Fabrication and Unique Characterization of Nanofiber Dispersion as Novel Anisotropic Materials

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Abstract

Anisotropic materials exhibit unique properties compared with isotropic materials. For instance, the disc-shaped particles exhibit higher viscosity and enhance aggregation ability than spherical particles. Polymeric nanofibers are one of the anisotropic materials with high aspect ratio between narrow diameter and length of the fibers. In this study, we propose a fabrication procedure of fragmented nanofibers dispersed stably in water, and their application to novel carriers for turbidimetric immunoassay. Polystyrene (PS) nanofibers were then fabricated by a conventional electrospinning method. The PS nanofibers suspended in water were fragmented by an ultra-high-speed homogenizer. The obtained fragmented nanofibers were stably dispersed in water. To improve the dispersion stability of the fibers and to introduce functional groups to their surface, bovine serum albumin (BSA) was physically adsorbed to the surface of the fragmented fibers. When the glutaraldehyde as a model cross-linker between BSA-coated nanofibers was added to the dispersion, the fibers were significantly aggregated compared to the spherical particles.

1. Introduction

Anisotropic materials exhibit unique properties compared with isotropic materials; *e.g.* the disc-shaped particles exhibit higher viscosity and enhance aggregation ability than spherical particles in our previous study[1)]. On the other hand, polymeric nanofibers are one of the anisotropic materials that have a high specific surface area and are used for the environmental and biomedical applications [2)]. In this study, we propose a fabrication procedure of fragmented nanofibers dispersed stably in water as a novel anisotropic material. Moreover, we explore their high aggregation properties derived from their anisotropic shape as novel carriers for turbidimetric immunoassay.

2. Experiment

Nanofibers composed of polystyrene (PS; M_w ~350,000, Sigma Aldrich Co.) were fabricated by the electrospinning method. PS was dissolved in *N,N*-dimethylformamide containing 1% poly(vinyl pyrrolidone) (PVP; K40, Sigma Aldrich Co.) as a surfactant at a concentration of 5-30 wt%. The solution was electrospun onto the aluminum foil at a voltage of 30kV, feed rate of 1.0 mL/h, for 3 min (NANON-03, MECC Co. Ltd., Japan). The PS nanofibers suspended in water (40 mL) were fragmented by an ultra-high-speed homogenizer (PHYSCOTRON NS-57, Microtec Co.Ltd., Japan) with a rotating speed of 24,000 rpm at 4ºC for 5-60 min. To improve the dispersion stability of the fibers and to introduce functional groups, bovine serum albumin (BSA, Sigma-Aldrich Co.) was dissolved in the dispersion at 10 mg/mL and stirred at room temperature overnight for physically adsorbing to the surface of the fragmented fibers. The BSA-coated PS nanofibers were collected by centrifugation (4ºC, 15,000 rpm, 10 min, 3 times) and then washed with water. The nanofibers were freeze-dried

and resuspended for 1 mg/mL to water. The aggregation test was used glutaraldehyde (GA) as a cross-linker between the amino group on the BSA-coated nanofibers. This reaction was used as a model for the antigen-antibody reaction utilized in the latex aggregation turbidimetric immunoassay. In fact, 34 µL of 2.5% GA aqueous solution (FUJIFILM Wako Pure Chemical Co.) was added to 166 µL of BSA-coated PS nanofibers or microspheres with a similar surface area. The transmittance (wavelength: 700 nm) of these dispersions into 96-well microplate were measured every ten seconds with a microplate reader (SH-9000Lab, Corona Electronic Co., Ltd., Japan).

3. Results and discussion

The fragmented PS nanofibers were homogeneously dispersed in water. Based on SEM images, the diameter and length of the nanofibers were measured to be 0.72 ± 0.1 µm and 19.9 ± 6.2 µm, respectively **(Fig. 1)**. The diameter increased with increasing polymer concentration just before electrospinning. Moreover, the length became shorter and more uniform as homogenization time increased. These results suggest that it may be possible to control the diameter and length of the fragmented nanofibers. When GA was added to the suspension, the nanofibers were gradually aggregated (**Fig. 2**). In particular, transmittance of the nanofibers became higher changing than that of spherical microspheres with almost same surface area.

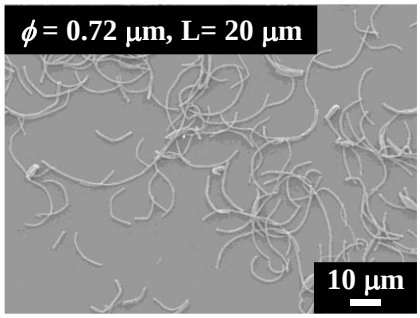

Fig. 1. SEM image of fragmented PS nanofibers.

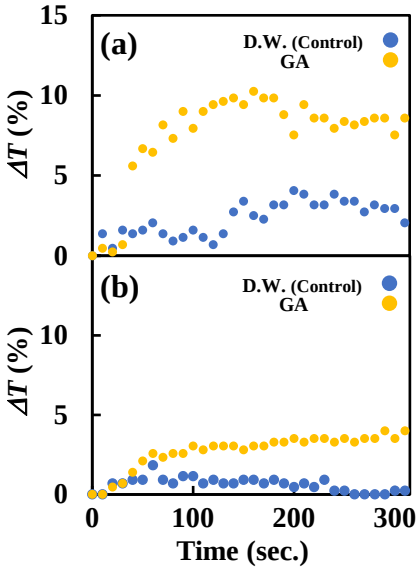

Fig. 2. Transmittance change by GA-induced aggregation of (a) fragmented PS nanofibers and (b) PS microspheres.

4. Conclusions

We succeeded in fabrication of the fragmented PS nanofibers by homogenization process. The obtained nanofibers were stably dispersed in water. The diameter and length of the nanofibers could be controlled by changing the polymer concentration just before electrospinning and homogenization time. Furthermore, the fragmented nanofibers exhibited an enhanced aggregability compared with the microspheres, based on the change in transmittance after the addition of GA solution to the dispersion. These results suggest that multiple interaction derived from anisotropic shape of nanofibers may be triggered. The detailed results on turbidimetric immunoassay of the nanofibers will be released on the 32nd annual meeting of MRS-J.

Acknowledgments

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References

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