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Review

Biomedical coatings on magnesium alloys – A review

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ABSTRACT

This review comprehensively covers research carried out in the field of degradable coatings on Mg and Mg alloys for biomedical applications. Several coating methods are discussed, which can be divided, based on the specific processing techniques used, into conversion and deposition coatings. The literature review revealed that in most cases coatings increase the corrosion resistance of Mg and Mg alloys. The critical factors determining coating performance, such as corrosion rate, surface chemistry, adhesion and coating morphology, are identified and discussed. The analysis of the literature showed that many studies have focused on calcium phosphate coatings produced either using conversion or deposition methods which were developed for orthopaedic applications. However, the control of phases and the formation of cracks still appear unsatisfactory. More research and development is needed in the case of biodegradable organic based coatings to generate reproducible and relevant data. In addition to biocompatibility, the mechanical properties of the coatings are also relevant, and the development of appropriate methods to study the corrosion process in detail and in the long term remains an important area of research.

1. Introduction

Magnesium is the lightest metal, which exhibits a high strength to weight ratio, good thermal and electrical conductivity, excellent vibration and shock absorption, a high damping capacity and electromagnetic shield performance [1–4]. The main disadvantage of Mg and Mg alloys is that they are prone to corrosion; magnesium is one of the most electrochemically active metals. In addition, the wear resistance of Mg and Mg alloys is not very high. Due to this a broad range of coating systems are being developed to overcome these weaknesses for numerous applications [5,6].

The low corrosion resistance of Mg makes Mg alloys appropriate candidates for degradable biomaterials due to their biocompatibility combined with outstanding physical and mechanical properties [7–9], e.g. in comparison with polymers. Magnesium ions are needed in the human body for physiological functions, with consumption lying in the range 250–500 mg day^{-1}. About 20 g of Mg is always present in the average 70 kg human body; the toxic dose is unknown. Magnesium and its alloys have been studied as implant materials for numerous medical applications since 1878, which has been discussed in a history review by Witte [10]. However, commercial medical products are still not available. Up to 1980 magnesium materials were generally expensive to produce, the possible processing routes and the resulting mechanical properties were limited, and many unsolved problems related to the low corrosion resistance existed. Due to the introduction of water-cooled cars and the increased requirements for corrosion resistant alloys the use of Mg alloys in the automobile industry ceased [11]. During the 1990s, these low density materials again became very attractive for transportation applications because of the fuel saving benefits obtainable, however, the relevant knowledge for industrial application was still incomplete [2]. This has led to extensive evaluation of the potential use of magnesium in transportation systems, but up to now tangible applications have been limited, e.g. in aircraft components [1,2]. Nowadays there are new expectations for a variety of applications of Mg alloys as the magnesium production technology is now highly developed.

There is a need of a new generation of biomaterials for innovative implants and tissue scaffolds which should be able to stimulate the healing responses of injured tissues at the molecular level [12–15]. In many cases the body needs only the temporary presence of an implant or device, in which case materials exhibiting biodegradability represent a better approach than stable and inert ones. The ideal biodegradable material, for example in bone regeneration strategies (polymer, ceramic, metal or composite), should provide adequate mechanical fixation, complete degradation once no longer needed, and complete replacement by new bone tissue.

Biodegradable polymers are the materials of choice in several applications, including surgical sutures, antibacterial coatings,

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