Synopsis

Metallic materials are widely used in load bearing orthopedic applications. The alloys used in the implants are 316L stainless steel (SS), commercially pure Ti (cp-Ti), Ti-6Al-4V and Co-Cr-Mo alloys. The life of implants depends on the surface and bulk properties of the material. The important surface dependent material properties that are considered in this work are corrosion-fatigue behaviour and cell response. The important bulk material properties that are considered here are the strength and elastic modulus. High performance implants will require appropriate surface engineering to improve the fatigue and cell response along with the design of new compositions which have high strength and low elastic modulus. In this work, surfaces of existing biomaterials 316L SS and cp-Ti were nanocrystallized using surface mechanical attrition treatment (SMAT) which is a surface severe plastic deformation technique. In addition, new compositions of Ti-Nb-Sn based β Ti alloys with high strength and low elastic modulus were designed and surface engineered with SMAT. The effect of surface modification of 316L SS, cp-Ti and Ti-Nb-Sn alloy by SMAT has been evaluated on their mechanical and biological responses.

In **Chapter 1**, a comprehensive literature survey on the effect of nanocrystalline and ultrafine grained metallic biomaterials on mechanical and biological responses has been presented. The design theories used to develop new compositions of metastable β Ti are discussed followed by the genesis of the thesis. In **Chapter 2**, details of experimental procedures and characterization techniques have been mentioned which are commonly employed in the entire work.

In **Chapter 3**, the mechanisms of nanocrystallization and strengthening in SMAT processed 316L SS have been discussed. The paramount roles of microbands and shear bands in nanocrystallization are outlined, as opposed to deformation twinning previously reported for low SFE austenitic stainless steels. The additivity of strengthening by dislocation density and grain size is studied which was neglected in the previous investigations. It is observed that both grain size and dislocation density contribute significantly to strengthening in the material processed by SMAT. In **Chapter 4** the effect of surface nanocrystallization by SMAT on corrosion-fatigue and osteoblast response of 316 L SS has been evaluated. Surface nanocrystallization led to an increase in the corrosion-fatigue strength in saline by 50% due to high surface hardness and compressive residual stresses. Nanocrystallization also enhanced attachment and proliferation of bone forming osteoblasts cells. The observed cell behaviour is explained in terms of the changes in electronic properties of the semiconducting passive oxide film present on the surface of 316L SS as opposed to common factors such as water wettability and surface roughness.

In **Chapter 5** the microstructural evolution and mechanism of nanocrystallization in cp-Ti have processed by SMAT been discussed. The dominated role of slip activity rather than twining in nanocrystallization process has been explained. The surface nanocrystallization is shown to occur though the process of continuous dynamic recrystallization. In **Chapter 6** the effect of surface nanocrystallization of cp-Ti on corrosion-fatigue and stem cell response has been evaluated. Surface nanocrystallization successfully increased the corrosion-fatigue resistance due to high surface hardness and compressive residual stresses. The cell attachment and proliferation improved after nanocrystallization due to increase in wettability and changes in the property of the oxide layer.

In **Chapter 7** a new β Ti alloy with composition Ti-32Nb-2Sn (wt. %) has been designed based on the electron/atom (e/a) theory. New insight into the control of nanoscale precipitation in a metastable β Ti-32Nb-2Sn alloy has been presented. Optimization of the aging treatment significantly improved the strength of the material while keeping elastic modulus low making the alloy suitable for orthopedic applications. In addition, the aged microstructure is found to have good corrosion resistance and cytocompatibility. In **Chapter 8** the role of Sn content on properties of Ti-32Nb-(2, 4) Sn alloys is investigated. The Sn content is found to alter the precipitation kinetics of α phase during aging treatment thereby affecting the mechanical properties. The increase in Sn content also marginally improved the corrosion resistance whereas the cytocompatibility remained unaffected by Sn content.

In **Chapter 9** the surface of high strength aged Ti-32Nb-2Sn alloy was processed with SMAT. A very interesting phenomenon of deformation induced reverse α to β transformation during SMAT processing has been observed. The corrosion-fatigue resistance improved after SMAT due to the increase in hardness and compressive residual stresses. Although the attachment of stem cells reduced due to increase in hydrophobicity after SMAT, the osteogenic differentiation improved due to the formation of a larger number of focal adhesions by cells on SMAT surface.

In **Chapter 10** the overall findings of the work are summarized. The scope of future work based on the outcome of this work is also presented.