Anodized Micro and Nanoporous Titania Layer for Controlled Drug Release

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Introduction: Among the metallic implant materials, titanium (Ti) and its alloys have been widely used because of their excellent biocompatibility. Because the biocompatibility of titanium is closely related to the surface properties, numerous chemical and physical treatments of the titanium surface were proposed. Electrochemically oxidizing (anodizing) is one of the most widely used surface treatment techniques for Ti alloys. Micro-arc oxidation (MAO) is another surface treatment technique which improves biocompatibility of Ti through formation of rough and micro-porous oxide layer on their surface [1]. Recently, nanotubular anodic titanium oxide (ATO) layer has been proposed as a drug delivering vehicle [2]. However, the pore structure was not so protective that the drug was released too fast. Silica xerogel has long been considered as an agent for controlled drug release. More recently, bioactivity and drug delivering capacity of silica xerogel have been reported [3]. The purpose of this study is to fabricate micro- and nano-porous layer on the Ti substrate and to control the drug release behavior using silica xerogel.

Methods: Polished pure titanium plates (cp grade 2) with dimensions of 10 mm x 10 mm × 1 mm were used as a substrate. MAO treatment of Ti specimens was carried out in an electrolyte containing Ca and P source (0.15M of calcium acetate monohydrate and 0.02M of glycerol phosphate calcium salt), by applying a pulsed DC field with 270V for 3 min. In order to obtain a uniform pore structure ATO, 3 processes were employed consecutively: i) ATO was carried out in an ethylene glycol-based electrolyte containing fluoride ions by applying a DC field with 60 V for 15 min, ii) the ATO layer was removed by ultrasonic cleaning, iii) second ATO treatment was carried out in the same electrolysis condition for 30 min. Surface treated substrates were immersed in a drug (tetracycline hydrochloride, TCH)-containing silica xerogel sol for the drug loading. The change in the surface morphology after anodizing was observed by field-emission scanning electron microscopy. Drug loading capacity was evaluated by drug release tests.

Results: Figure 1 shows the scanning electron microscopy images; (A) as-machined, (B) MAO treated, (C) first ATO and (D) second ATO treated Ti substrates. MAO treated Ti had uniform micro pores, as shown in Figure 1(B). Pre-ATO treated surface showed nano pores which were aligned through machining grooves as shown in Figure 1(C). After the second anodizing, its pore structure was more uniform as shown in Figure 1(D). Figure 2 shows the drug release profiles of the as-machined, MAO treated and ATO treated titanium substrates. Compared to the as-machined substrate, both the ATO and MAO treated substrates loaded more drugs.

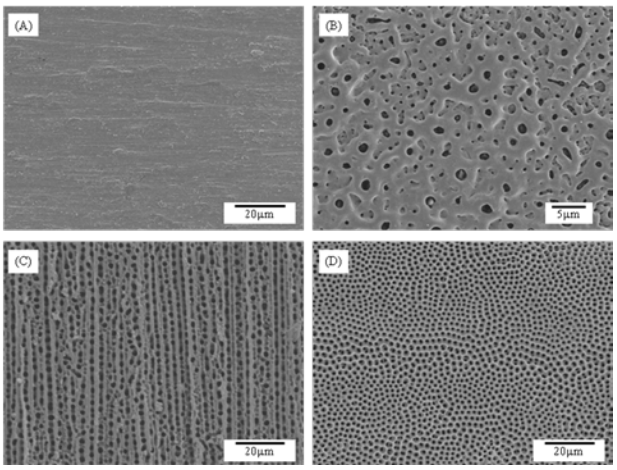

Figure 1. Scanning microscopy images of surface of (A) as-machined, (B) MAO treated, (C) pre-ATO treated and (D) second ATO treated Ti substrate.

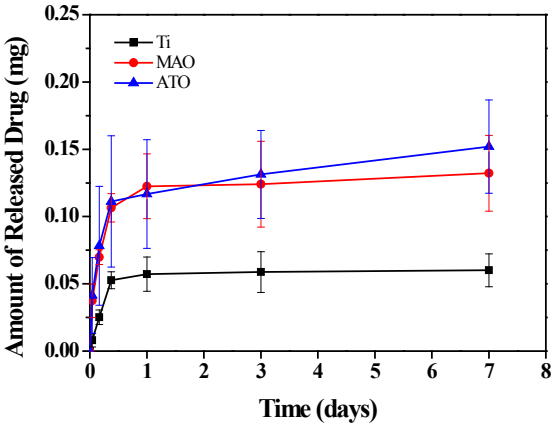

Figure 2. Drug release profiles from the as-machined, MAO treated and ATO treated Ti substrates.

The ATO treated substrate released the drug more steadily than the MAO treated substrate.

Conclusions: Surface modified titanium implants which have micro- and nano-porous layer were fabricated by MAO and ATO method, respectively. Both the MAO and ATO treated substrates showed improved drug loading capacity. The ATO substrate showed relatively steady drug release behavior.

References:

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