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# Cross-sectional Porosity and Oil Sorption of PLA Nanofibers with Hollow and Lotus Root-like Structures

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**Abstract**

Lotus root-like fibers and hollow structure fibers have been extensively studied in many different fields due to a large specific surface area and high porosity. However, most of the prepared materials have only one lotus root-like or hollow structure. Here, in this paper, the coaxial electrospinning poly(lactic acid) (PLA) nanofibers had hollow and lotus root-like structures. The porosity of the cross section was quantitatively analysed by MATLAB, and the oil sorption experiment was also carried out. In the hollow structure, when the flow rate ratio of the core/shell solution was 1:2 or 1:4, the pore porosity was about 41%, larger than 34.88% (1:3), while the pore porosity at 19-22 kV was stable at about 41% ± 2%. On the contrary, the lower the porosity, the better the spinning state and the higher the hollow ratio. In the lotus root-like fibers, the porosity values were about 23% ± 2% under different spinning conditions, which means that the lotus root-like porosity was not significantly affected by the flow rate ratio of core/shell solution and voltage. Meanwhile, the absorption capacity of the lotus root-like fibers to diesel oil is more than 1.5 times that of hollow fibers.

*Keywords*: Coaxial Electrospinning; Hollow and Lotus Root-like Structures; Porosity; Oil Sorption

# 1 Introduction

Poly(lactic acid) (PLA) is considered to be one of the most promising renewable, green and environmental friendly material. Starch, which is the raw material, can be extracted from some plants such as corn, wheat, and cassava. Enzymes break down to produce glucose, and the lactic acid bacteria are fermented to become lactic acid. When lactic acid is added with catalyst at high temperature and low pressure, poly(lactic acid) (PLA) can be directly synthesized by condensation polymerizations [1-8].

Nowadays, the oil spill on the sea surface is one after another, which has a serious impact on ecological environment. Due to its advantages of high efficiency and no secondary pollution, nanofiber membranes have unique advantages in oil/water adsorption [8-12], and gradually become the subject of study.

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In the present study, poly(lactic acid) (PLA) nanofibers with hollow [13-14] and lotus-root-like [15-17] structures were prepared using the coaxial electrospinning method [18-19]. To achieve this goal, the prepared PLA/PVA nanofibers with a core/shell structure were immersed in deionized water for 48 h to remove the core (PVA). The cross-sectional porosities of the prepared nanofibers were analysed quantitatively using MATLAB, and the oil sorption experiments were also performed. The results of the porosity analyses show that, for the hollow structure, when the flow rate ratio of the core/shell solution was 1:2 or 1:4, the cross-sectional porosity was about 41%, larger than 34.88% (flow rate ratio=1:3). However, the cross-section porosity seemed to be voltage-independent, which was demonstrated by the fact that the porosity was stable at $41\% \pm 2\%$ when the voltage varied in the range of 19-22 kV. While in the lotus-root-like fibers, the porosity value was not affected by these parameters. The results of the oil sorption experiments demonstrated that the absorption capacity of the lotus-root-like structure fibers to diesel oil is more than 1.5 times that of the hollow structrue fibers.

# 2 Materials and Experiments

## 2.1 Materials

PLA (Mw=$1.0 \times 10^5$ g/mol) was purchased from Zhejiang Hai Zheng Biological Materials Co., Ltd., Zhejiang, China. PVA (Mw=$9.5 \times 10^4$ g/mol, percent hydrolyzation 95%) was purchased from J&K scientific Co., Ltd., Beijing, China. N, N- Dimethylacetamide (DMAC), Dichloromethane (DCM) and Dimethyl sulfoxide (DMSO) were purchased from National Medicine Group Chemical Reagents Co., Ltd., Beijing, China. Diesel oil was obtained from Suzhou Difite Filtration Technology Co., Ltd., Suzhou, China. All chemicals were of analytical grade and used without further purification.

## 2.2 Preparation of PLA Nanofibers with Hollow and Lotus-root-like Structures

8 wt.% PLA was dissolved in a DCM/DMAC (mass ratio of 10:1, w/w) mixed solvent, 2 wt.% PVA was dissolved in DMSO, and DCM was added to the PVA/DMSO solution (where the DMSO/DCM ratio was 2:1, w/w) after PVA was completed dissolved. Then both of them stirred at room temperature for about 12 h. Two 5 mL syringes were used—one to absorb the shell solution (PLA) and the other to absorb the core solution (PVA or PLA), and then fixed onto two syringe pumps (KDS-100, KD Scientific, Inc., Holliston, MA, USA). The general setup of the apparatus is shown in Fig. 1. Tubes were used to connect the syringes and the coaxial needle, and a high-voltage power supply (DWP503-1ACDF, Tianjin Dongwen High Voltage Co., Tianjin, China) was connected to the coaxial needle through a wire.

The electrospun PLA/PVA or PLA/PLA composite nanofiber membrane was deposited onto the metallic roller, which was positioned 12 cm from the needle tip. Meanwhile the relative humidity (RH) of the environment was $45\% \pm 3\%$. PLA nanofibers with hollow and lotus-root-like structures were prepared by adjusting the flow rate ratio of core/shell solution (0.3 mL/h: 0.6 mL/h (1:2), 0.3 mL/h: 0.9 mL/h (1:3) and 0.3 mL/h: 1.2 mL/h (1:4)) and spinning voltage (19 kV, 20 kV, 21 kV, 22 kV and 23 kV). The control sample which only has lotus-root-like structure