

The preparation and morphological investigation of polyacrylonitrile electrospun nanofibre with different loading of carbon nanotube

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ABSTRACT – Polyacrylonitrile (PAN) electrospun nanofibres with different loading of multi-walled carbon nanotube (MWCNT) were successfully prepared using electrospinning method. PAN powder was dissolved in dimethylformamide and the solution was electrospun under constant electrospinning parameters. The morphological structure and average fibre diameter of the nanofibres were examined using electron scanning microscopy. It was found that the solution with a higher content of MWCNT produced fibres with thicker fibre diameter. It was also observed that the surfaces of the fibres were rougher compared to control fibres. The results suggest that the inclusion of MWCNT reduced the electrospinnability of the PAN polymer solution.

1. INTRODUCTION

In the recent years, studies on conductive nanomaterials have gained a significant amount of interest from researchers due to their unique properties such as high surface area, high electrical conductivity and superior mechanical properties[1]. As a result, various new nanomaterials have been introduced and proposed for a wide range of applications in industries such as textile, composites, biomedical, aerospace, and electronic industries [2].

Electrospinning process is one of the most versatile and cost effective methods for preparing polymeric nanofibres [3]. A basic electrospinning setup consists of a high voltage power supply, polymer solution, spinneret tip and a grounded collector. The high voltage power supply is used to charge the polymer solution with a high amount of electrostatic forces, causing a jet of polymer to be ejected from the pipette tip flying towards the grounded collector. During the flight, fibre thinning process takes place which is due to stretching as the result of applied electric forces and solvent evaporation. The typical average fibre diameter is about 80 nm and the length was about higher than a kilometer [4].

Previously, filler materials have been incorporated to further enhance the properties of the nanofibres. For example, it was reported that a small addition of MWCNT into the nanofibre could improve the mechanical and electrical properties of the nanofibres [5]. However, the fabrication process of the fibre is quite challenging due to the hydrophobicity nature of the MWCNT. This could cause agglomeration of the solution and subsequently producing fibres with defects such as beads and ribbons. The focus of this study was to investigate the effects of different MWCNT loading on

morphological structure and fibre diameter of PAN electrospun nanofibres.

2. RESEARCH METHODOLOGY

2.1 Samples preparation

The PAN polymer which has an average molecular weight of 124,000-130,000 g/mol and N,N-Dimethylformamide (DMF) was purchased from Sigma Aldrich. The MWCNT used was an industrial-grade from Nanostructured & Amorphous Materials, Inc. (USA). A control PAN polymer solution was prepared by dissolving 10 wt% of PAN into N,N-Dimethylformamide (DMF) and stirred for 6 hours at room temperature using a magnetic stirrer model C-MAG HS7 (Ika Works, Malaysia).

The preparation of polymer solution with the addition of MWCNT was slightly different. Firstly, the MWCNT was added to the DMF and sonicated for 1 hour to break the bundles of MWCNT. After that, the solution was transferred to the magnetic stirrer to disperse the solution. PAN powder was added carefully by a small amount at a time to avoid agglomeration. The solution was stirred for 24 hours until a clear and homogeneous solution was obtained. Different weight percentage of the MWCNT were used to produce samples of NF1 to NF4, as shown in Table 2.1.

Table 2.1 Different weight percentage of MWCNT

Sample	MWCNT concentration (wt%)
NF 1	0.0 (control)
NF 2	0.3
NF 3	0.5
NF 4	1.0

The electrospun nanofibres were produced by using Electrospinz Model ES1a (Electrospinz Ltd., NZ). Throughout electrospinning process, the voltage was set at 18 kV whilst the distance between the spinneret to the collector was set at 13 cm. All the electrospun nanofibres collected were stored in vacuum for 24 hours to ensure the solvent has completely vaporized.

2.2 Samples characterization

Scanning electron microscope (SEM) Model JSM-5010PLUS/LV (Jeol Ltd., Japan) was used to examine the morphology of the fibres and ImageJ version 1.50 software (National Institutes of Health, USA) was used

to measure fibre diameter based on the SEM micrographs.

3. RESULTS AND DISCUSSION

The as-spun electrospun nanofibre samples are showed in Figure 3.1. The NF 1 (control) sample appeared white in appearance. However, for NF 2, NF 3 and NF 4, the samples turned greyish. The darkest sample was NF 4 which contains the highest amount of MWCNT (1.0%).

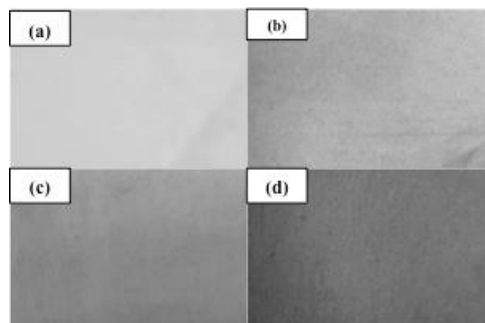


Figure 3.1 Physical appearance of as-spun electrospun nanofibre with different loadings of MWCNT (a) NF 1 (0.0%), (b) NF 2 (0.3%), (c) NF 3 (0.5%) and (d) NF 4 (1.0%), respectively.

SEM micrographs of electrospun nanofibres are showed in Figure 3.2. The average fibre diameters of the samples are presented in Table 3.1. It was clearly shown that the fibre diameter increased as the weight percentage of MWCNT increased.

Table 3.1 Different weight percentage of MWCNT

Sample	Fibre diameter (nm)
NF 1	868.72±79.03
NF 2	1731.64±54.10
NF 3	2515.08±196.02
NF 4	2732.73±159.33

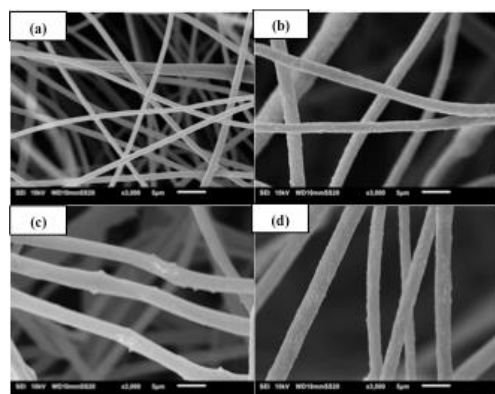


Figure 3.2 SEM image of electrospun nanofibre with a different weight percentage of MWCNT (a) NF 1, (b) NF 2, (c) NF 3 and (d) NF 4, respectively.

The control sample NF 1 produced smooth and uniform fibres (Figure 3.3). However, the formation of beads was obvious as the amount of MWCNT increased.

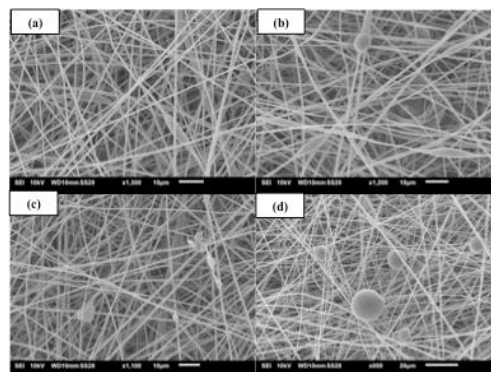


Figure 3.3 SEM image of deformation in electrospun nanofibre with a different weight percentage of MWCNT (a) NF 1, (b) NF 2, (c) NF 3 and (d) NF 4, respectively.

The results suggest that the electrospinnability of PAN solution was reduced as the amount of MWCNT increased. This is evidenced by the formation of thick fibres with rough surfaces and beads. Another reason for this was due to inhomogeneous dispersion of MWCNT of the PAN solution causing inconsistency in electrospinning process.

4. SUMMARY

In this study, MWCNT filled PAN electrospun nanofibres were prepared and investigated. The inclusion of MWCNT reduced the electrospinnability of the PAN polymer solution, producing thick and beaded fibres. Further studies on mechanical, chemical and electrical properties are needed to better understand the effects of MWCNT loading on the properties of the nanofibres.

REFERENCES

- [1] J. K. Pandey (2015). *Handbook of Polymer Nanocomposites. Processing, Performance and Application*.
- [2] S. K. Nataraj, K. S. Yang, and T. M. Aminabhavi (2012). "Polyacrylonitrile-based nanofibers - A state-of-the-art review," *Prog. Polym. Sci.*, vol. 37, no. 3, pp. 487–513.
- [3] N. A. Munajat, A. H. Nurfaizey, S. H. S. M. Fadzullah, G. Omar, J. Jaafar, and N. S. A. Roslan (2017). "Fabrication and Characterization of Carbon Nanofibres from Polyacrylonitrile Precursor," no. March, pp. 1–2.
- [4] A. H. Nurfaizey, N. Tucker, J. Stranger, and M. P. Staiger (2012). "Functional nanofibers in clothing for protection against chemical and biological hazards," Woodhead Publishing, pp. 62–86.
- [5] H. Guo, M. L. Minus, S. Jagannathan, and S. Kumar (2010). "Polyacrylonitrile/carbon nanotube composite films," *ACS Appl. Mater. Interfaces*, vol. 2, no. 5, pp. 1331–1342.