# Preparing and Enhancement of (Ti 6 Al 4 V) dental implant by Niobium Oxide ($Nb_2O_5$) Nanoparticles

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**Abstract**

Titanium – Aluminum – Vanadium alloys are considered one of the most important applications in medical applications that are used in dental implant applications because of their stability and high resistance to corrosion caused by bodily fluids. In the current study Ti6Al4V and $Nb_2O_5$ composites were prepared by adding different percentage of $Nb_2O_5$ ranging (1 – 2.5) %. The results of the X-Ray Diffraction analysis reported the hexagonal ( α-Ti ) and for the cubic (β-Ti), β phase is clearly characterized by the (110) with (d=0.2284 nm). The hardness was increasing to 8.25 $Kg/mm^2$ by adding 2.5% of the $Nb_2O_5$ and the compressive strength was increasing about 47% at 2.5% $Nb_2O_5$.Weight loss was decreasing as the percentage $Nb_2O_5$ was increasing to 4.6 gm at 2.5% $Nb_2O_5$. The addition of a $Nb_2O_5$ to Ti-6AL-4V alloy, led to decreasing in the thermal conductivity values of the Nanocomposite in (25, 50, 75 and 100)C by (41% , 39% , 54% , and 47%) respectively. The scanning electron microscope examination noted the good distribution of the $Nb_2O_5$ nanoparticles within the microstructure and their spread along the grain boundaries.

## 1. Introduction:

Titanium is a metal that is light in weight and has a luster. It has a high toughness, malleable and often has a relatively high melting point of 1650 C. It is also highly corrosion resistant and conductive of heat and electricity(1). Titanium alloys have high resistant to corrosion, it isn't affected by acids or alkaline water, and has a low thermal expansion coefficient, and good mechanical properties at low and high temperatures. These qualities make titanium a precious metal of great importance. Titanium, aluminum and vanadium alloys are considered one of the most important metals used in the field of biological applications in the teeth and bones due to its high compatibility and excellent mechanical, chemical and physical properties. It has a relatively low density that combines light weight and high hardness and is characterized by high rigidity, so it is used in biomedical applications in the field of artificial organ replacement. As a result of these various characteristics, it has many fields of using titanium alloy. Since titanium does not interact with the compounds of the human body and it is a non-toxic metal, it is used in a range of replacement operations, including tooth roots and tooth extraction clamps (2). It is used in the work of plates and screws connecting bones, which require to be fixed for a long time, and the implantation of artificial joints in the knee, heart pumps and heart valves(1).

It is also used in the manufacture of surgical instruments such as forceps and scalpels, as well as in the manufacture of wheelchairs and crutches(3). Titanium prostheses with special surfaces control friction with the bone, which leads to stronger bonds and a longer life span between the bone and the device. Titanium alloys developed rapidly after aluminum additions, and titanium-aluminum alloys became economically available. There are two alloys that are widely used so far in the medical fields, especially Ti-5AL-2.5Sn, Ti-6AL-4V(4).

With the great development in medical materials engineering and its applications, we find that there is an increasing demand for Ti-6Al-4V alloys. The using of some additives to titanium alloys is for the purpose of increasing the resistance and hardness to be as close as possible to the hardness and resistance of teeth and bones, reducing operating time, used to improve the quality of implants, and used to improve the wear-resisting properties that are weak in titanium and its alloys(5).

*Keywords: Titanium Alloys, Niobium Oxide, Dental Implants, Nanocomposite Materials.*

Experimental and Procedure

### *2.1* Materials

Ti-6AL-4V alloy / Niobium Oxide has been prepared by mixing of Ti-6AL-4V and $Nb_2O_5$ powders by mixing using mixture with speed 120 rpm for three hours, then samples were pressed by pressing under 150 MPa and 750 ˚C for 7 hours., finally sintering of samples were done in a furnace at 600 ˚C for 5 hours. Table 1 show the properties of Niobium Oxide and titanium alloys.

***Table 1. Properties of Niobium Oxide and Titanium alloys powder.***

| Ti-6AL-4V powder | $Nb_2O_5$ powder | purity % |
|---|---|---|
| size | size | |
| 95 µm | 90 nm | 99.99 |

*2.2 Examinations and Tests*

- X-Ray Diffraction: X-ray diffraction exam was used to study composition of the (Ti-6Al-4V) samples(6).
- Micro hardness: Micro hardness was done according to ( ASTM E92-82 ) by Vickers tester. This apparatus was used to measure the hardness with load 1000g and 20 sec on the surface of the specimens using a standard 136° Vickers diamond pyramid indenter combined with an optical microscope(7).
- Compressive Strength: was achieved by universal tester according to(ASTM C623–92)(6,8).
- Weight loss: The pin on disc wear tester was used to calculations weight loss of samples. The tests can be both vertical and horizontal, while vertical configuration mode enables to eliminate the debris during wear tests. The relative motions such that is a circumferential wear pathway on the disc surfaces are generated(9).
- Thermal Conductivity: The thermal conductivity examination was achieved for the Ti-6AL-4V alloy and its composites in different Temperature ( 25, 50, 75 and 100 ) □C to illustration the effect of $Nb_2O_5$ nanowires on the thermal conductivity using hot disk device(10).
- Scanning Electron Microscope (SEM): SEM uses a focus beam of high electrons energy to produce a variation of signals at the surfaces of the specimens. The signal reveal information about the samples including orientation , crystalline structure , chemical composition and morphology of the sample(10).

**3. Results and discussions**

***3.1*** **XRD**

Figure (3.1) shows the X-Ray Diffraction pattern for the Ti6Al4V. The results reported according to ( JCPDS card #44-1294) and (JCPDS card #44-1288)(11) the the cubic (β-Ti) and hexagonal ( α-Ti ) , β phase is clearly characterized by the (110) with (d=0.2284 nm).

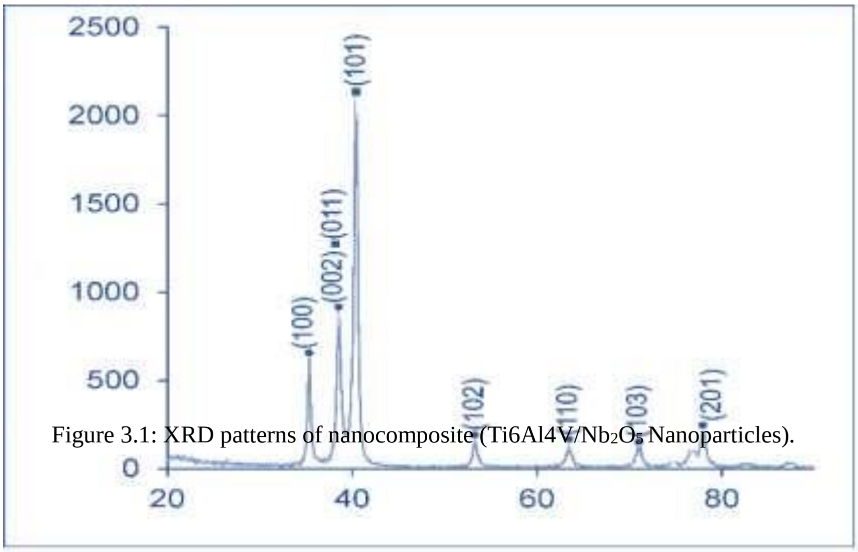



Figure 3.1: XRD patterns of nanocomposite (Ti6Al4V/$Nb_2O_5$ Nanoparticles).

***3.2*** **Microhardness**

The figure shows the change in Vickers hardness values for samples with the increase of the percentage of ( $Nb_2O_5$ ), where it was observed that the hardness increased slightly by adding ( 1 , 1.5, 2 and 2% of $Nb_2O_5$ ) to each sample, as the total increase rate of the above percentages was approximately 7.2%, while the hardness value increased to 8.25 $Kg/mm^2$ by adding 2.5% of the $Nb_2O_5$ That is, an increase of 24.6% compared to the material that does not contain any percentage of oxide, the reasons of increasing result from addition of harder phase ( $Nb_2O_5$ ) and high coherence between ( $Nb_2O_5$ ) nanoparticles and base metal (titanium)(12).

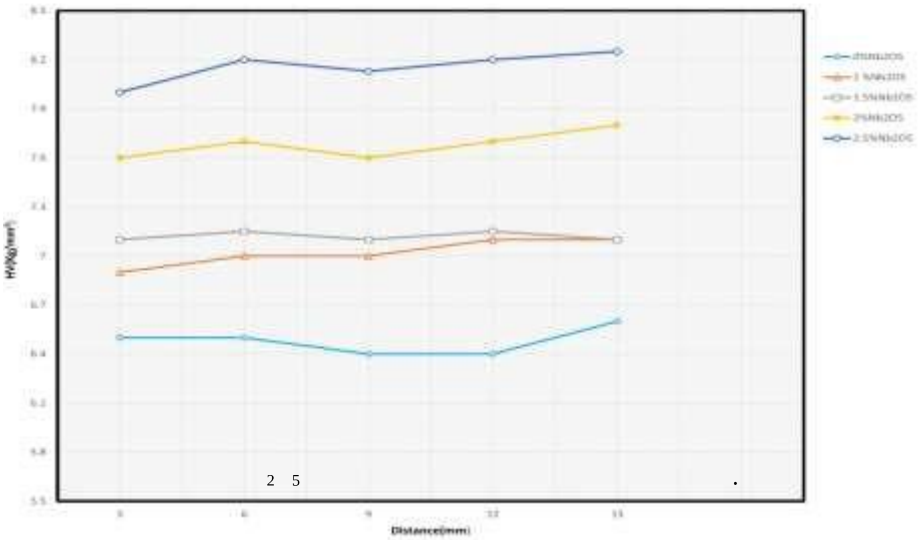



Figure 3.2: Effect of Nb2O5 Nanoparticles on hardness of Ti6Al4V alloy

### *3.3* Compressive Strength

The figure shows the change that occurs in the compressive strength and the percentage of strain with the addition of ($Nb_2O_5$) to the substrate by 1% to 2.5% for each sample. The figure shows a significant increase in the compressive strength property with the increase in the percentage of the additive. The material that was 0% $Nb_2O_5$, any material free from any addition, gave a compressive strength of approximately 156MPa, while with an increase of 1% of ( $Nb_2O_5$ ) it increased to 185Mpa and with the same strain the increase in compressive strength continued with an increase in the oxide added to 1.5 and 2% until it reached 230 MPa when 2.5% of the oxide was added. That is, an increase of about 47% compared to the material without any addition. The reason is the incorporation of hard and brittle addition ($Nb_2O_5$) to Ti alloys leads to enhance mechanical properties also could be improvement of wettability of Ti alloys powder with ( $Nb_2O_5$ ) nanoparticle during mixing process[9,13].

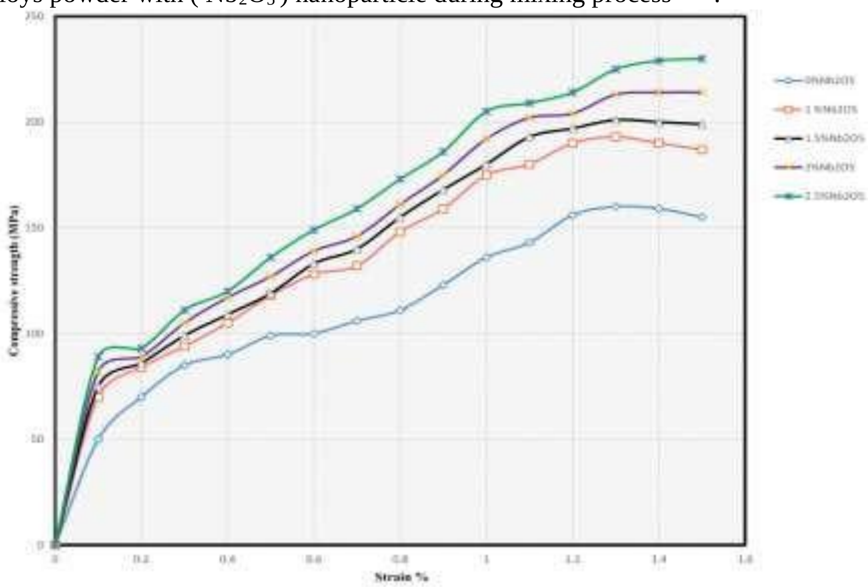



Figure 3.3: Effect of Nb2O5 Nanoparticles on Compressive strength of Ti6Al4V alloy.

### *3.4* Weight loss

The figure shows the effect of adding niobium oxide to the base material on weight loss, as ($Nb_2O_5$ ) was added at different rates from 1% to 2.5%, with an increase of 0.5% for each sample. The results showed a decrease in weight loss with the increase in the percentage of ($Nb_2O_5$ ) until the weight loss reached at 2.5% $Nb_2O_5$ to 4.6 gm, while the T6Al4V sample, the weight loss was 8.2gm, meaning that adding 2.5% of $Nb_2O_5$ reduced the weight loss by up to about 44%. The reasons of decreasing result from high coherence between ($Nb_2O_5$ ) and (Ti-6Al-4V) alloys[14].

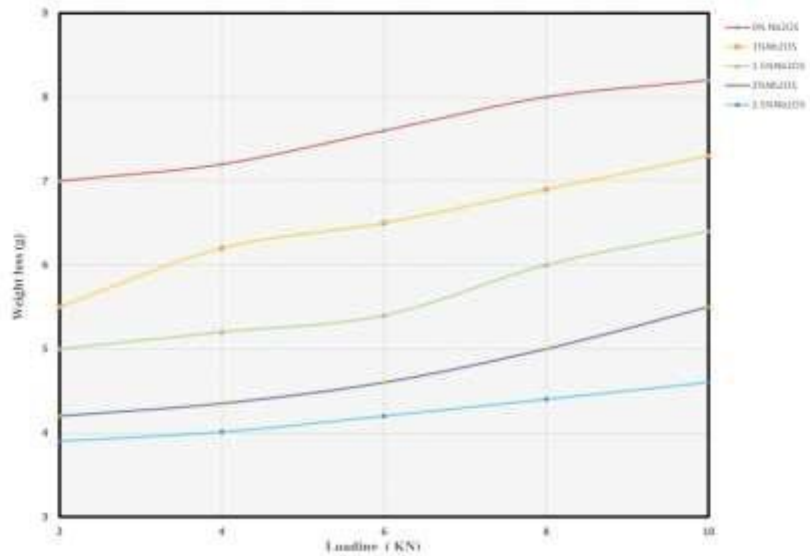
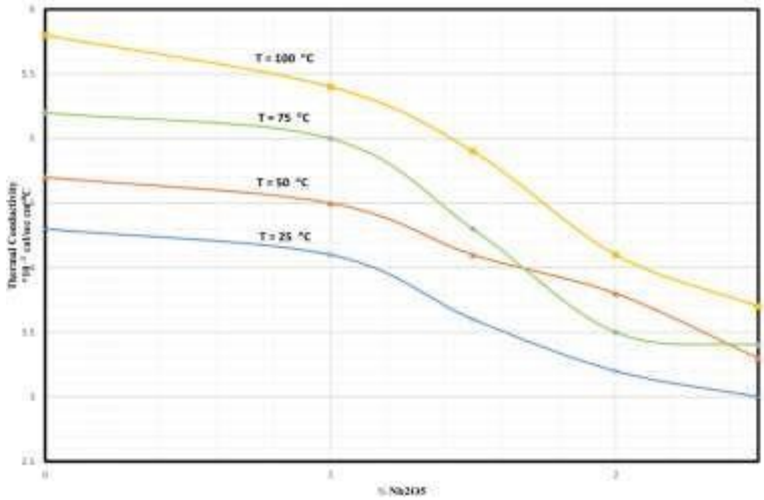


Figure 3.4: Effect of $Nb_2O_5$ Nanoparticles on weight loss of Ti6Al4V alloy.

### *3.5* Thermal Conductivity

The figure shows that the addition of a Niobium Oxide to ( Ti-6AL-4V ) alloy, led to decreasing in the thermal conductivity values of the Nanocomposite in ( 25, 50, 75 and 100 ) □C by ( 41% , 39% , 54% , and 47 % ) respectively the reasons of decreasing of thermal conductivity is addition of phase ($Nb_2O_5$) has lower thermal conductivity. It can also be noted that this increase in the thermal conductivity values of the compound is within the required range of work in dental implant applications (5,7).




### *3.6* Scanning Electron Microscope

The figure (6) represents the results of the scanning electron microscope examination of the Figure 3.5: Effect of $Nb_2O_5$ Nanoparticles on thermal conductivity of Ti6Al4V alloyTi6Al4V. alloy before and after the addition of niobium oxide, as we note the good distribution of the niobium oxide nanoparticles within the microstructure and their spread along the grain boundaries, which confirms the results of the mechanical tests. Figure (6-a) represents the scanning electron microscope examination of the Ti6Al4V, while Figure (6-b) picture of the microstructure after adding (1.5 % ) of niobium oxide to the Ti6Al4V alloy. The figure ( 6-c ) represents the microstructure after adding a ( 2.5 % ) of niobium oxide to the Ti6Al4V alloy.

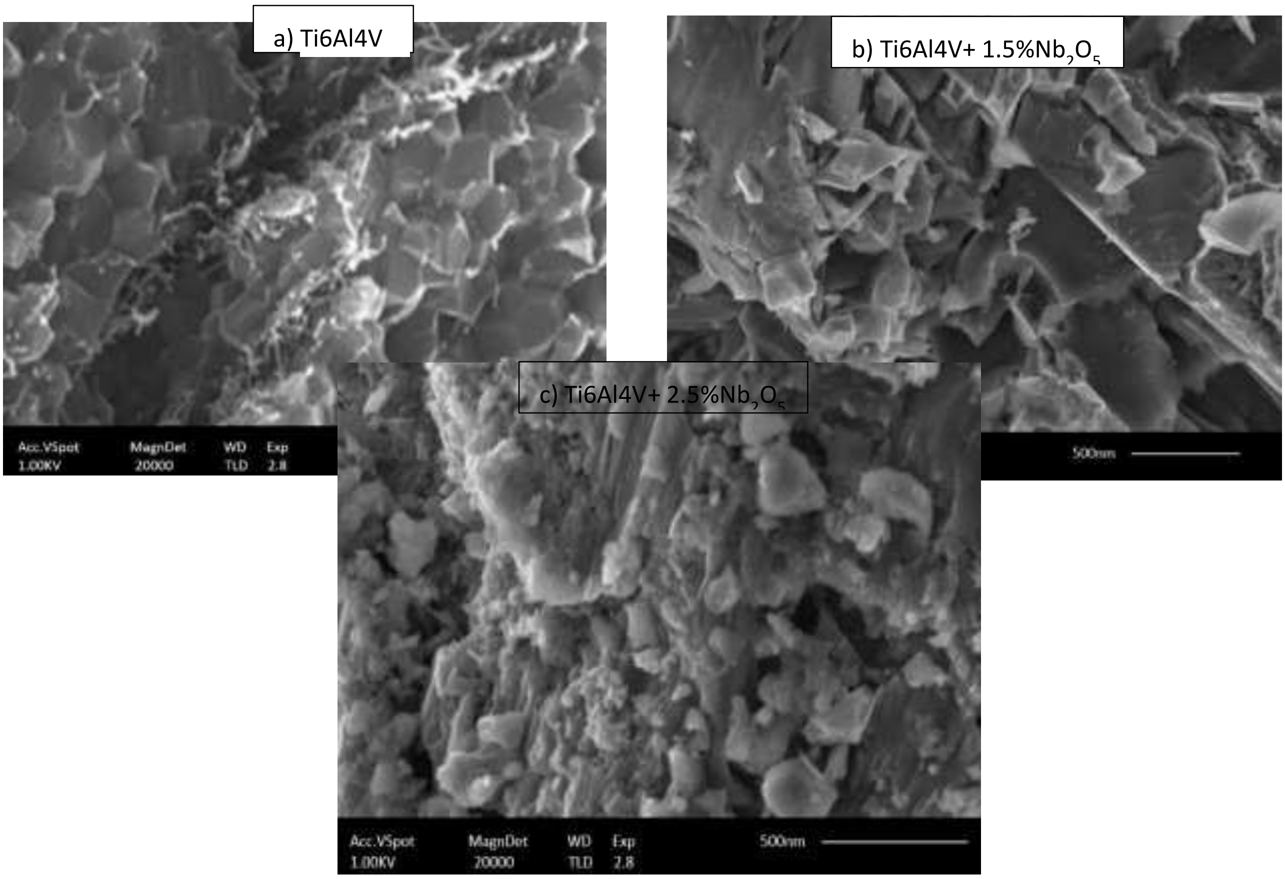



Figure 3.6: SEM of Ti6Al4V alloy and (Ti6Al4V/$Nb_2O_5$) Composite.

## 4. Conclusions

1. The results of the X-Ray Diffraction analysis reported the the cubic (β-Ti) and hexagonal (α-Ti ).
2. The reinforcement of Ti6Al4V alloy by $Nb_2O_5$ led to increase the hardness slightly.
3. The compressive strength increased in the percentage of the additive of $Nb_2O_5$ %, This increasing was about 47% (at 2.5% $Nb_2O_5$).
4. Weight loss was decreasing as the percentage $Nb_2O_5$ was increasing, the weight loss reached to 4.6gm at 2.5% $Nb_2O_5$.
5. The addition of a $Nb_2O_5$ to Ti-6AL-4V alloy, led to decreasing in the thermal conductivity values of the Nanocomposite in (25, 50, 75 and 100)□C by (41% , 39% , 54% , and 47%) respectively
6. In SEM noted the good distribution of the $Nb_2O_5$ nanoparticles within the microstructure and their spread along the grain boundaries.

## 5. References

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