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Bioactive Coatings for Implants by Electrophoretic Deposition

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INTRODUCTION: In the field of orthopaedics, hydroxyapatite (HA) plasma-spray coatings have been used in order to enhance implants fixation. However, due to high temperatures, the plasma spray process does not allow for a rigorous control of the final chemical and structural coating properties. Moreover, coatings on complex shapes are critical[1]. Electrophoretic deposition (EPD) is an alternative coating technique with the following advantages: Control of the stoichiometry, uniformity on any shape, flexibility in the choice of materials, simplicity and low cost. We aim to develop graded coatings by EPD, consisting of a biocompatible matrix and bioactive elements with different rates of bioresorbability. In the present study, composite coatings of Bioglass® (45S5) and a "bioresorbable phase" were prepared by EPD on Ti6Al4V substrates.

METHODS: As received 45S5 (wt%: 45.0 SiO_2, 24.5 Na_2O, 24.5 CaO, 6.0 P_2O_5, Schott Glas Export GmbH) powder and additional "bioresorbable particles" were used as precursors for the coatings. The powders were characterized by particle size distribution analysis (Beckman Coulter LS 230 instrument) and SEM (Hitachi S-4800). Cathodic EPD was carried out in an electrochemical cell (parallel plate geometry, 50V/cm). Etched Ti6Al4V discs were used as cathode. A mixed suspension of 45S5 and "bioresorbable particles" in isopropanol was used as electrolyte. After EPD, the samples were rinsed, dried and sintered in Ar flow (900°C, 2h). Roughness and thickness of the coatings were measured by white light profilometry (Altisurf). The morphology was investigated by SEM (Hitachi S-3600N). Chemical depth profiling with Glow Discharge Optical Emission Spectroscopy (GD-OES, Jobin-Yvon 5000 RF) was performed. Hardness tests (Zwick ZHU 2.5) were carried out as a preliminary characterization of the coatings mechanical properties.

RESULTS: The measured mean size of the 45S5 particles (not agglomerated) was 4,3 μm. The coatings thickness ranged from 25 to 35 μm, with R_a between 2.5 and 3.5 μm. The sintered coatings showed some cracks. The 45S5 particles were partially melted forming a coherent matrix (Fig. 1).

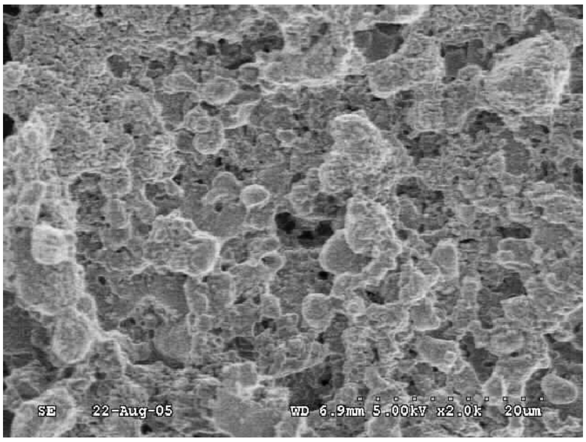

Fig.1: 45S5 coating with bioresorbable phase.

The smaller "bioresorbable particles" seemed preferentially adsorbed on the 45S5 particles. The GD-OES analysis confirmed the chemical composition as expected from the powders nominal chemistry. Hardness tests showed a clear improvement in mechanical properties after sintering.

DISCUSSION & CONCLUSIONS: The bioactive glass developed by Hench (Bioglass®) is known for its bioactivity[2]. Moreover, its glass transition temperature of 560°C[3] allows for sintering at relatively low temperatures, avoiding alteration of the substrate's properties. However, 45S5 particles gain a negative charge in organic suspensions[4] and cannot be deposited cathodically. We found that the addition of the "bioresorbable particles" acts as surface functionalization of the 45S5 particles, charging them positively. This enabled to prepare 45S5 coatings deposited by cathodic EPD. The mechanical properties of these coating could be improved, for example by incorporating of ZrO_2 particles in the 45S5 matrix. The biological behavior of such composite coatings needs further investigation.

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