

Surface Functionalization of Cobalt-Chromium Alloy Using Phosphoric and Phosphonoacetic Acids

Eagappanath Thirupathi, Jon R Peacock, Gopinath Mani.

Biomedical Engineering Program, The University of South Dakota, Sioux Falls, SD 57107.

Statement of Purpose: Cobalt-Chromium (Co-Cr) alloys have been extensively used for cardiovascular, orthopedic, and dental implants [1]. The functionalization of Co-Cr alloy surfaces with reactive functional groups such as hydroxyl (-OH) and carboxylic acid (-COOH) has numerous biomedical applications. A variety of biomolecules including proteins, peptides, antibodies, DNA, and therapeutic drugs can be immobilized and delivered from Co-Cr alloy surfaces using -OH and -COOH functional groups. In this study, the Co-Cr alloy was surface modified using phosphoric acid (PA) and phosphonoacetic acid (PAA) coatings to provide -OH and -COOH surface groups. The coatings were characterized using contact angle goniometry, Fourier transform infrared spectroscopy (FTIR), and atomic force microscopy (AFM).

Methods: Co-Cr alloy specimens (1cm x 1cm) were mechanically polished using 600, 800, and 1200 grit SiC papers and chemically cleaned by sonication in ethanol, acetone, and methanol for 10 minutes each followed by N₂ gas drying. The cleaned specimens were immersed in three different concentrations (1, 25, and 100 mM) of PA and PAA in deionized water for 24 hours. The specimens were then transferred to an oven without rinsing and heated in air at 120 °C for 19 hours. The specimens were cleaned by sonication in H₂O for 1 min to remove physically adsorbed molecules followed by N₂ gas drying. The control, PA, and PAA coated Co-Cr alloy were characterized using CAG, FTIR, and AFM.

Results: The contact angles of control, PA, and PAA coated specimens are provided in Fig 1. The contact angle measured for the control Co-Cr alloy was 53 ± 5°. For 1 and 25 mM PA, no significant difference in the contact angle was observed when compared to that of control. However, the 100 mM showed a significant decrease in the contact angle (8 ± 2°). For PAA coating, the 1 and 25 mM PAA showed a significant decrease in the contact angle when compared to that of control. The 100 mM PAA showed a contact angle of 6 ± 3°. These results suggested the presence of dense -OH and -COOH groups on Co-Cr alloy surfaces after coating with 100 mM of PA and PAA, respectively. The FTIR spectra of PA and PAA coating were provided in Fig 2 and Fig 3, respectively. For PA, the IR peaks at 807, 1107, and 1265 cm⁻¹ were assigned to P-OH, P-O-Metal, and P=O, respectively. The peak at 3743 cm⁻¹ belongs to the -OH groups of PA. For PAA, the IR peaks at 945, 1120, and 1295 cm⁻¹ were assigned to P-OH, P-O-Metal, and P=O, respectively. A peak at 1695 cm⁻¹ belongs to the C=O of -COOH groups. Also, the peaks observed at 3745 and 3860 cm⁻¹ belong to the -OH of -COOH groups. Fig 4 shows the AFM topography images of control, PA, and PAA coated specimens. No significant difference in the surface topography was observed between the specimens. The RMS roughness values measured by AFM for the control, PA, and PAA coated specimens were 22 ± 7, 25 ± 9, 31 ±

6 nm, respectively. No significant difference in the roughness values were observed between control and PA or PAA. This suggests that PA and PAA formed a uniform coating which followed the contour of polished Co-Cr alloy surface.

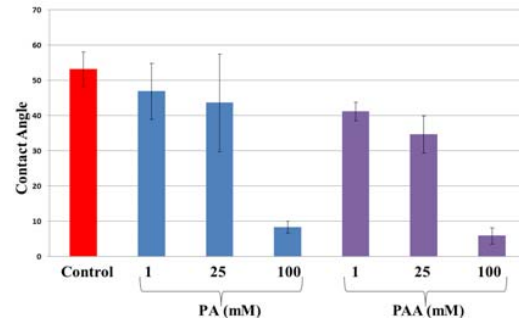


Fig 1. Contact Angle of PA and PAA coated Co-Cr alloy

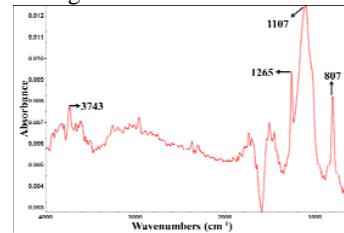


Fig 2. FTIR spectrum of PA (100 mM) coated Co-Cr

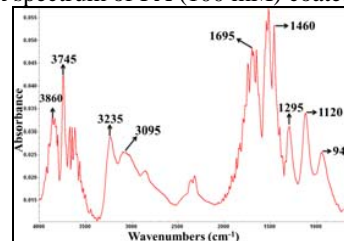


Fig 3. FTIR spectrum of PAA (100 mM) coated Co-Cr

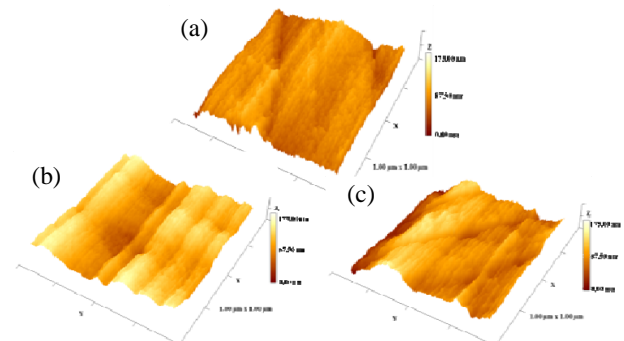


Fig 4. AFM images of control (a), PA (b) and PAA (c)

Conclusions: PA and PAA were successfully coated on Co-Cr alloy to provide -OH and -COOH surface groups. Thus, the surface modification technique employed in this study has potential applications for immobilizing and delivering therapeutic drugs and biomolecules from Co-Cr alloy surfaces.

Reference: (1) Mani G. Applied Surface Science 2009; 255: 5961-5970.