coatings

Editorial

Advanced Biomaterials and Coatings

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Citation: Drevet, R.; Benhayoune, H. Advanced Biomaterials and Coatings. *Coatings* **2022**, *12*, 965. https://doi.org/10.3390/coatings12070965

Received: 25 June 2022
Accepted: 5 July 2022
Published: 7 July 2022

Everywhere on Earth, people are living longer and longer. The World Health Organization predicts that by 2050, the world's population of 60 years or older will double to reach 2.1 billion, and the population of 80 years or older will triple to reach 426 million [1]. Due to the aging of the population, the clinical demand for biomaterials used for bone tissue repair increases every year [2,3]. Academic and industrial research is constantly developing innovative biomaterials and coatings to improve the properties and extend the lifetime of bone implants. The main metallic materials used in orthopedic or dental surgeries are made of titanium alloys [4–6], stainless steel [7,8], and CoCr alloys [9,10]. The mechanical properties of these alloys are suitable for bone tissue replacement, and their biocompatibility with the body environment is good. The International Union of Pure and Applied Chemistry (IUPAC) defines biocompatibility as the *ability of a material to be in contact with a biological system without producing an adverse effect* [11]. These alloys are biocompatible, but their biological interaction with bone tissue is very low. The surface bioactivity of these implants must be improved to avoid any bone anchorage failure that would induce mandatory revision surgery. The osseointegration of bone implants can be enhanced by a surface coating of bioactive material, such as calcium phosphate or bioglass. These materials initiate the formation of a strong bond to bone tissue [12–14]. The bioactive coating is a scaffold to bone growth that provides a rapid biological response and improves the adhesion of the implant to bone [15,16]. Several methods can be used to produce a bioactive coating on the surface of implants. This Special Issue aims to describe the latest developments in deposition methods used to synthesize advanced biomaterials and coatings for bone implant applications. The main deposition processes are plasma spraying, magnetron sputtering, pulsed laser deposition, electrospray deposition, electrophoretic deposition, and electrodeposition.

Plasma spraying (PS) is the main industrial process due to its ability to produce large quantities of coatings with good reproducibility. Plasma spraying involves the injection of calcium phosphate or bioglass powder into a hot plasma jet whose temperature is thousands of degrees [17,18]. Inside the plasma, the grains of powder are in a molten or semi-molten state. They are accelerated toward the surface of the bone implant, where they cool down and solidify instantly to form a coating. There are some drawbacks with the high temperatures involved in plasma spraying that produce uncontrolled phase changes, chemical decompositions, and structural modifications. The physicochemical and biological properties of the coating are different from those of the initial powder [19].

Magnetron sputtering (MS) of a calcium phosphate or bioglass target is another process to produce bioactive coatings on bone implants. Magnetron sputtering is a physical vapor deposition (PVD) process. In a vacuum chamber at room temperature, high-energy ions from a plasma collide with the atoms of the target with enough energy to eject and transport them toward the surface of the substrate to form a coating [20]. Magnetron sputtering produces dense, uniform, and adherent coatings. However, the different atoms of a multicomponent target have different sputtering behaviors. The chemical composition of the deposited coating usually differs from that of the target. The experimental parameters of the process can be used to modify the stoichiometry, morphology, and structure of the bioactive coating, corresponding to different physicochemical and biological properties [21].

Pulsed laser deposition (PLD) uses a high-power laser that hits a calcium phosphate or bioglass target inside a vacuum chamber [22]. The laser–matter interaction induces the ablation of the target and generates a plasma plume containing ejected atoms, ions, and electrons. The plasma plume is directed toward the surface of the substrate where the material is collected and condensed to form a coating. The process rapidly produces uniform and adherent thin coatings [23]. As described for magnetron sputtering, the stoichiometry of the coating may differ from that of the target, resulting in variations in the physicochemical and biological properties of the coating.

Electrospray deposition (ESD) uses an aerosol that contains calcium phosphate particles, bioglass particles, or precursors of these materials. The aerosol is produced by injecting a solution through a nozzle connected to high voltage [24]. Charged droplets are produced at the tip of the nozzle, and they are directed toward a grounded and heated substrate. The droplets lose their surface charge, and the solvent is evaporated to produce the bioactive coating. The process produces uniform coatings with different morphologies as a function of the experimental parameters [25].

Electrophoretic deposition (EPD) requires two conductive electrodes connected to a generator and immersed in a stable colloidal suspension of calcium phosphate or bioglass powder. In contact with the solution, the colloidal particles carry a positive or negative electrostatic charge on their surface [26]. They move through the liquid under the influence of the electric field between the two electrodes. They agglomerate on one electrode surface to form a bioactive coating. Post-deposition thermal annealing in a furnace is necessary to evaporate the solvent and improve the cohesive and adhesive properties of the coating [27].

Electrodeposition (ELD) is a low-temperature process that requires two metallic electrodes connected to a generator and immersed in an aqueous solution containing calcium ions and phosphate ions. In academic research, a reference electrode is also usually connected in a three-electrode setup that provides electrochemical measurements. In the electrolytic cell, the anode is the positive electrode, and the cathode is the negative electrode. Electrical energy from the generator is used to trigger a series of chemical reactions at the electrode–electrolyte interfaces. At the cathode, where the bone implant is connected, the main electrochemical reaction is the reduction of water, the solvent of the electrolyte solution. This reaction results in a local pH variation in the vicinity of the cathode that induces surface precipitation of the calcium phosphate coating [28]. As a function of the experimental parameters, various chemical compositions, phases, and morphologies are obtained. Direct current was typically used first, but pulsed current electrodeposition became more interesting in recent years [29]. Since the process takes place in an aqueous medium at room temperature, ionic additives (Na^+, Ag^+, F, Co^{2+}, Cu^{2+}, Mg^{2+}, Sr^{2+}, Zn^{2+}, etc.) or organic components (polymers, proteins, drugs, etc.) can be added to enhance the biological and mechanical properties of the calcium phosphate coating [30]. Post-deposition annealing is also required to evaporate the solvent and improve the cohesive and adhesive properties of the electrodeposited coating [31].

Author Contributions: Conceptualization, R.D. and H.B.; validation, R.D. and H.B.; resources, R.D. and H.B.; writing—original draft preparation, R.D. and H.B.; writing—review and editing, R.D. and H.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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