Combinatorial Laser Technologies

Subjects: Materials Science, Coatings & Films

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Modification of metallic implants with biocompatible coatings is usually required to avoid premature loosening of prosthesis. Specific to the bone implant tissue, coatings with specific characteristics are proposed in order to provide optimal osseointegration. Pulsed laser deposition (PLD) became a well-known physical vapor deposition technology that has been successfully applied to a large variety of biocompatible inorganic coatings for biomedical prosthetic applications. Matrix assisted pulsed laser evaporation (MAPLE) is a PLD-derived technology used for depositions of thin organic material coatings. In an attempt to surpass solvent related difficulties, when different solvents are used for blending various organic materials, combinatorial MAPLE was proposed to grow thin hybrid coatings, assembled in a gradient of composition. Thus, by applying combined laser technologies one may develop composite coatings with biomimetic features able to modulate cellular behaviour for tissue engineering or cancer research applications.

Keywords: Coatings, Laser processing, Biomimetics

1. Introduction

During the last two decades, new challenges in ***nanoscience and nanotechnology*** have been continuously addressed, in particular within the biomedical field [1,2,3]. The necessity of ***new biomaterials*** with improved properties have led to interdisciplinary studies at the interface between physics, chemistry, materials science, biology, and medicine [1]. There are, by now, four generations of biomaterials with the latter one capable of adapting to extra- and intra-cellular processes that could allow for the understanding of signaling pathways mediating inter- and intra-cellular communications [4,5,6]. However, there is still a breach in the in-depth understanding of nanomaterial interactions with biological entities both in vitro and in vivo. The design of innovative biomaterials should aim to precisely control the composition–properties relationship in order to modulate cell behavior in the field of tissue engineering and regenerative nanomedicine [7] or cancer theranostics [8].

Biomimetics rely on the ability to create synthetic characteristics from nature-inspired shapes and principles with the aim to achieve the desired biological responses. As a consequence, an improvement in the biomaterial surface could be attained by modifying their basic morphological properties to create a biomimetic environment that could eventually control the cell–surface interaction. In addition, in order to structurally and functionally recapitulate the natural micro-environment, inorganic–organic composite structures become necessary.

2. Specifics

There are various ***physical and chemical deposition techniques*** employed for the ***synthesis of bio-coatings*** and they exhibit advantages and limitations regarding the type of material, the preservation of stoichiometry, control of morphological and structural properties, or processing of the coating area. Among them, plasma vapor deposition (PVD) techniques, usually apply to inorganic material coating. One may enumerate thermal evaporation, atomic layer deposition, electron beam evaporation, sputter deposition in plasma, reactive sputter deposition, cathodic arc deposition, pulsed electron deposition, electroless plating, or laser deposition. On the other hand, there are also coating methods appropriate for organic materials such as the Langmuir–Blodgett dip coating, sol-gel, layer by layer deposition, aerosol spraying, dip coating, spin coating or laser evaporation that entail liquid solutions of the material in a volatile solvent. Typically, each method is suitable to a limited class of compounds, either inorganic or organic. This represents a limiting factor, particularly in the case of a composite bio-coating. Composites become necessary to solve specific medical problems such as to improve osseointegration or to decrease local tissue inflammation and avoid infection.

Technological advancements have encouraged research to challenge biomimetic environments. ***Laser deposition techniques*** have been successfully used to fabricate bio-coatings, in particular pulsed laser deposition for inorganic materials and matrix assisted pulsed laser evaporation for both organic and inorganic materials. They have since progressed and were found applicable to either inorganic, organic, or inorganic–organic multi-layers or blended bio-coatings. Thus, combinatorial-PLD and combinatorial-MAPLE were proposed as alternatives to classic combinatorial chemical and physical deposition methods to synthesize biomimetic assemblies of complex composite and hybrid materials, with gradient of composition. combinatorial-MAPLE offers the unique characteristic of combining, in a controlled process, blended or multi-layer coating configurations of compounds dissolved in different solvent solutions, without the impediment of not being able to choose combinations with non-mixable solvents. Such combinations could allow for the synthesis of new materials with properties close to those of the native biological environment. *In vitro* evaluations of the bio-coatings fabricated by laser technologies confirmed their biocompatibility and capacity of modulating cell behavior.

By combining the newly developed laser technologies with other chemical or physical methods, great perspectives could be open for domains like tissue engineering, nanomedicine, or controlled drug delivery in cancer research.