Microwave Assisted Alkaline Earth Phosphate Biomimetic Coating Deposition on Implants

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Statement of Purpose: Conventional plasma sprayed coatings generate high temperatures and lack the ability to produce uniform coating to porous implant structure [1]. As compared to that, biomimetic coating is time consuming and has the risk of contamination [2]. This work demonstrates a novel microwave assisted coating technique to deposit ultra-thin and uniform apatite coating on implant surfaces with a short time for biomedical applications. It is believed this coating technique is applicable for polymer materials such as PEEK, but also can be applied to carbon nanotubes (CNTs), metals, and bioceramics. This process is combined with a microwave assisted surface etching using NaOH solution and a microwave assisted coating deposition using aqueous solutions containing mostly Ca^{2+} and PO_4^{3-}ions. Additionally, the composition of the aqueous solution can be modified to deposit other alkaline earth phosphates to implant surface, one example is active phosphate (MgP) coating.

Methods: The method uses household microwave heating of 10M NaOH solution for implant surface etching and aqueous solution containing alkaline earth elements ions (Mg^{2+}, Ca^{2+}, Sr^{2+}) and phosphate ions (PO_4^{3-}) for coating deposition. For etching, a beaker with an implant in 100 ml 10M NaOH was placed onto alumina insulating fiberboards and covered with a 250 ml-capacity glass beaker. To proceed with the microwave-assisted process, the sample assembly was placed into an 800 W household microwave oven heating at maximum power for 5 min. The etched implant was washed using water and moved to 100 ml aqueous solution for microwave assisted coating. The procedure for 5 min coating deposition was similar to the etching step. To ensure the whole surface of implant was uniformly coated, this coating process was repeated twice with solution refreshed each time. At the end of microwave heating, implant was washed several times with water to remove attached loose powders formed in coating. The coated implants were characterized using SEM. Their activity and biocompatibility were also evaluated.

Results: It was observed that the new microwave assisted etching can significantly shorten the etching time from regular 24 hrs to minutes with improved water contact angle and surface roughness (Fig. 1).

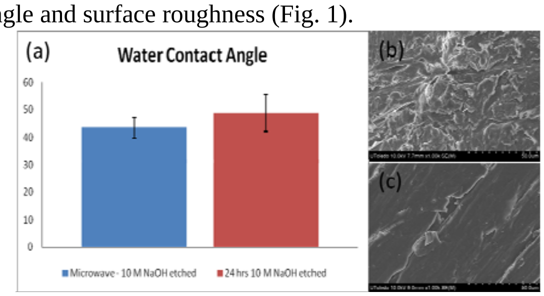

Figure 1. (a) water contact angle of PEEK after 5 min microwave assisted 10 M NaOH etching and 24 hrs etching at 60 ˚C environment; (b) surface morphology of microwave assisted etched PEEK; (c) surface morphology of regularly etched PEEK

The as-deposited coating was uniform and bioactive (Fig. 2). This coating can assist the proliferation of osteoblast bone cells (Fig. 3). This approach also works well for other materials and other coating compositions (Fig. 4&5).

Figure 2. SEM images of (a) coating on PEEK implant; (b) coating crystal structure; (c) a new apatite layer deposited on coating surface after 7 days incubation in cell culture medium

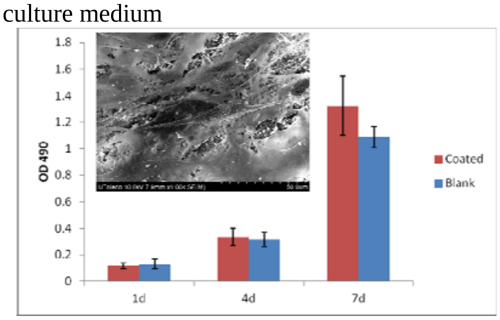

Figure 3. Results of MC3T3 preosteoblast cells proliferation on PEEK and PEEK with coating

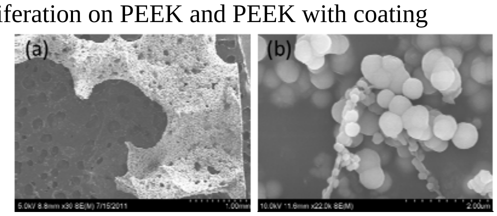

Figure 4. SEM images of (a) porous Ti scaffold with CaP coating; (b) CNTs with CaMgP coating

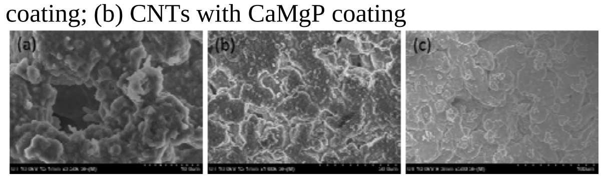

Figure 5. SEM images of (a) MgP coating on Ti scaffold at high magnification; (b) MgP coating features at low magnification; (c) MgP coated Ti implants after 7 days incubation in SBF

Conclusions: This microwave assisted route provides an avenue to deposit uniform alkaline earth phosphate apatite coatings on different implant materials. The formed coatings can be biocompatible and bioactive. Such apatite coatings are expected to have potential applications in tissue engineering.

References:

1. De Groot K. J Biomed Mater Res A. 1987;21:1375-1381.
2. Gil FJ. Mater Sci Eng C. 2002;22:53-60.