Conference Paper

Features of Polymeric Structures By Surface—Selective Laser Sintering of Polymer Particles Using Water as Sensitizer

Churbanov S.N.[1], Minaev N.V.[1], Grinchenko V.D.[2], Minaeva S.A.[1], Bagratashvili V.N.[1], and Timashev P.S.[2]

[1]Institute of Photon Technologies of Federal Scientific Research Centre "Crystallography and Photonics" of RAS, Troitsk, Russia
[2]Departament for Advanced Biomatherials, Institute for Regenerative Medicine, I.M. Sechenov First Moscow State Medical University, Moscow, Russia

Corresponding Author:
Churbanov S.
churbanov.semyon@gmail.com

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Abstract

The development of scaffolds with strictly specific properties is a key aspect of functional tissue regeneration, and it still remains one of the greatest challenges for tissue engineering. This study is aimed to determine the possibility of producing three-dimensional polylactide (PLA) scaffolds using the method of surface-selective laser sintering (SSLS) for bone tissue regeneration. In this work, the authors also improved PLA scaffold adhesion properties, which are crucial for successful cellular growth and expansion. Thus, SSLS method proved to be effective in designing three-dimensional porous scaffolds with differentiated mechanical properties.

Keywords: regenerative medicine, scaffolds, polylactide, surface – selective laser sintering, tissue engeneering.

Tissue engineering plays a pivotal role in regenerating specific and functional tissues and organs. Tissue-engineered scaffolds, in their turn, are designed to serve as a platform for cell migration and growth. Scaffolds should have some essential characteristics to facilitate cell colonization by enhancing cell attachment, proliferation, migration and expression of native phenotypes [1]. Biodegradability, mechanical properties similar to the regenerated tissue, material hydrophilicity, and biocompatibility are critically important in the fabrication of matrices. In the case of bone tissue regeneration, where mechanical properties are highly differentiated [2], the manufactured scaffold should exactly recapitulate them. Only if the scaffold meets all the requirements mentioned above it can be used in tissue regeneration according to the scheme indicated in Figure 1. Even though he method of selective laser sintering is very effective in the creation of three-dimensional structures, the sensitizers used in this method [3] usually leave foreign particles when the scaffold is implanted *in vivo*. In our work, water was used as the sensitizer and heating regulator. During the sintering process, the water evaporates and heats up only the thin surface zone of the polymer particles. Hence, this method is known as surface-selective laser sintering [4] (SSLS).

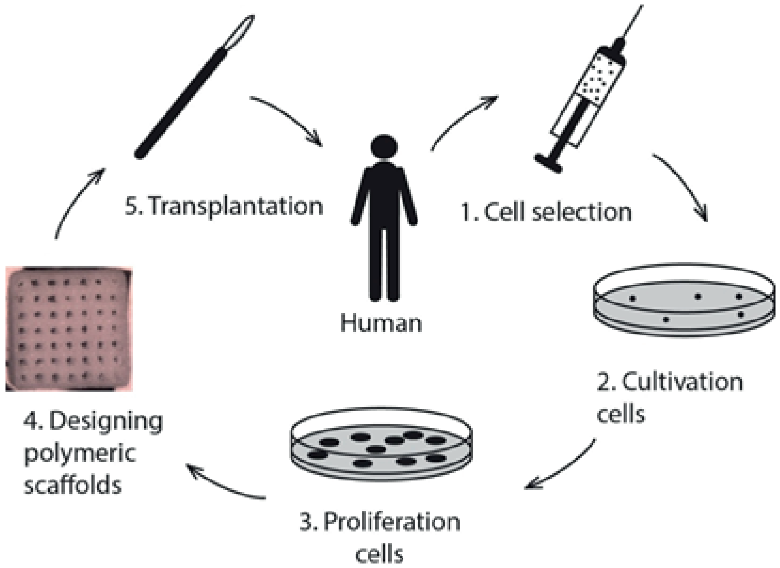

Figure 1: Scheme of tissue regeneration.

1. Materials and methods

An experimental setup for applying the SSLS method is shown in Fig. 2. In this study, polymer sintering was performed by infrared fibre laser scalpel-coagulator LS 1.9 (IPG IRE-Polus, Russia) with a wavelength of 1.94 microns.

PURASORB PDL 02A (PURAC), which is approved for tissue engineering by Food and Drug Administration, was used as a source material for 3D printing. Since polylactide has hydrophobic properties, it hinders the process of cell adherence and growth. Therefore, the polymer powder was treated with 1% solution of hyaluronic acid (HA) to hydrophilize the material.

2. Results

In order to confirm the improved material adhesive properties, we applied the spreading droplet method [5] (Fig. 3). The method included measuring the wetting contact angle for both the initial and modified powder. These powders were also analyzed on a Raman spectrometer (Nicolet Almega XR, Thermo Fisher Scientific, USA), and subsequently, the modified polymer degradation rate was determined.

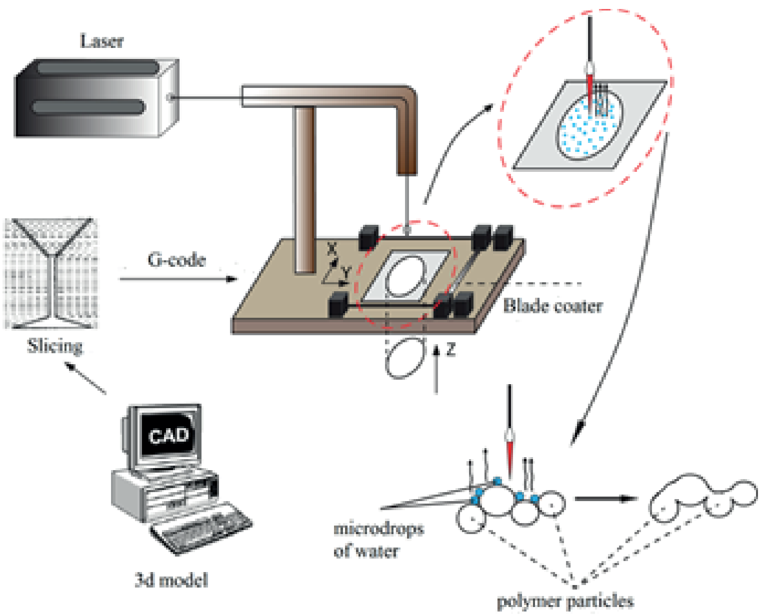

Figure 2: Scheme SSLS.

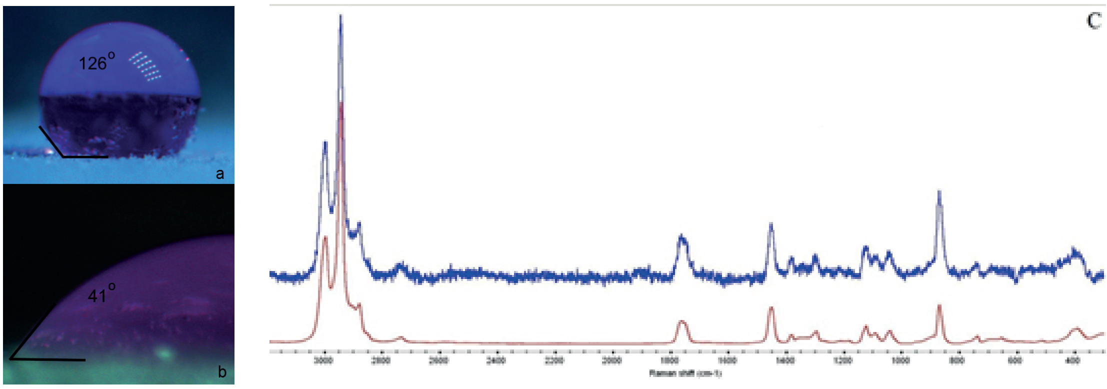

Figure 3: Change in material compatibility after modification: a-contact angle initial polymer, b - contact angle of the modified polymer, c - Raman spectra, red line - initial polymer, blue line – modified.

Three-dimensional porous scaffolds were printed from the PLA-HA polymer, layer by layer. As reported in Figure 4, their structure and morphology were studied with a scanning electron microscope (Phenom ProX), while the analysis of mechanical property distribution was performed on a nanoindenter (Piuma Nanoindenter, Netherlands).

3. Discussion

During the measurements, it was found that the modification of the polylactide powder with 1% hyaluronic acid as indicated in Fig. 3 did not lead to material degradation. Moreover, it changed the material wetting contact angle from 126 ° to 41 °, which due to increased material adhesion properties will potentially lead to the significant acceleration of cell growth and expansion.

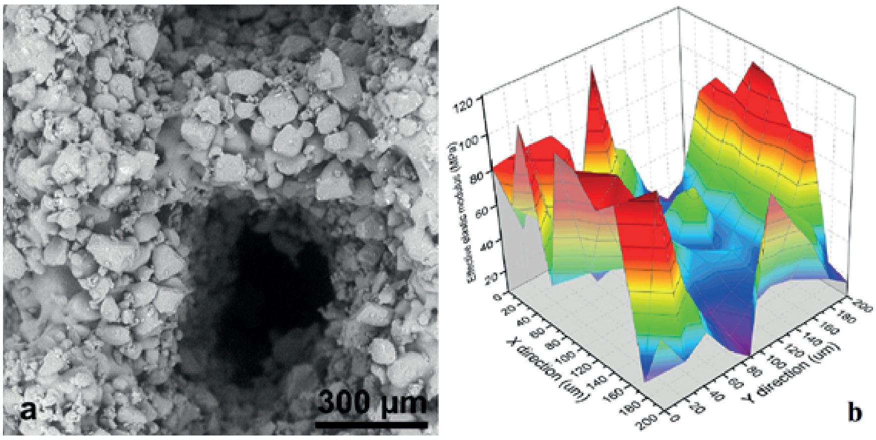

Figure 4: SEM picture (a), distribution of mechanical properties over the scaffold surface (b).

On magnification, the modified SSLS-treated polymers (Fig. 4, a) had the form of separately fused particles, which confirmed their surface penetration during processing. As a result, such construction has the sufficient porosity for cell attachment [6].

The distribution of the Young's modulus over the scaffold surface was various (Fig. 4, b), but it strongly correlated with the laser power effect on printed areas. Thus, our work demonstrated the fundamental possibility of programming mechanical properties with the SSLS method for printing tissue-engineered structures.

4. Conclusion

This study showed the possibility of creating hydrophilic biodegradable porous structures with the SSLS method. In addition, the method allows to differentiate scaffold mechanical properties, which is vital for building reliable bone implants.

Acknowledgments

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