Surface Bioactivation of Cobalt Base Alloy Surgical Implants with Hydroxyapatite-Bioglass via Heat Treatment

H. Minouei, M.H. Fathi, M. Meratian.
Department of Materials Engineering, Isfahan University of Technology, Isfahan, 8415683111, Iran.

Statement of Purpose: Metallic biomaterials consist of stainless steel, cobalt base alloys and titanium alloys are widely used for manufacturing orthopedic prosthesis due to their biocompatibility, good mechanical properties and excellent corrosion resistance. However these materials are classified as bioinert materials, because they have not ability to bonding with living bone tissue (Karl-Heinz Frosch. EJT. 2006; 2: 149-159). On the other hand, the biomaterials such as hydroxyapatite (HA) and bioactive glass (BG) are bioactive. This means that when they are placed in contact with human blood plasma, they promote osteointegration and chemically bonded to bone but they have not good mechanical properties. A desired method for obtaining implants which have both good mechanical properties and bioactive surfaces is preparing the HA or the BG coating on metallic implants. The most common process for manufacturing ASTM F-75 cobalt base alloy is investment casting. An alternative method to enhance ductility and other mechanical properties such as yield and ultimate tensile strengths is solution treatment process (Dobbs HS. J Biomed Mater Res 1983; 18: 391–401.). Performing the solution treatment accompanied with surface bioactivation will be very interesting because of shortening the manufacturing process.

Methods: ASTM F-75 cobalt alloy was melted in an induction furnace and was cast by investment casting method. Specimens were ground with silicon carbide papers and polished using alumina paste. Bioglass with a close composition to Bioglass® 45S was prepared by sol-gel method. Mixture of HA-BG, contain of 70wt% HA were placed between polished metallic surface of the specimens. Meanwhile the surfaces of the specimens were in contact to HA-BG mixture, metallic specimens under the pressure of 65 MPa were heat treated in 1220°C for 1 hour followed by water quench. In order to in vitro bioactivity evaluation, simulated body fluid (SBF) was prepared with ionic concentration of nearly equal to human blood plasma. After heat treatment, specimens were immersed in simulated body fluid at 37 °C for 4 weeks. X-ray diffraction (XRD) and SEM techniques were used to characterize the samples. Microscopic images were quantitatively analyzed by Image Tool software.

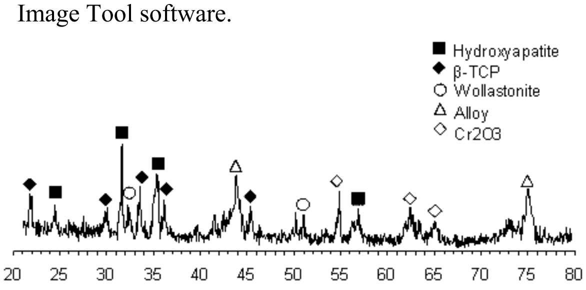

Figure 1. XRD pattern of HA-BG coated metallic specimens after heat treatment.

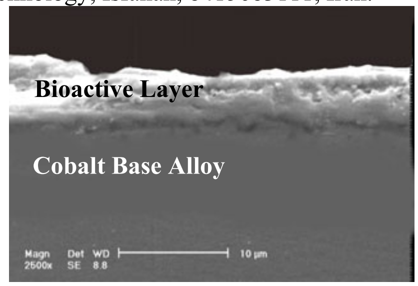

Figure 2. SEM micrograph of the cross section of HA-BG coated metallic specimens after heat treatment.

Results: XRD pattern of the specimen surface after heat treatment is shown in Figure 1. Figure 2 shows the cross section of bioactive coating on Co-Cr-Mo alloy substrate. A continuous bioactive layer on the surface of specimen could be clearly observed. Figure 3 shows SEM micrograph of specimen after 4 weeks immersion in SBF. This micrograph demonstrates the nucleation and growth of apatite after 4 weeks immersion which confirms the required surface bioactivation. By quantitative image analysis of this micrograph, the percentage of apatite formation on the surface was specified (Figure 4). It was observed that percentage of apatite on the surface increasingly reached to 61.1% after 4 weeks immersion in SBF.

Figure 3. SEM micrograph of the specimen surface after 4 weeks immersion in SBF.

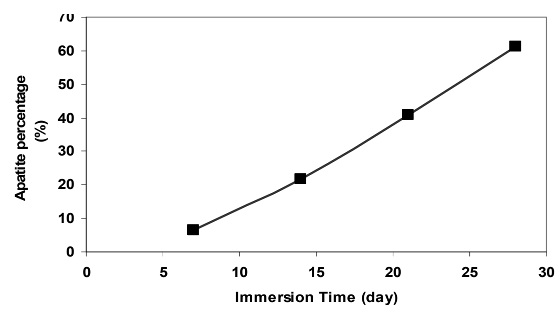

Figure 4. The apatite percentage versus immersion time in SBF.

Conclusions: Bioactive coating on ASTM F-75 Cobalt base alloy could be obtained with solution heat treatment, simultaneously. Results showed that a continuous bioactive layer on the surface of specimens as well as appropriate microstructure of substrate after heat treatment could be obtained. In vitro surface bioactivity evaluation showed apatite nucleation and growth on the surface of specimens, indicated improvement of surface bioactivity.