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Effect of ultrasound on the electrochemical deposition of antibacterial copper particles on anodized titanium implant surfaces

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INTRODUCTION: Bacterial infections taking place immediately or years after orthopaedic, trauma or dental surgeries cause serious problems for the patients. Implant surfaces exhibiting antibacterial properties preventing infections are therefore highly desired. We have recently established an electrochemical method to deposit the antimicrobial agent copper on the rough, fine-porous surface of spark anodized titanium samples. The antibacterial effect and the copper release rate were demonstrated [1]. Copper was deposited as clusters of different sizes, forms and surface distribution [1]. In this study we demonstrate how the surface distribution of the copper deposits can be affected by ultrasound applied during the electrochemical process.

METHODS: Mechanically pre-treated and ultrasonically cleaned discs of cp Ti (grade 4, ∅ 14 mm, 1.5 mm thick) were anodized according to the spark-assisted anodizing (SAA) method [2] to produce a rough, fine-porous surface. Copper was electrochemically deposited using proprietary electrolytes and process parameters. During the deposition process ultrasound was applied with a frequency either of 27 kHz or 80 kHz and a power of 350 W each. Deposition studies were performed for different copper concentrations in the electrolyte and different deposition times. The copper deposits were characterized by SEM/EDX.

RESULTS: In the absence of ultrasound, copper is deposited on the fine-porous oxide layer of the anodized samples as large clusters of nanometer-sized copper particles and with inhomogeneous surface distribution (Fig. 1 left). When ultrasound is applied, the copper deposits are much smaller (size of few nanometers) and homogeneously distributed over the sample surface (Fig. 1 middle). Compared to the experiments without ultrasound the amount of deposited copper is significantly increased for all deposition times when 27 kHz is applied (Fig. 2). However, for 80 kHz, less copper is deposited after longer deposition time (120 s) and the copper deposits are slightly larger than for 27 kHz (Fig. 1 right).

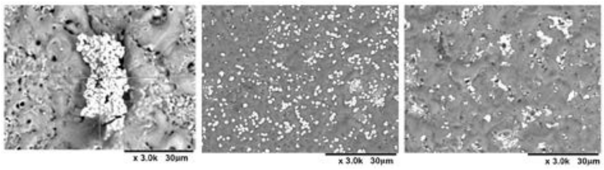

Fig. 1: SEM pictures of the surface of titanium discs (3000x magnification). Left: without ultrasound; middle: 27 kHz; right: 80 kHz. Copper appears as white spots.

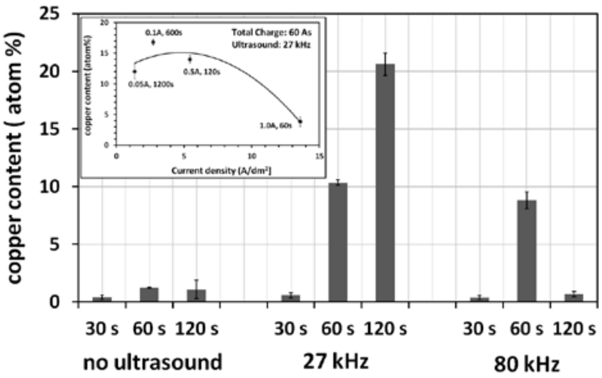

Fig. 2: Amount of copper deposited on the sample surface in the absence and presence of ultrasound and at three different deposition times.

DISCUSSION & CONCLUSIONS: Application of ultrasound during electro-chemical deposition of copper leads to a more homogeneous Cu allocation, to a frequency dependent deposit distribution and to an increased amount of deposited copper. It is suggested that the different size of the cavitation bubbles and acoustic streaming velocities for 27 kHz and 80 kHz may explain the different results [3].

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