Effect of electric current on Beads formation in Electrospinning of Poly(vinyl alcohol)

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Abstract

We investigate formation of beads on electrospinning by changing processing parameters, such as strength of electric field, applied voltage, distance between the tip of needle and the collector, and humidity. From the results of experiments done by changing processing parameters, it seems that beads formation is related to electric charges at the tip of the sample. In order to clarify relation between the electric charge stored at the tip of the samples and beads formation, electric current measurements are performed in electrospinning process. As the results of electric current measurements, it is found that the time dependence of the observed electric current can be classified into two typical patterns (I) and (II). In the first pattern (I), the electric current is stable during the measurement. In this case (I), beads are not observed. On the other hands, in the pattern (II), the electric current is unstable during a measurement. In this case (II), many beads are formed. From averages of electric currents, a strength of tensile force that acts on the sample tip is calculated. It is found that the strength of tensile force in the case (II) is stronger than that of the case (I) with stable electric currents. This result indicates that beads formation is enhanced by a higher electric current.

1 Introduction

Electrospinning is one of spinning techniques to produce nonwoven consist of ultra thin fibers from a polymer solution or melt by applying a high voltage between a tip of needle and a grounded collector. This technique enables us to easily fabricate ultra thin fibers than the conventional fiber spinning processes based on melt and solution spinnings. The electrospun fibers have quite thinner diameters and larger surfaces than those obtained by the conventional fiber spinning processes. These unique characteristics bring us possibilities of a number of applications, for example, filtration for nano-sized materials, tissue scaffolding and other biomedical applications. One of the most serious problems in applications of electrospinning is a formation of beads on fibers. The formation of beads makes functions of products deteriorate. It is reported that the formation of beads depend on electric field strength [1]. However, the origin of formation of beads is still not clear. In this work, we focused on relation between electric charges at the tip of the sample and beads formation.

2 Experiments

-Sample

PVA (Poly vinyl alcohol) solution was used in this study. PVA with molecular weight of 40,000 g/mol was dissolved in distilled water and which was prepared to be 15wt%.

-Electrospinning

The apparatus of electrospinning is shown in Fig.1. Electrospinning was performed at room temperature in the horizontal mode. Experimental conditions were as follows; the distance between the tip of needle and the collector was changed from 5 to 20cm, the applied voltage was changed from 4.5 to 18kV, and humidity was controlled in the range of 50 ~ 60 %. The electric charge stored at the tip of the sample was measured by ammeter which was attached to the grounded collector. The current measurement was performed every 0.5s. The electrospun samples were observed by Scanning Electron Microscopy (SEM).

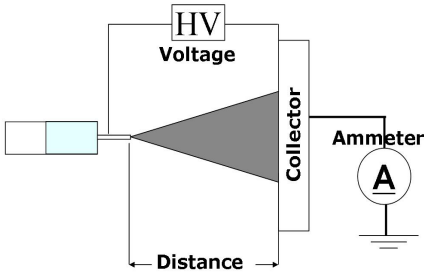

Fig.1 Scheme of electrospinning apparatus.

3 Results and discussion

Figure 2 shows SEM images at different distances, but under the same strength of electric field ((a) 9kV and 10cm, (b) 13.5kV and 15cm, and (c) 18kV and 20cm). In case of 4.5kV and 5cm, the electrospinning could not be realized since the strength of applied voltage is too low to elongate the sample. In case (a), beads on electrospun fibers were not observed. On the other hands, in cases of (b) and (c), many beads were formed. The results of electric current measurements are shown in Fig.3. From these results, observed electric currents could be classified into two typical patterns (I) and (II). In the first pattern (I), the electric current is stable during the measurement. On the other hands, in the pattern (II), the electric current is unstable during a measurement. Figure 4 shows averages of electric currents. Strength of tensile force that acts on the sample tip is calculated as shown in Table 1. These results show that the electric currents are different even at the same electric field strength. Additionally, amount of beads formation on electrospun fibers is different among these three cases, namely the beads are easily formed with increasing the tensile force. We concluded that the higher tensile force incites unstable deformation of sample at the tip of needle.

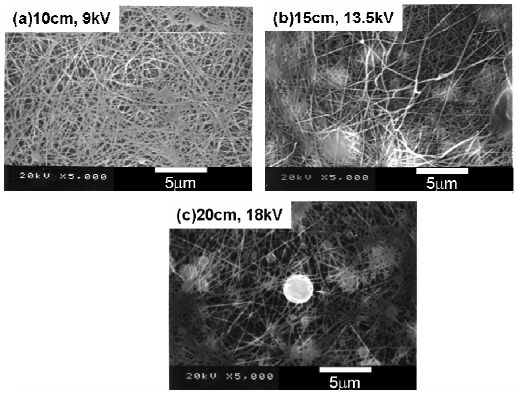

Fig.2 SEM image of electrospun PVA fibers at different distances between the tip of needle and the collector, (a)10cm, (b)15cm and (c)20cm, and at constant strength of electric field, 0.9kV/cm.

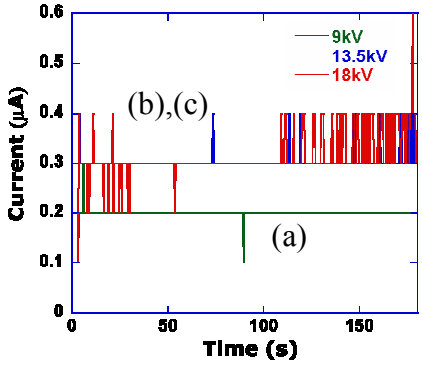

Fig.3 Results of current measurements in electrospinning under condition (a), (b) and (c).

Table 1 Calculated tensile forces.

Spinning condition	Tensile force[cN]
(a) 9kV, 10cm	1.8
(b) 13.5kV, 15cm	2.4
(c) 18kV, 20cm	3.0

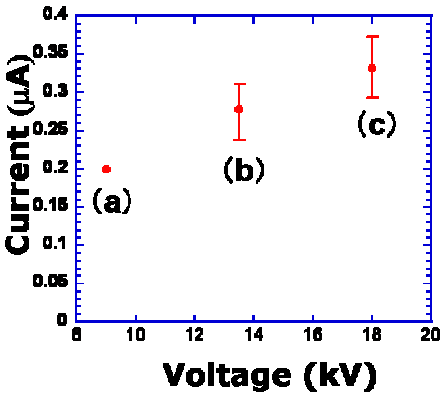

Fig.4 Relation between currents and voltages in cases (a), (b) and (c).

4 Summary

We found that the pattern of electric current is drastically changed by varying the distance between tip of the needle and the collector while keeping the electric field strength constant. At the stable current, the beads were not formed. On the other hand, when the current was unstable, many beads were easily formed. Additionally, the higher tensile force incites beads formation.

5 References

1. Geng XY, Kwon OH, Jang JH, *Electrospinning of chitosan dissolved in concentrated acetic acid solution*, Biomaterials, **26(27)**, 5427-5432 (2005)