2nd Conference on Green Chemistry and Sustainable Coatings

greenchemco

Pisa, Italy, 28th-30th June 2023

Development of polymeric micro-patterned alveolar-like coatings

Matteo Sestini[1], Mario Milazzo[1], Giuseppe Gallone[1], Serena Danti[1]

[1]Dept. of Civil and Industrial Engineering, University of Pisa, Pisa, Italy;
Telephone: +390502217874, matteo.sestini@ing.unipi.it

Keywords: Electrospinning, masked stereolithography, PEOT-PBT, tissue engineering.

Introduction

Three-dimensionality is one of the most relevant aspects in biological systems. In particular, it has been observed an interplay between the curvature of a cell substrate in a near-cell range and the functional and morphological cellular response [1]. Therefore, there is an increasing need of new processing methods to fabricate biomimetic micro-curved structures to increase the fluid/structure interface thus improving the functional performance of a tissue engineered scaffold.

To achieve such specific features, additive manufacturing techniques, and in particular masked stereolithography appearance (MSLA) 3D printing and electrospinning (ES), can be used for: i) fabricating structures with high surface/volume ratio [2] ii) rapidly manufacturing 3D-micropatterned structures with a high degree of resolution (<50 µm) [3].

This work proposes a combination of such technologies to manufacture coatings inspired to the lung alveoli, in order to achieve a coating with features in the order of 300 µm. The combination of the two methods allows to exploit the versatility and controllability of the targeted 3D printed structures, thus obtaining ECM-like structural features.

Experimental

The MSLA 3D printing process was optimized to obtain hemispherical structures with features in the order of 300 µm. This procedure included a process of progressive miniaturization of such features by studying the effect of a number of process parameters: layer height, time of exposure, anti-aliasing functions. To make the surface of the 3D printed object conductive, a sputter coater was employed to deposit a nanometric layer of gold (Figure 1a).

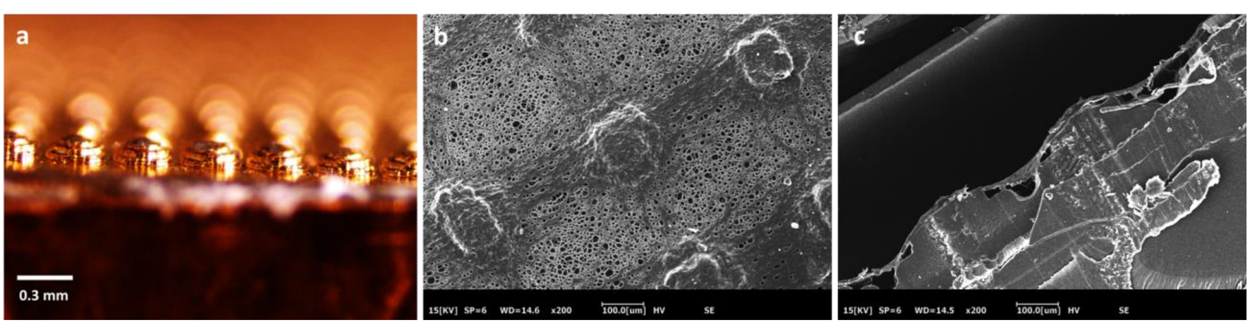

Figure 1: (a) 3D printed pattern covered with gold. (b-c) Thermally treated fibers at 140°C for 2 min in top-view and section-view, respectively.

For the ES process, the random block copolymer polyethylene oxide terephthalate/polybutylene terephthalate (PEOT-PBT) was proposed as a candidate material. Then, a polymeric solution was prepared with 18% w/v of PEOT-PBT in 70% chloroform/30% hexafluoro-2-propanol. An *ad-hoc* setup for the ES was developed by using the 3D-printed objects with concave features as collectors. A thermal characterization of PEOT-PBT was performed on the electrospun fibers, and different thermal treatments were performed on the coatings by varying the temperature and time parameters. The 3D-printed collectors and coatings were further characterized with an optical microscope and SEM imaging.

Results and Discussion

The combination of the MSLA 3D printing process and ES led to alveolar-like coatings with features in the order 300 µm. The average diameter of the fibers was 1.4 ± 0.3 µm. After 45 min of ES, the thickness of fibrous structure was between 100 and 200 µm. Bridges of fibers were obtained between neighbouring features, leading to an architecture based on the convolution of the 3D-printed pattern (Figure 1c).

The thermal analysis evidenced the presence of two types of amorphous phases, with one glass transition temperature at about -20°C with the crystalline fraction of PBT of about 62%. A melting temperature of 156°C was also observed.

The morphologies of the coatings were characterised by SEM imaging: by increasing the temperature of thermal treatments, different morphologies were observed starting from the PEOT-PBT electrospun fibrous structure (In Figure 1b-c fibers treated at 140°C for 2 min). Eventually, a fibrous coating was obtained with self-sustaining 300-µm alveolar-like features.

Conclusions

The combination of the ES process and MSLA 3D printing is a powerful approach for obtaining fibrous coatings characterized by an alveolar-like microstructure with concave features in the order of 300 µm. Such results can be applied in a number of applications both in the biomedical and chemical fields where high contact surface areas for heat/mass transfer is required.

References

[1] D. Baptista, L. Teixeira, C. van Blitterswijk, S. Giselbrecht, and R. Truckenmüller, "Overlooked? Underestimated? Effects of Substrate Curvature on Cell Behavior," *Trends Biotechnol.*, vol. 37, no. 8, pp. 838–854, Aug. 2019, doi: 10.1016/J.TIBTECH.2019.01.006.

[2] N. Shah Hosseini and N. Khenoussi, "Structuring of electrospun nanofiber mats by 3D printing methods," *Electrospun Mater. Tissue Eng. Biomed. Appl. Res. Des. Commer.*, pp. 73–85, Jan. 2017, doi: 10.1016/B978-0-08-101022-8.00003-X.

[3] S. Goss *et al.*, "Mod3D: A low-cost, flexible modular system of live-cell microscopy chambers and holders," *PLoS One*, vol. 17, no. 6, p. e0269345, Jun. 2022, doi: 10.1371/JOURNAL.PONE.0269345.

Acknowledgments

This study has not received external funding.

Biography

Matteo Sestini graduated in Materials & Nanotechnology (MSc) in 2023 at University of Pisa. He is actually a Research Assistant at the Department of Civil and Industrial Engineering at University of Pisa.