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Characterization of Ti Alloys for Biomedical Applications

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Introduction:

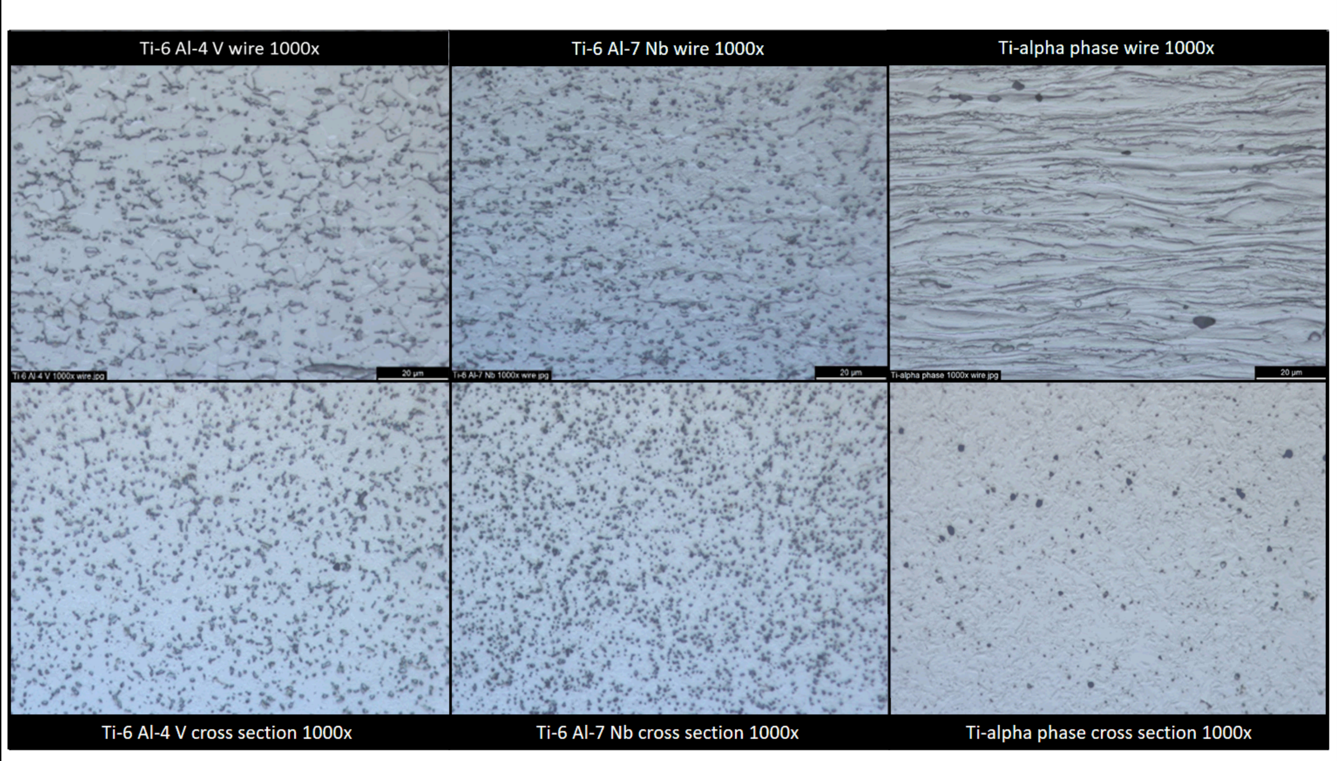
Ti alloys are gaining attention in the medical field due to their reputation in the aerospace industry for lightweight properties and high performance. The goal is to use Ti alloys for medical implants and devices. Some alloys are known to possess properties superior to pure titanium; specifically, alloys containing Al and V. Furthermore, the replacement of V with Nb has proven enhanced physical behavior for biocompatibility. In this study, the microstructure of wires from Ti, Ti-6 Al-4 V, and Ti-6 Al-7 Nb alloys are examined to compare the underlying scale and features of their microstructure to previous tensile test results, and present nano-indentation elastic modulus and hardness measurements.

Optical Imaging:

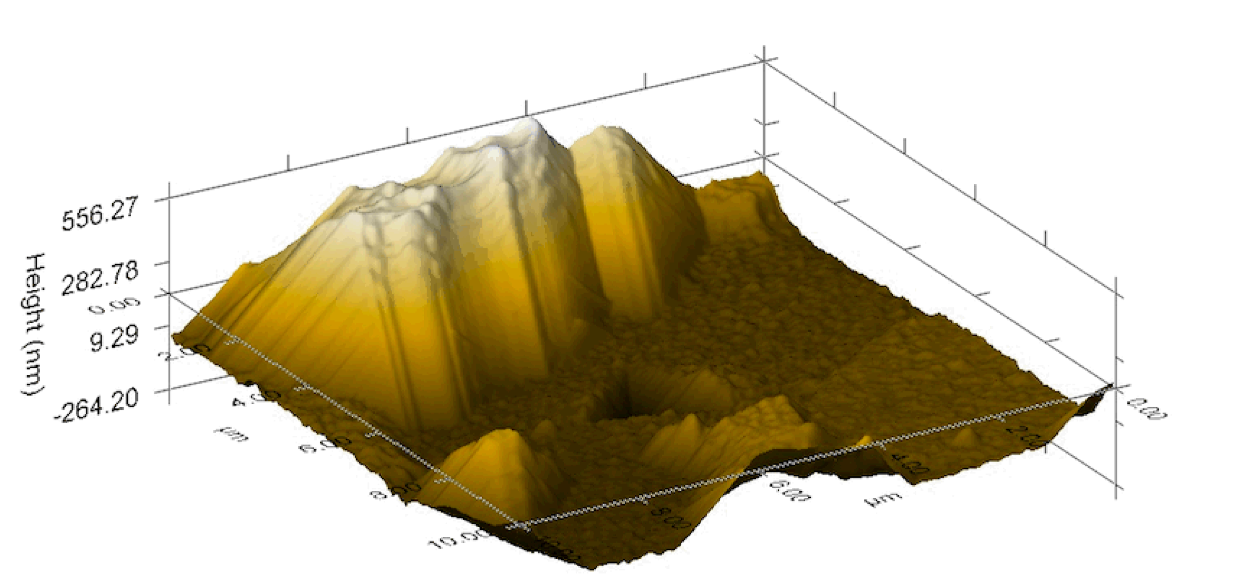
The pure Ti wires were cold drawn samples, therefore, a structure with elongated grains along the wire axis is expected. In contrast, the Ti alloy wires are hot drawn, which anticipates the extent of elongation to be less.

The specimens were prepared in Albuquerque using metallographic mounting, polishing, and etching techniques. The wires were mounted in a two-part epoxy resin, ground and polished to a submicron surface finish, then finally etched using Kroll's solution. The etching reveals details of the sample's structure, including the outline of the grain boundaries, as well as the shapes and distribution of the secondary phases of Ti that are created with the addition of Al, V, and Nb.

The specimens were then examined with a LEICA optical microscope. In the figure below, the top row are longitudinal sections of the wires and the bottom row are circular cross sections.

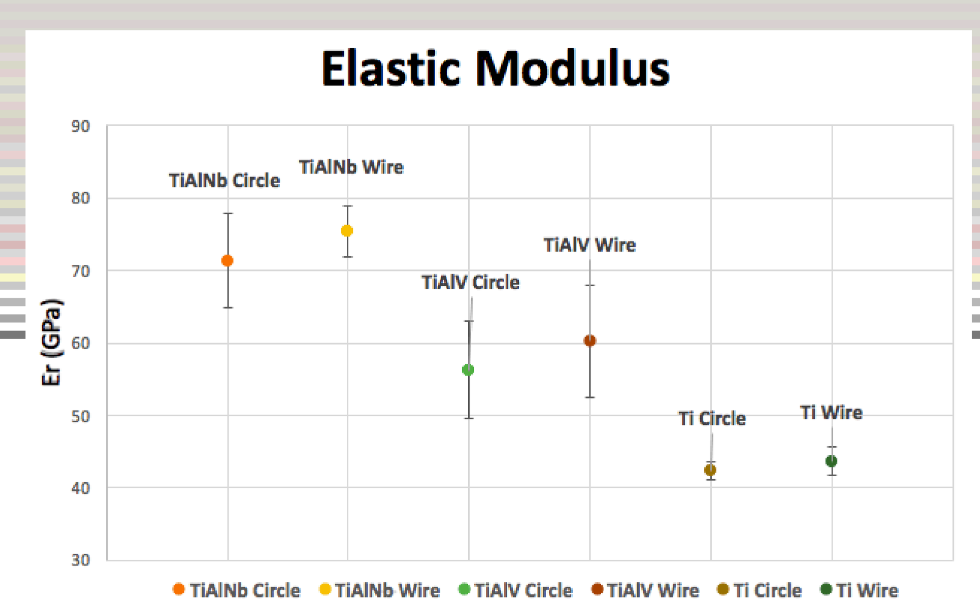


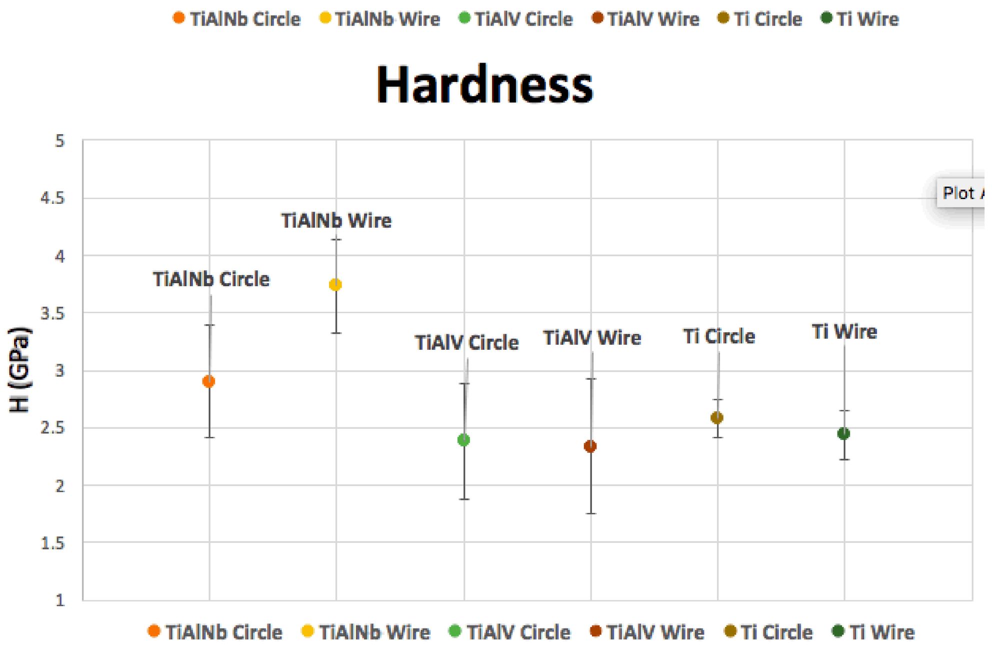
After close examination of the samples, the Ti-6 Al-7 Nb alloy appears (bottom middle image) to have the most refined microstructure. The pure Ti wire sample was the hexagonal alpha-phase titanium, and its strength is relatively low. Both Ti-6 Al-4 V, and Ti-6 Al-7 Nb possess alpha and the body-center cubic beta phase titanium characteristics.



Nanoindentation:

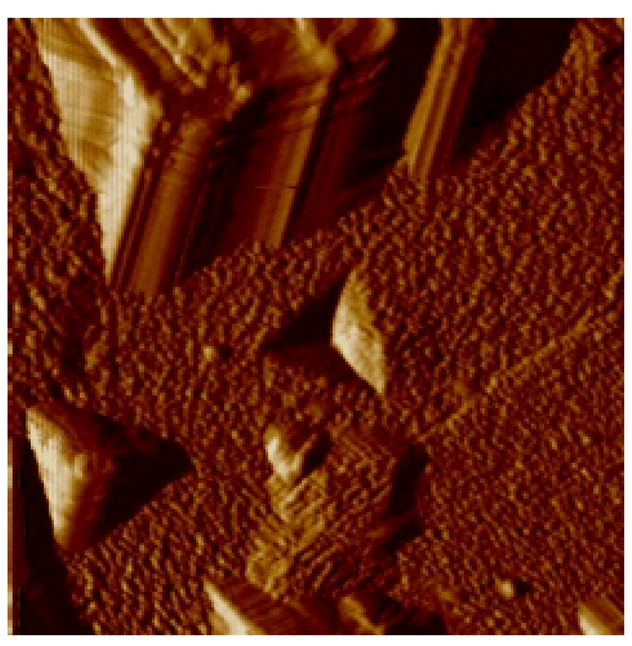
Nano-indentation measures displacement by a diamond stylus under a very fine load. The displacement of just a few atomic planes of material is quantifiable. Hardness is equivalent to the the maximum load applied divided by the projected area displacement under the indenter. A three-sided pyramidal diamond, i.e. Berkovich tip, was used. 20 indents were made on each alloy- 10 on the circular cross section and 10 on the longitudinal cross section, for a total of 60 indents. The corresponding average Elastic modulus and Hardness values are given with standard deviation bars in the figures below.





Indentation hardness values were approximately one-third of the tensile strength from published data, which correlates as expected. Previous tensile test results revealed the Ti-6 Al-7 Nb alloy was the strongest, with an ultimate strength that exceeded 1200 MPa at 2% strain elongation. Next was Ti-6 Al-4 V, at 1000 MPa (12% strain), and then pure Ti at 850 MPa (10% strain).

The indents were also examined using Atomic Force Microscopy. The figure (right) shows a sample indent in one of the alloys and a 3D plot (left) created using this AFM method.



Scanning Electron Microscopy:

The SEM images below provide a closer look at the titanium alloy microstructures. Figure 1 shows the alpha phase titanium microstructure and Figure 2 the Ti-6 Al-7 Nb alpha-beta phase microstructure.

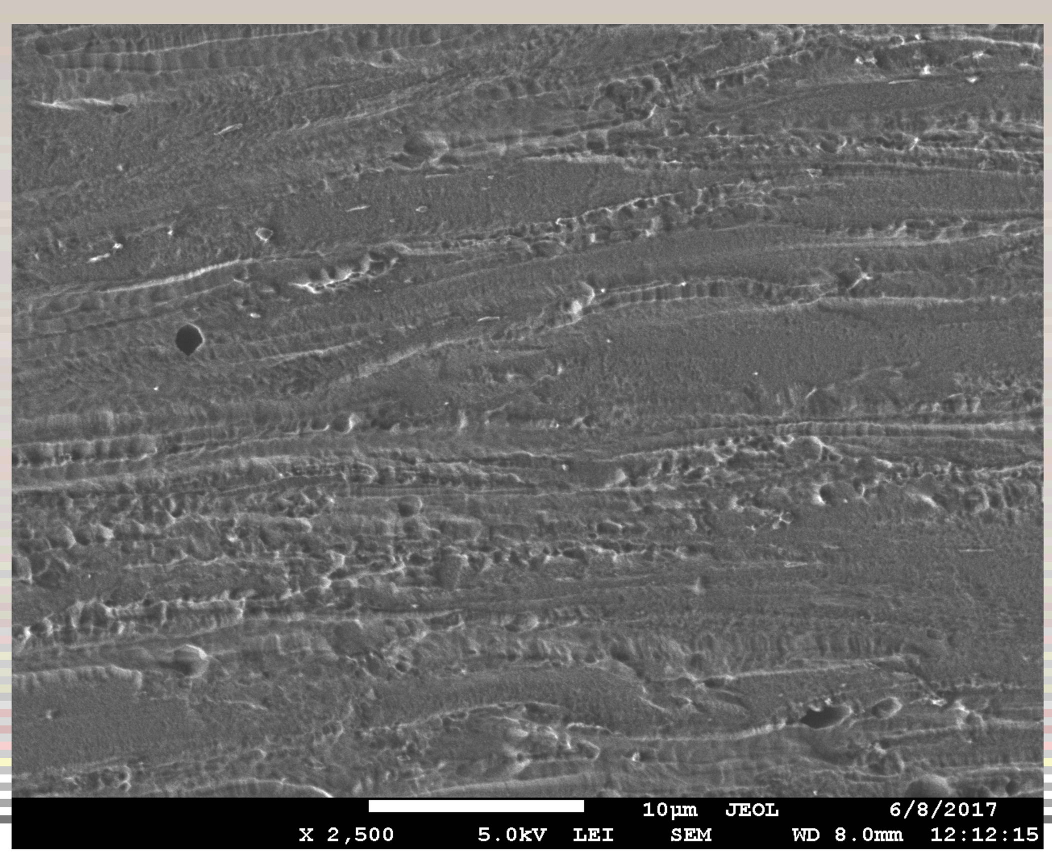


Figure 1. Ti SEM

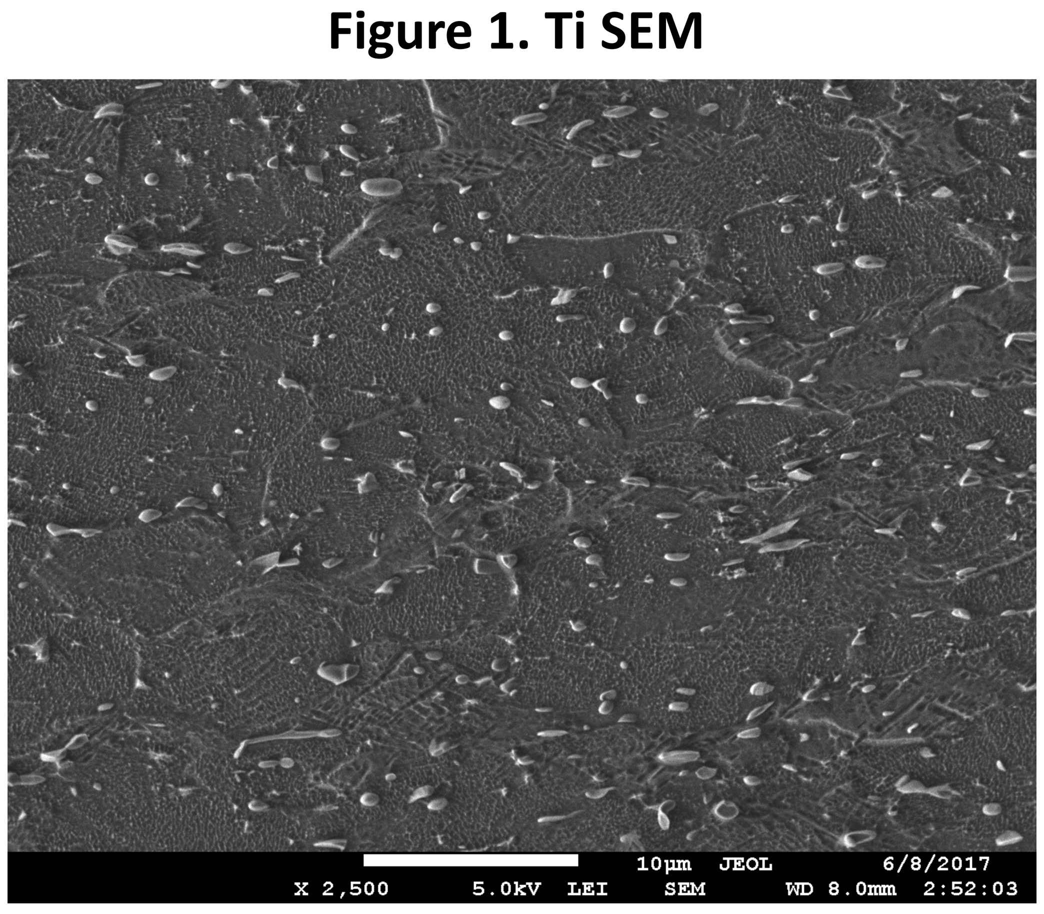


Figure 2. Ti-6 Al-7 Nb SEM

Conclusion:

The published tensile strength data were consistent with the nanoindentation hardness values. The Ti-6 Al-7 Nb alloy was stronger than the pure titanium and the Ti-6 Al-4 V alloy. The findings are relevant for the medical field because Ti-6 Al-7 Nb is useful for biomedical applications such as implants due to its strength and hardness.

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