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Review

Calcium orthophosphate deposits: Preparation, properties and biomedical applications

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ABSTRACT

Since various interactions among cells, surrounding tissues and implanted biomaterials always occur at their interfaces, the surface properties of potential implants appear to be of paramount importance for the clinical success. In view of the fact that a limited amount of materials appear to be tolerated by living organisms, a special discipline called surface engineering was developed to initiate the desirable changes to the exterior properties of various materials but still maintaining their useful bulk performances. In 1975, this approach resulted in the introduction of a special class of artificial bone grafts, composed of various mechanically stable (consequently, suitable for load bearing applications) implantable biomaterials and/or bio-devices covered by calcium orthophosphates ($CaPO_4$) to both improve biocompatibility and provide an adequate bonding to the adjacent bones. Over 5000 publications on this topic were published since then. Therefore, a thorough analysis of the available literature has been performed and about 50 (this number is doubled, if all possible modifications are counted) deposition techniques of $CaPO_4$ have been revealed, systematized and described. These $CaPO_4$ deposits (coatings, films and layers) used to improve the surface properties of various types of artificial implants are the topic of this review.

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1. Introduction

All existing materials have the specific properties of their own. Namely, some of them are aggressive, corrosive or biologically incompatible, certain ones are sensitive to light, heating or oxidation, others are hydrophilic, transparent or slimy in nature, *etc*. Depending on the situations and applications, such properties might be either desirable or undesirable. In the latter case, to get rid of the undesired properties, the surface of such materials should be modified. This is the subject of a special sub-discipline of materials science called *surface engineering*, which implies various surface modifications of the solid matter. In broad terms, surface engineering has applications to chemistry, mechanical engineering and electrical engineering (particularly in relation to semiconductor manufacturing) [1]; however, the latter case is beyond the scope of this review.

In general, all available types of the surface modifications can be broadly classified into 3 categories: 1) deposition of materials possessing the desirable functions and properties onto the surface, 2) conversion of the existing surface into more desirable compositions, structures and/or topographies, and 3) partial removal of a material from the existing surface to create specific topographies [2]. As seen from the list of the available options, 2 of 3 categories comprise an application of surface coatings, films and layers to solve the problems in a conventional form. In the case of artificial bone grafts, synthetic materials to be used in the biological environments must display an adequacy of both their surface and bulk characteristics in order to fulfill the dual requirements of biocompatibility and suitable mechanical properties for the given application. Otherwise, either fibrous tissues encapsulate the implants made from non-biocompatible materials or mechanically weak grafts do not function properly. Both types of flaws prolong the healing time. Considering that surface is always the first part of any insert that interacts with the host, various types of surface deposits (coatings, films and layers) have been developed to enhance biocompatibility and osteoconductivity of the implants.

On the other hand, it is well known that, due to the great chemical similarity to the inorganic part of bones and teeth of mammals, calcium orthophosphates ($CaPO_4$) appear to be very friendly compounds for the *in vivo* applications [3–6]. The full list of the existing $CaPO_4$ is presented in Table 1. However, since bulk $CaPO_4$ have a ceramic nature, they are mechanically weak (brittle) and cannot be subjected to the physiological loads as encountered in human skeletons, other than compressive ones. Therefore, for many years, the clinical applications of $CaPO_4$