ABSTRACT

The main emphasis of the thesis is on the corrosion and wear behavior of the surface engineered prosthetic Ti-13Nb-13Zr alloy which is considered to be superior because of their low modulus, high strength to weight ratio and the presence of non-toxic alloying elements. However, it suffers from the severe drawbacks of its poor wear resistance and high friction coefficient.

Various surface modification techniques such as Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), Plasma nitriding and Ion implantation have been employed to improve the wear resistance of this alloy. However these techniques cannot guarantee adequate wear resistance of critical Total Joint Replacement (TJR) components and long-term service due to the rapid thinning of the hardened layer. Hence in order to enhance the service period wear of the Ti-13Nb-13Zr alloy, an attempt has been made to increase the surface hardness by laser nitriding and nano ceramic coatings using plasma spraying process, as these techniques will lead to higher thickness of the coatings. The surface modified samples were characterized using Optical Microscope (OM), Scanning Electron Microscope (SEM), Energy Dispersive Spectroscopy (EDS) and X-ray diffraction (XRD) techniques. The studies on the corrosion and wear behavior were carried out in simulated body conditions.

In the first phase, the laser nitriding was performed on two standard biomedical materials viz., commercially available pure titanium (Cp Ti) and Ti-13Nb-13Zr alloy. The laser nitriding performed at high scanning speed (720 mm/min) enabled smooth and crack free surface. The corrosion resistance of the laser nitried Cp Ti is 19% higher than that of the laser nitried Ti-13Nb-13Zr alloy. There has been a three fold and two fold increases in the hardness of the laser nitried Cp Ti and Ti-13Nb-13Zr alloy respectively than that of the bare substrate. The wear resistance of the laser nitried Cp Ti was much superior to that of the laser nitried Ti-13Nb-13Zr alloy.
Nanoceramic coatings have opened a new window in the field of surface engineering as these coatings offer superior properties in all aspects for various applications. Nanoceramic Al₂O₃-13TiO₂ coating is being extensively used as a wear resistant coatings in Naval and Submarine applications. However, much research has not been carried out on nanoceramic coating in the field of biomaterials. Hence, the second phase of the work deals with the fabrication of three different nano coatings like monolayer coating of Al₂O₃-13TiO₂, and ZrO₂ and bilayer coating of ZrO₂/Al₂O₃-13TiO₂ on Ti-13Nb-13Zr alloy using plasma spray process. Among the three coatings, bilayered coating exhibited 72% and 66% increase in the wear and corrosion resistance respectively when compared with that of the bare Ti-13Nb-13Zr alloy. This remarkable enhancement in the wear and corrosion resistance of the bilayered coating is attributed to the high hardness and micro structural variations with very less porosity. The microstructure of the Bilayered coating revealed that the coating was found to be dense with more amount of fully melted regions together with very few unmelted alumina particles embedded in it compared to the other two coatings. XRD studies of the bilayered coating clearly reveals the presence of larger amount of α phases with few amount of γ phase along with brookite titania. The presence of harder nano sized α phase and the brookite titania in the bilayered coating have led to the substantial improvement in the hardness and wear resistance.

As nano powders tend to fly off due to its low mass, it needs to be agglomerated into micron size and later it can be utilized for plasma spraying. Hence in the third phase, an attempt is made to agglomerate the nano powders using spray drying technique. The percentages of solid loading, binder and dispersant were varied in order to obtain spherical shaped powders with uniform size. The slurry with pH in the range of 3.2 – 3.5 were found to be suitable for spraying. Viscosity of the optimized slurry displayed negligible thixotropy and only a mild shear thinning behavior. The slurry sprayed with 22 vol % Al₂O₃, 6 wt% binder and 0.08 wt% dispersant has yielded spherical shaped particles with size ranging from 10-25μm.