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Laser rapid prototyping techniques for fabrication of advanced implants and scaffolds for tissue engineering

Popov V. K.

(Institute of Laser and Information Technologies, Russian Academy of Sciences, Moscow 142190, Russia)

Rapid prototyping (RP) techniques become more and more extensively used instrument for numerous biomedical applications ranging from 3-D biomodels design to fabrication of custom-designed implants and scaffolds for tissue engineering. In this paper we present the results of our development of advanced Laser Stereolithography (LS) and new Surface Selective Laser Sintering (SSLS) methodologies for these purposes.

Our LS approach is based on photopolymerisation of a new liquid mixture of polyfunctional acrylic monomers and hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) powder. Using this technique a wide range of LS samples have been produced and then treated with supercritical carbon dioxide to remove toxic residues and to provide intrinsic microporosity of the implants. We describe cytotoxicity tests and detail study of Human Osteoblast cell attachment, spreading and proliferation on these implants as well as in vivo analysis of living tissue response and osteogenesis process after implantation in animals.

We have proposed and developed a new Surface Selective Laser Sintering (SSLS) technique which unlike conventional SLS based not on volumetric absorption of the CO_2 laser radiation ($\lambda=10.6$ μm) by the polymer, but on initiation of the polymer particle fusion due to the near-infrared ($\lambda=0.97$ μm) laser beam absorption by a small amount (ca. 0.1%, mass fraction) of carbon black uniformly distributed along the polymer powder surface. SSLS enabling us to avoid internal domain overheating of the polymer particle by delicate melting of the particle surface only. SSLS technique allows to use thermosensitive biodegradable polymers (like D, L-polylactic acids and their copolymers) to produce custom-designed scaffolds preventing any significant structural transformations and changes in their chemical composition. Moreover, this approach permits incorporation of enzymes (e. g. ribonuclease and catalase) into the matrix structure retaining their bioactivity.

These results along with our mechanical, in vitro and in vivo testing allow us to consider these new materials and developed techniques as a promising approach for direct laser RP production of mineral-polymer both biostable and biodegradable custom-designed implants and scaffolds for tissue engineering based on CAD/CAM data.

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