Ion Beam Modification of the Ti-6Al-4V Alloy  
For Improvement of Mechanical Properties

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Background  
Titanium has grown in popularity over the past few decades, based on its superior properties to many other metals, and our increasing ability to process Titanium ore. Titanium has a great potential for application within the fields of aeronautics, automobiles and medicine, because of its superior mechanical and corrosion resistant properties. Despite Titanium’s already respectable properties, the field of materials science is constantly trying to improve. Ion implantation has shown to fulfill this goal by creating significant lattice distortion in near-surface regions of the sample. As a result, wear resistance and surface hardness of the material will be improved because of this distortion and the added internal stresses from the implantaions.  

Ion implantation range was estimated using the SRIM program (Stopping and Range of Ions in Mater), as well as the total displacement of ions and vacancies created within the Ti alloy.  

Experimentation  
Each of the polished Ti-6Al-4V samples was implanted with ions using an Ion Beam Accelerator at the W.R. Wiley Environmental Molecular Sciences Laboratory (EMSL) in Richland, WA. N+ and Au++ ions were implanted in the Titanium samples at an angle of 60 degrees, a temperature of 25° C, and a dose rate of 2.5E16 ions per square cm. The Nitrogen ions were implanted at 1.5 MeV, whereas the Gold ions were implanted at 5 MeV. These samples were then analyzed using:  
-Nano-indentation (both quasi-static and dynamic indentation methods)  
-Electron Backscatter Detection (EBSD)  
-Wear testing through a tribology test  

Rutherford Backscatter Spectroscopy (RBS) was also performed at the EMSL facility, in order to find absolute values for the depth of ion implantation. These results were to be compared against the results gained from other tests, as another way of giving validity to each result.  

Procedure and Results  
A sliding wear tester was used in order to perform tribology tests upon the 5 mm square samples. The tester was set up so the low carbon steel wheel wore the implanted surface of the sample as shown in Figure 4.  

A load of 286.49 g was applied to each sample as it was worn by the wheel operating at 125 revolutions per minute. Thickness measurements were taken at specified time intervals in order to determine the wear rate of each of the samples. Thickness values were measured and graphed as a function of time. The resultant chart is shown in Figure 5, plotting the wear rates of the implanted samples with the control sample. Despite the graph’s coherence, results could have had the possibility of error due to the fact that the samples could have had slightly different areas.  

Results (Cont.)  
Electron Backscatter Detection (EBSD) was also used in order to determine lattice distortion due to implantation, and the effect that this would have on image quality of the kiluchi patterns reflecting off the sample. Figure 8 shows a graph of this.  

Conclusions  
From the research completed, it can be concluded that ion implantation is a definitive way to alter some of the near surface properties of a Titanium alloy. It appears that ions with a smaller radius have a greater impact upon hardness and elastic modulus on the sample’s surface, up to a depth of approximately 150 nanometers, based on the implantation energies that were used. The wear testing of the samples turned out to be slightly inconclusive due to the fact that the samples were worn too quickly for accurate measurement, however there is a slight difference in wear between the implanted and control samples. Further wear analysis would have to be performed to more fully understand each sample’s altered wear resistance.  

Future Research  
Although the samples have been analyzed using the various techniques intended for this project, there is still a possibility for further research to be done. For example, whether would be implanted to test whether there was a better option than the two samples that were tested. The wear test could also be improved to better represent the implanted alloy’s applications. A plastic wheel made to simulate bone could be used to determine the alloy’s wear in biomedical applications.  

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Tables

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