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The art of fine surface tuning: electrochemical micropatterning of biomedical surfaces

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INTRODUCTION: Interaction between living matter and an implant surface is a vastly studied subject. From an osseointegration point of view the influence of the surface topography is largely documented [1,2]. Alternatively drug-eluting implants is a booming research field (especially for cardiovascular stents). From a material science point of view, recent advances in electrochemical micromachining methods [3] offer new surface modifications possibilities, which could be of interest for bio-surface applications. The objective of the present paper is to present two illustrative examples. The first one deals with titanium dental implants and the second with stainless steel stents.

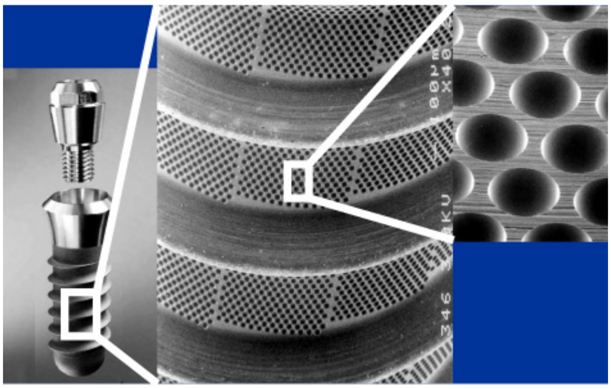

Fig. 1 set of pictures showing the precise micro-structuring of a titanium dental implant (27000 cavities, 50 μm in diameter).

METHOD: After thorough cleaning, the devices are coated with a protective film. This protection is realized through an anodic oxidation process for the titanium implant. On other types of metals as in the stainless stent example, part protection is obtained by the electrodeposition and heat curing of a polymeric resin. The protective film is then locally exposed using an excimer laser (UV). A video imaging setup and motorized stages piloted by specific software allows for the precise positioning of the laser irradiation sites. Laser irradiation locally modifies the oxide film insulating properties. Alternatively clean ablation of the resin is obtained. In both cases the results of this lithographic process is a protected part with well-defined unprotected areas. The pieces are then dipped into an electropolishing electrolyte and connected to a power supply. While applying optimized voltage and hydrodynamic conditions, the unprotected areas are attacked. Under electropolishing conditions (mass transport), dissolution results in perfectly hemispherical, smooth cavities. Precise dimensioning of the features is obtained by controlling the electric charge flown through the system. After dissolution, the titanium oxide film remains on the surface of the dental implant while the polymeric film is removed with a stripper from stainless steel stents.

RESULTS & DISCUSSION: In both cases precise positioning and smooth surface finish is obtained (see Fig. 1 and 2). The laser operation time ranged from 30 s for the dental implant to 5 min for the stent, this time can be reduced by further optimization of the process parameters. Electrochemical dissolution times ranged from 5 to 20 min depending on the cavities diameter.

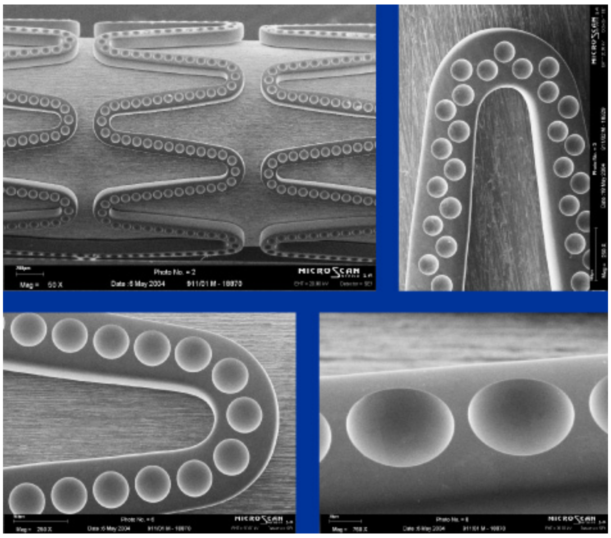

Fig. 2 SEM images of microstructured stainless steel stents showing precise positioning of cavities, geometry versatility (2920/5644 cavities 70/35 μm in diameter) and smooth surface finish.

CONCLUSIONS: The use of modern electrochemical methods allows precise micro-patterning of biomedical devices. The technique presented herein offers new possibilities in the optimization of implant surface topographies. Alternatively surface micropatterning represents an elegant and robust vehicle in drug eluting implants applications.

REFERENCES: [1] C. Larsson et al., *Biomaterials*, **15**, 1062 (1994). [2] A. Curtis and C. Wilkinson, *Trends Biotechnol.*, **19**(3), 97 (2001). [3] P.-F. Chauvy et al., *Applied Surface Science*, **208**, 165 (2003).