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厦门大学

硕 士 学 位 论 文

微纳三维结构电纺直写电场聚焦控制技术研究

Electrohydrodynamic Direct-Write Mirco/Nano Three Dimensional Structure Based on Electrical Field Focusing

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摘 要

作为一种新颖的微纳制造技术，电纺直写技术已在信息、生物医疗、航空等应用领域显现出强大的潜力。增强射流稳定性、提高喷印沉积精度、诱导纤维叠加沉积，实现微纳三维成型是促进电纺直写技术应用发展的关键。本文引入辅助针尖构建聚焦电场增强对射流的引导与约束作用，以克服射流螺旋鞭动、提高喷射稳定性，实现了电纺直写高精度图案化喷印与微纳三维结构叠加沉积。

仿真分析了系统结构和工艺参数对聚焦电场的作用机制，优化电场聚焦电纺直写实验系统，进一步增强聚焦电场对射流的约束能力。实验研究了射流喷射沉积与流变行为的控制规律，研究发现通过减小施加电压、喷嘴至收集板距离、喷嘴内径有利于提高射流的稳定性，为高精度电纺直写提供了实验基础。

探索了电场聚焦电纺直写的喷印沉积规律。收集板的运动将拉伸射流，增强射流稳定性，减小鞭动幅值和纤维沉积范围。当收集板运动速度与射流喷射速度相近时，有助于克服射流的螺旋鞭动干扰，促进纤维稳定沉积，提高沉积精度，可实现纳米纤维的电场聚焦精确沉积控制，完成网格、五角星、徽章与凤凰花等复杂图案的喷印制造。

聚焦电场加快了纤维中电荷的转移，有利于促进纤维的稳定叠加沉积，诱导图案化三维结构的直接喷印制备。基于电场聚焦控制技术，通过改变喷嘴高度可成功地实现圆柱状、碗状、圆锥状、瓷瓶状等多种外形可控自螺旋微纳三维结构的电纺直写制造，螺旋结构直径 20μm~80μm，高度 10μm~1.68mm。研究了工艺参数对三维结构叠加沉积行为的作用规律，成功喷印了纤维墙、网格、五角星、椭圆柱、空心柱状等多种图案化三维结构。

通过本文研究，明确了射流稳定沉积的电场聚焦控制方法，实现了直写纤维的高精度图案化喷印与微纳三维结构的可控叠加沉积，有利于促进电纺直写技术的产业化应用。

关键词： 电纺直写；电场聚焦；精确沉积；图案化喷印；三维成型

Abstract

Electrohydrodynamic Direct Writing (EDW), which is a novel micro/nano-manufacturing technology, has shown great potential in the fields of information, biomedical and aerospace. Enhancing the stability and improving the deposition precision of charged jet to realize the micro/nano 3D molding, have been the key to expand the application of EDW. The focusing electrical field built up by the assistant tip, by which the spiral bending can be overcome to increase the stability of charged jet. Then, the focused jet can be used to direct-write precise pattern and three-dimensional micro/nano structure.

The Ansys software was utilized to analyze the effects of configuration and process parameters on the focusing electrical field. The configuration of EDW system is optimized to enhance the constraint of focused electrical field. The control strategies of ejection and rheological behaviors of charged jet are investigated. The stability of jet can be improved by reducing of applied voltage, inner diameter of nozzle and distance between nozzle and collector, which provides the research basis of high precision EDW.

The deposition behaviors of EDW jet under focused electrical field are discussed. The charged jet is stretched by moving collector, which is helpful to enhance the stability of jet. Both of the whipping amplitude of jet and deposition area of nanofibers is reduced by the moving collector. When the velocity of collector is approximately equal to the ejecting speed of charged jet, the interferences can be overcome to increase the deposition precision. Based on the focusing of electrical field, the complex patterns are direct-written, such as grid, star, badge and flowers.

The transfer of charge on nanofiber is accelerated by the focused electrical field, which is contributed to direct-write three-dimensional patterned micro/nano structure. Based on the focusing electrical field of EDW, the shape and diameter of self-spiral micro/nano three-dimensional structures can be controlled by changing the height of nozzle. The diameter of spiral three-dimensional structures is 20μm~80μm, and the height is 10μm~1.68mm. The effects of process parameters on deposition behaviors of three-dimensional structure are investigated further, and various three dimensional micro/nano pattern can be printed successfully, such as wall, grid, star and cylinder patterns.

The controlling strategies of stable jet under focused electrical field are obtained, which contributes to print high precise pattern and deposition of three-dimensional micro/nano structure. This paper proposed an effective way to promote the industrialization application of EDW.

Keywords：Electrohydrodynamic Direct Writing; Electrical Field Focusing; Precise Deposition; Pattern Printing; Three Dimensional Micro/nano Structure

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