The effect of surfactants on the properties of poly(vinyl alcohol) (PVA) nanoweb by electrospinning

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Abstract : Poly(vinyl alcohol) nanowebs were prepared by electrospinning technique. The electrospinning technique produced nanometer scale of polymer fibres. This technique used the electrostatic force draw the polymer solution from the needle tip and deposited on substrate to from nanowebs. The PVA nanowebs were prepared with various surfactant types (anionic, cationic and nonionic surfactant). The cetyltrimethylammonium bromide, polyethylene glycol sorbitanmonolaurate, polyoxyethylenesorbitanmonolaurate, sodium lauryl sulfate were employed as surfactants. The morphology of PVA nanowebs were investigated using scanning electron microscope (SEM). The SEM micrograph shows that PVA nanowebs with all surfactants were successfully prepared with no beat. Thermal properties were measured by using differential scanning calorimetry (DSC). The results show that the %crystalline of PVA with SLS surfactant was slightly decreased. The mechanical property of nanowebs were measured using universal testing machine. The structure of nanowebs were analyzed by x-ray diffraction technique.

Keywords: Poly(vinyl alcohol), nanowebs, electrospinning technique;

1. Introduction

Electrospinning has been considered as a simple and a unique technique for the fabrication of nanowebs or nanofibres. The widely applications are in the areas of textile applications and medical applications such as wound dressings, drug delivery systems and tissue engineering.\textsuperscript{1,2} The electrospinning process is that a polymer solution or melt (polymer or polymer blended) is loaded into a syringe. An electrostatic force is applied by the high voltage and then the polymer is pushed from the nozzle by the pump. The Taylor cone shape was observed at the tip of the nozzle. The continuous electrostatic fields are maintaining the polymer jetanda find fibresdeposited on a collector. The shape of the base depends on the surface tension of polymer solution.\textsuperscript{1}

The nanowebs prepared by the electrospinning process have been shown straightforward properties such as high surface area compared to the film, small pore sizes and high porosity. Therefore, numerous studies have highlighted the various types of polymer as the carrier in wound dressings and drug delivery application.\textsuperscript{2,3}

Poly(vinyl alcohol) (PVA) are one of the most widely used polymers in biomedical, because of their unique properties such asbiocompatibility, good chemical resistance, high hydrophilicity and nontoxic. These properties have led to its broad industrial used. Many researchers have been reviewed on various parameters of the PVA nanofibressuch as degree of hydrolysis, polymer solution concentration, polymer solution flow rate, applied voltage, tip-target distance and pH of the polymer solution.\textsuperscript{2,3,5} Therefore, it has become more interesting to explore the effect of surfactants on the properties of poly(vinyl alcohol) (PVA) nanowebs such as morphology and thermal properties.
2. Experimental

2.1. Materials

Poly vinyl alcohol (PVA) was supplied from Vam&Poval, Japan. Sodium lauryl sulfate (SLS), polyethylene glycol sorbitan monolaurate (TW20), polyoxyethylene sorbitan monolaurate (TW80), and cetrimonium bromide (CTAB) were purchased from Sigma-Aldrich at the highness purity. All samples were used as received. All other chemicals were used as supplied by the companies.

2.2. Preparation of poly(vinyl alcohol) solution

Poly(vinyl alcohol) solution 10wt% was prepared by adding PVA into hot water. The solution was stirred for 2 hours. The 0.25wt% of surfactants, sodium lauryl sulfate, polysorbate 20 and polysorbate 80 and cetrimonium bromide were mixed with the PVA solution. It was continuously stirred for 1 hr. PVA with surfactants were obtained.

2.3. Preparation of PVA nanowebs by electrospinning

PVA solution was placed in a syringe pump. The pump was set 0.3mL/hr. Power supply was set 15kV-20kV. The high voltage was supplied by Glassman high voltage Inc., USA. The distance between needle and substrate was 12 cm. The needle number was 18. The nanowebs were obtained after 4 hr.

2.4. Characterization

The morphology of the nanowebs was observed on scanning electron microscope (SEM) JSM-7600F from Jeol, Japan. All of the samples were coated with palladium prior to use. Thermal properties were measured using differential scanning calorimetry (DSC) model 200 F3 from Netzsch, Germany. The scan was performed from 30°C to 300°C under nitrogen atmosphere. The heating rate and cooling rate were set at 10°C/min. The tensile tests were recorded on Instron 5569 universal testing machine. The cross head speed was 10 mm/min.

3. Results and discussion

3.1. Morphology of the nanowebs

The morphology of the nanowebs of pristine PVA with various apply voltage were examined using scanning electron microscope (SEM), as seen in Fig. 1a-1c. It was found that the diameter of PVA nanowebs decreased from 0.33μm to 0.194μm with increasing apply voltage form 15kV to 17kV, respectively. However, the diameter was raised to 0.32μm when applied high voltage at 20kV. Therefore, it was hard to control nanowebs diameter at high voltage while the diameter of nanowebs was irregular at low voltage. The medium voltage was selected due to the well-defined structure as showed in Fig 1b.

In order to understand the effect of surfactant to the morphology of the nanowebs, the various of surfactants were investigated. As presented the Fig. 1d-1f, the SEM image of SLS/PVA nanowebs offered the smallest diameter 0.015μm whereas diameter of TW20/PVA nanowebs and TW80/PVA nanowebs were 0.137μm and 0.128μm, respectively.

3.2. Thermal properties of the nanowebs

The thermal properties of the PVA nanowebs with various surfactants were performed on differential scanning calorimetry (DSC). The melting temperature, glass temperature, crystalline temperature and %crystalline were summarized in Table 1. The results from Table 1 are demonstrated in Fig. 2. It was found that the glass temperature, crystalline temperature and melting temperature of PVA nanowebs with all surfactants were increased higher than pristine PVA nanowebs. Except, crystalline temperature of CTAB/PVA nanowebs was similar to pristine PVA nanowebs and melting temperature of TW80/PVA nanowebs was slightly lower than pristine PVA nanowebs. Therefore, the %crystalline of CTAB/PVA nanowebs was highest at 49.88% while both of SLS/PVA nanowebs and TW20/PVA nanowebs were lowest at 37.89 and at 37.93, respectively.
3.3. Mechanical properties

The mechanical properties of the various surfactants/PVA nanowebs were inspected by using tensile testing method. The results show that SLS/PVA nanowebs offered the best tensile strength at 39.06 N/mm² as presented in Fig. 3. Moreover, the tensile strength of TW20/PVA nanowebs was 23.60 N/mm² which higher than pristine PVA nanowebs. On the other hand, the tensile strength of TW80/PVA nanowebs was lowest at 6.27 N/mm².

Table 1. The thermal properties of melting temperature, glass temperature, crystalline temperature and %crystalline of PVA nanowebs with various surfactants.

| Sample    | T_g (°C) | T_c (°C) | T_m (°C) | ΔH_f (J/g) | %Crystallinity (%) |
|-----------|----------|----------|----------|------------|--------------------|
| PVA       | 63.6     | 108.2    | 181.1    | 55.42      | 39.99              |
| SLS/PVA   | 71.1     | 115.6    | 193.6    | 51.2       | 37.89              |
| TW20/PVA  | 67       | 109.8    | 197      | 51.27      | 37.93              |
| TW80/PVA  | 66.4     | 110.7    | 173.1    | 58.51      | 43.30              |
| CTAB/PVA  | 66.7     | 108      | 192.5    | 67.41      | 49.88              |
4. Conclusion

The PVA nanowebs was successfully blended with various surfactants. The morphology of the PVA nanowebs were investigated by using SEM. The SEM images presented no beat with all PVA nanowebs. Most of thermal properties were higher than pristine PVA nanowebs. However, melting temperature of TW80/PVA nanowebs was slightly lower than pristine PVA nanowebs. Moreover, the SLS/PVA nanowebs was highest tensile strength.

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