The effects of plasma ion immersion implantation on the tribological performance of a medical grade Ti alloy

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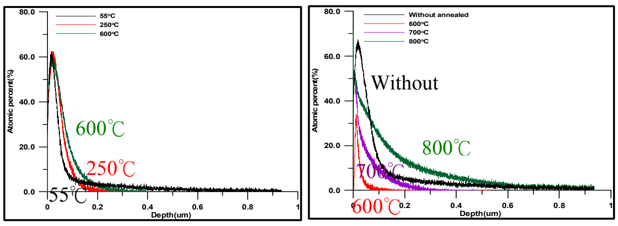
Statement of purpose: Ti-6Al-4V alloy is commonly used for bone implants because of its excellent chemical and mechanical properties, such as high corrosion resistance, high strength-to-weight ratio, etc. [4]. However, the tribological performance of this alloy is poor and which prevents its applications as being a sliding component [4]. Previous studies reported that the wear problem of a Ti6Al4V surface could be improved by plasma ion immersion implantation(PIII) and the subsequent annealing treatments [1,2,3,5]. The implantation or annealing temperature could affect the resulting implantation depth, phase structure and hardness of the surface layer. However,its effects on the tribological performance of the material are yet to be studied. In this study the effects of implantation temperature (55℃~600℃) and annealing temperatures (600℃~800℃) on the surface properties of a Ti6Al4V alloy modified by the plasma ion immersion implantation (PIII) technique were studied. The results are to be applied to the development of a wear-resistant Ti alloy surface by the plasma ion immersion implantation technique.

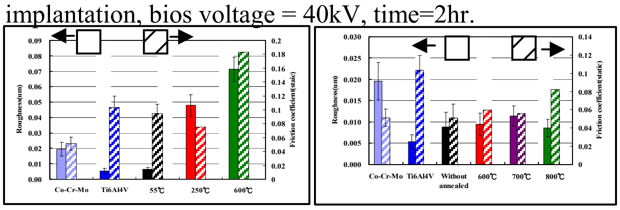
Methods: Specimens of 3 mm thick and 60 mm in diameter were prepared from a rod of medical grade polycrystalline Ti-6Al-4V alloy. The surfaces of these specimens were polished (Ra < 0.05 µm with L = 0.8mm , ISO 7026, 7027) and implanted on one side, using N_2 plasma of doses ranging from 2×10^{16} to 5×10^{16} N^+ cm^{-2} and with a bios voltage of 15~40 keV. Injection gas flow rate was 50 sccm and the work pressure was 10^{-3} torr. Surface properties of: nitrogen distribution profile, surface morphology/roughness, crystallographic structure, and friction coefficient were analyzed to evaluate the performance of the modified surfaces.

Results: Increasing the implantation temperature in a PIII process slightly decreases the peak concentration of the implanted nitrogen layer while increases the penetration depth (fig1a and 1b). As the implantation temperature rises, the surface roughness and friction coefficient increases (fig2a). Surfaces annealed at 600-800℃ is accompanied with the increases in nitrogen penetration depth(fig1b). The surface roughness is slightly increased with annealing temperature (fig2b). And, increasing the implantation or annealing temperature favours the formation of TiN or Ti_2N crystalline structure (fig3).



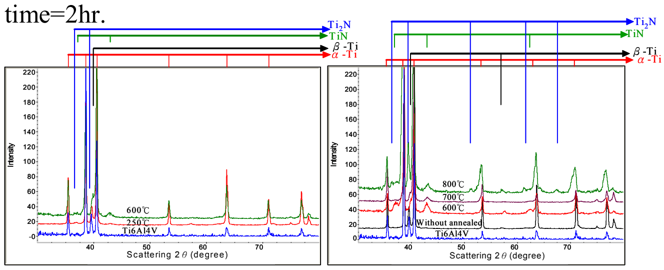
(a) (b)

Figure 1. Nitrogen depth profiles (a)effect of implantation temperature, bios voltage = 15kv, doses = 5×10^{16} N^+ cm^{-2} (b)effect of annealing temperature (30min)after implantation, bios voltage = 40kV, time=2hr.



(a) (b)

Figure 2. Roughness and friction coefficient (a)effect of implantation temperature,bios voltage = 15kv, doses = 5×10^{16} N^+ cm^{-2} (b)effect of annealing temperature, annealing time=30min, bios voltage = 40kV, implantation time=2hr.



(a) (b)

Figure 3. Crystallographic structure: effect of (a) implantation temperature (b) annealing temperature .

Conclusions: The Ti-6Al-4V alloy surface modified by PIII with high implantation temperature or annealing temperature is accompanied with the increases in nitrogen penetration depth, TiN and Ti_2N formation and surface hardness. However, as the temperature rises, the plasma ions strike a surface with higher energy and thus increase surface roughness. By analyzing the chemical, physical and mechanical properties of a surface modified by plasma ion immersion implantation technique, it is found that a Ti6Al4V surface implanted at room temperature followed by annealing at 700℃ for 30 min gives high surface hardness and the lowest friction coefficient and appeared to be the most promising technique for improving the wear resistance of a Ti6Al4V alloy material.

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