TiO2 nanofiber yarns. The curve obtained is linear in range of 0-10 seconds, and the capillary rate coefficient of the nanofiber yarns is bigger than 0.99, so Lucas-Washburn Equation is valid in PAN/TiO2 nanofiber yarns for establishing kinetics of liquid capillary rise [4]. Thus, by the presence of nanoparticles in the nanofiber structure, the height of liquid rise in yarn increased, which indicates a reduction in the radius of the capillary space. By keeping the twist and nanoparticles in constant value and increasing in polymer solution concentration, the capillary rise furthered, but it was not noticeable and statistically significant. Moreover, during the capillary tests, the effect of gravity on liquid rise was ignored.

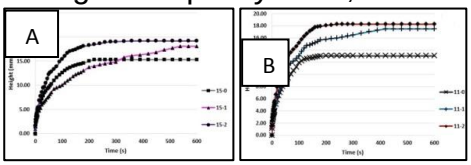

Fig. 3 (A) and (B). Wicking height of 11% and rise 15% PAN nanofiber yarn with different percentages of TiO2

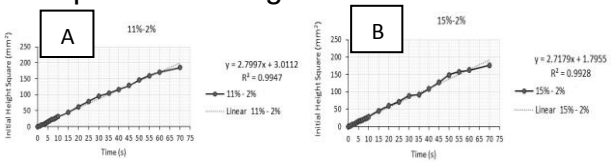

Fig. 4 (A) and (B). Square height of the capillary on PAN/TiO2 nanofiber yarns

Conclusion: The aim of this work was study of wicking behaviour in PAN/TiO2 nanofiber yarns. Results showed by adding TiO2 nanoparticles to PAN nanofiber yarns, the height of liquid rise in the nanofiber yarns increased. However, by keeping the values of twist and nanoparticles constantly and increasing in PAN polymer solution concentration, the capillary rise was not noticeable and statistically significant.

References

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