Effect of Solidification of Solution on Hollow Silica Fiber by Co-electrospinning

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[Introduction]

Electrospinning has been actively exploited as a simple and versatile method for generating nanofibers made of various materials.

Hollow nanofibers with walls made of ceramics have been prepared by electrospinning two immiscible liquids through a coaxial, two-capillary spinneret, followed by selective removal of the cores (Fig.1).

Our previous investigation revealed that changing the viscosity of the precursor can control the diameter of the fibers and that higher viscosity values lead to cracks on the fiber wall.

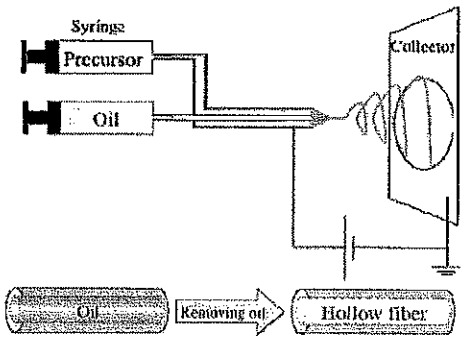

Fig.1 Set up for hollow fibers by co-electrospinning

Therefore the purpose of this study is to investigate the possible mechanisms for crack formation in the process of solidification of precursor and fabricate crack-less fibers.

[Experiment]

Samples were tetraethyl orthosilicate (TEOS), ethanol, water, and hydrochloric acid (as a catalyst). Samples were kept at 80°C and 30% RH to prepare a precursor. Reaction time is 4800-8400 sec, and the viscosity varies with the curing time. Co-electrospinning was carried out at room temperature, 20-50% RH, 20 kV, 10 cm nozzle-collector distance, and 0.0012 ml/min (inner) – 0.012 ml/min (outer) flow rate.

[Results and discussion]

In the range of 0.07-0.7 Pa s of precursor viscosity, we could fabricate the hollow fiber. Above 0.7 Pa s, the cracks were observed on the walls of the hollow fiber. The diameter of fiber increases with an increase of precursor viscosity. When the viscosity of precursor is high, the sol-gel reaction of higher viscosity precursor progresses more. Therefore the solidification of solution progresses faster, and the skin layer is also formed in spinning of higher viscosity solution.

Then we investigated the effect of humidity on the fiber spinning by using the precursor with viscosity of 0.2 Pa s. In the 20-40 %RH, the continuous hollow fiber was fabricated. In the 50 %RH, however, the crack was formed on fiber surface. When the humidity in the spinning atmosphere is high, the more hydrolysis of un-reacted ethoxy group progresses by the moisture in the air. Therefore the higher humidity may accelerate the reaction of solution. This solidification by hydrolysis progresses inward from the outermost layer. Therefore the skin layer is formed at around the spinning jet.

We considered that the crack on the wall is caused by the shrinkage by evaporation of solvent. The evaporation of solvent leads to shrinkage toward orthogonal direction with fiber axis. And the skin layer is formed on the outermost layer of fiber, the shrinkage occur only in the skin layer. Therefore the crack on the fiber wall is observed.