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When nanotechnology meets filteration: From nanofiber fabrication to biomimetic design

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ABSTRACT

Nanotechnology for the scientific and economical revival is of indispensable importance, and the so-called nano-age or nano-industrialization is coming. The paper reveals the very frontier of nanotechnology in mass-production of nanofibers, and the bubble-electrospinning is introduced, and its application to filteration is emphasized. By mimicking the structure of silkworm cocoon, the filteration efficiency reaches its maximum, while the pressure drop through the filter is minimal, and small water cluster is obtained after nanofiber membrane for water purification.

Keywords: nanofiber, bubble electrospinning, Bubbfil spinning, biomimetic design, cocoon, small water cluster, PM2.5, PM1.0

1. INTRODUCTION

Nanomaterial always behaves extremely and extraordinarily, and it is defined as nanoscale material with nano-effect properties, which always result in, for example, excellent thermal and mechanical properties independent of the bulk material. There are many techniques for producing nanomaterials, and in the issue some advanced ones are introduced, they are Bubbfil spinning including bubble-electrospinning, blown-bubble spinning, and membrane spinning [1~5] and melt blowing [6], and cellulose nano-fiber producing[7]. Generally, nano-effect occurs when the size of a subject tends to 100nm. To show this, we consider a thinner layer of nanofibrous membrane, the flow rate through the membrane can be expressed as [8]

$$\eta = \eta_0(1+\frac{1}{d^{\alpha}}) \tag{1}$$

where η_0 is the flow rate of the bulk material with large scale, i.e., the fibers involved are macroscopic , d is the fiber diameter, $\alpha > 0$ is a scaling exponent, in Ref.[8] we recommend $\alpha = 1/2$ for qualitative analysis.

Eq. (1) can explain some phenomena of nano scale flows. Majumder et al found that liquid flow through a membrane composed of an array of aligned carbon nanotubes is 4 to 5 orders of magnitude faster than would be predicted from conventional fluid-flow theory [9]. To show this, we consider the membrane with diameter of 10 nm, according to Eq. (1), we have

$$\eta = \eta_0(1+\frac{1}{(10\times 10^{-9})^{1/2}}) = \eta_0(1+10^4) \tag{2}$$

or

$$\frac{\eta}{\eta_0} \approx 10^4 \tag{3}$$

This theoretical prediction meets the experimental observation by Majumder et al. [9].

2. AN EXPERIMENT

We applies the bubble electrospinning [8] to produce nanofibers, which are then used for air filteration. The

bubble electrospinning is to use electrostatic force to overcome the surface tension of polymer bubbles. When the bubble is broken, multiple jets are formed, and then solidified as nanofibers, which are received on a metal receiver. Fig.1 shows the filteration rate for nano-membranes (first 5 samples) and other filters obtained in open market. Fig.2 is the pressure drop through the membranes, and by mimicking silkworm cocoon [10, 11], the pressure drop can reach minimum (the third sample) [12, 13].

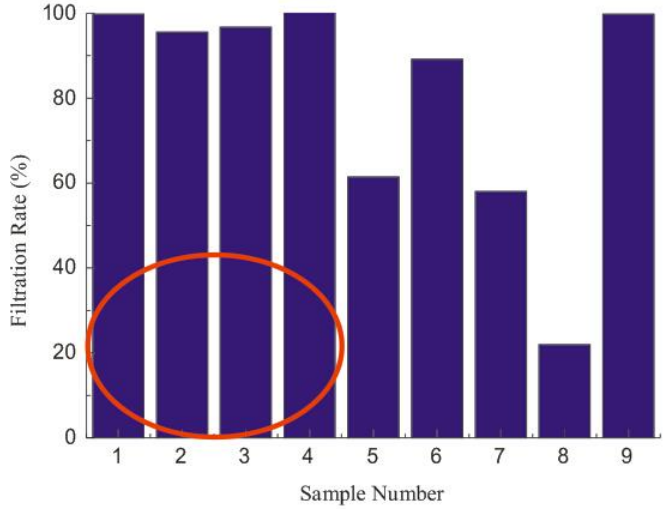

Figure 1: Filtration rate of 9 samples. Nos1~5 are nano-membranes obtained by bubble-electrospinning, the left ones are bought in open market.

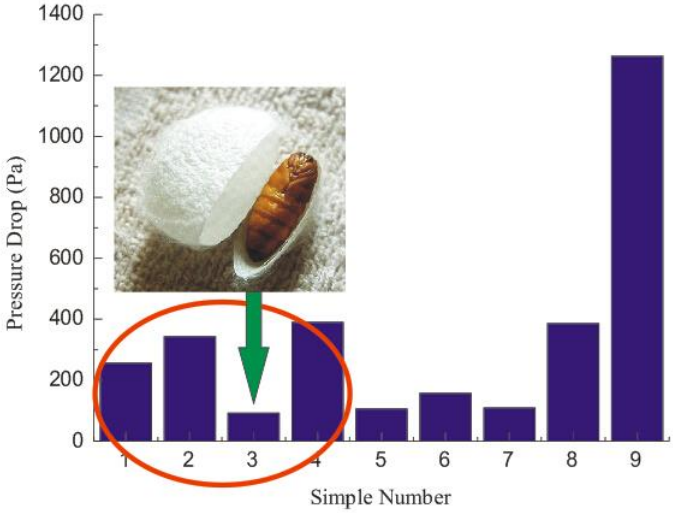

Figure 2: Pressure drop through the membrane. The marked one is designed by mimicking silkworm cocoon

3. SMALL WATER CLUSTER

There are similar properties of nanofiber membranes for water filteration, when water flows through nanoscale pores of the membrane, all nanoparticles especially PM2.5 and PM1.0, bacteria, virus, and heavy metals can be effectively blocked, and produce small water cluster[14,15], which is different with pure water without any impurities, the small water cluster involves some useful and healthful minerals.

Water in human body is used for chemical reaction, and small water cluster is important for metabolism. To show the importance, we begin with a cubic meters of charcoal, which can be burned in air slowly. Now if the charcoal is decomposed into nano particles, the combustion efficiency increases tremendously due to the remarkably high surface-to-volume ratio. The small water cluster is of structure of $(H_2O)_n$ (n=2~20), and the metabolism becomes vigorous, similar effect will occur when we breathe in oxygen-enriched air.

4. CONCLUSION REMARKS

Nano-industrialization is important for each country, and it can help greatly develop economy and improve people's life. Further nano-industrialization will be something of a Hemingway line of demarcation between the have and the have not for the present industrial revolution or nano revolution. This issue focuses on nano-fibers fabrication, both experimental and theoretical papers are considered, and it is especially useful for researchers in materials science, politicians, economist and entrepreneurs as well.

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