

## Study of the Biocompatibility of Ti6Al4V Medical Alloys

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**Abstract:** In this study, nitriding with plasma (using nitrogen gas) was used as a method to treat the surface of titanium alloy (Ti6Al4V) for different time periods (5-10-15-20 hours), and the measurements showed that nitrogen deposited on the alloy. The highest rate of nitrogen deposition was found at a treatment period of 20 hours. The results of immersing the samples for a month in a simulated body fluid showed the growth of a hydroxyapatite (HA) layer on the samples, where the growth of the hydroxide apatite layer was good on the samples within the simulated body fluid environment. The results of this examination indicated the compatibility of the alloy with the living organism's body.

**Key points:** Plasma nitriding, Nitrogen gas, Nitriding and atomization system, Hydroxyapatite.

**Introduction:** Biological and Porous Simulation relies on the growth of calcium phosphates using specific fluids such as Simulated Body Fluid (SBF) or Ringer to simulate body fluids to produce a layer of apatite and hydroxyapatite on the surface of Ti6Al4V alloys, increasing bone conductivity and therefore favoring it. A biologically active coating on the porous surface is important to enhance the quality of the bone implant interface. Porosity is defined as the percentage of void spaces in a solid material. The achieved integration using porous Ti is accomplished through bone growth in the pores, improving the fine mechanics of interlocking, the interweaving of bone tissues inside the implant, preventing migration by increasing the contact area between biological materials and bone tissues, leading to improved implant stability over time, as well as accelerating the growth process. Porous structure must be produced with high porosity to provide sufficient space for cell adhesion and subsequent bone formation, allowing the transfer of body fluids while providing sufficient mechanical properties to withstand pressure[1]. Researcher Prosolov has brought attention to radiofrequency-sputtered calcium phosphate coatings derived from dual-phase calcium phosphates, designed for bio-medical implant applications. By utilizing pure titanium and HA, they successfully deposited biologically active calcium phosphate coatings through radiofrequency magnetron sputtering from dual-phase targets comprising hydroxyapatite and tricalcium phosphate. The concentrations of HA and TCP were varied as 75% HA/25% TCP, 50% HA/50% TCP, and 25% HA/75% TCP (all in mass%). These processes enabled the production of thin, amorphous CaP coatings on Ti bases, achieved by sputtering from dual-phase targets containing homogeneous mixtures of HA and TCP at different ratios, along with individual HA and TCP targets. The configuration of these dual-phase targets allows precise control over the structure, composition, and formation of the coatings [2].

### Experimental Part

The plasma system shown in Figure (1) is used. The samples are placed in the plasma chamber on the cathode, which is connected to a continuous power source while the chamber is grounded at the anode. As for the plasma nitriding process by glow discharge, it is carried out according to the conditions specified in Table (1). The plasma chamber is evacuated to a vacuum pressure ( $3-10 \times 1$  mbar) to ensure the removal of heavy gases such as hydrocarbons. After reaching the vacuum pressure, nitrogen gas is introduced into the chamber through the needle valve at a pressure of (1-

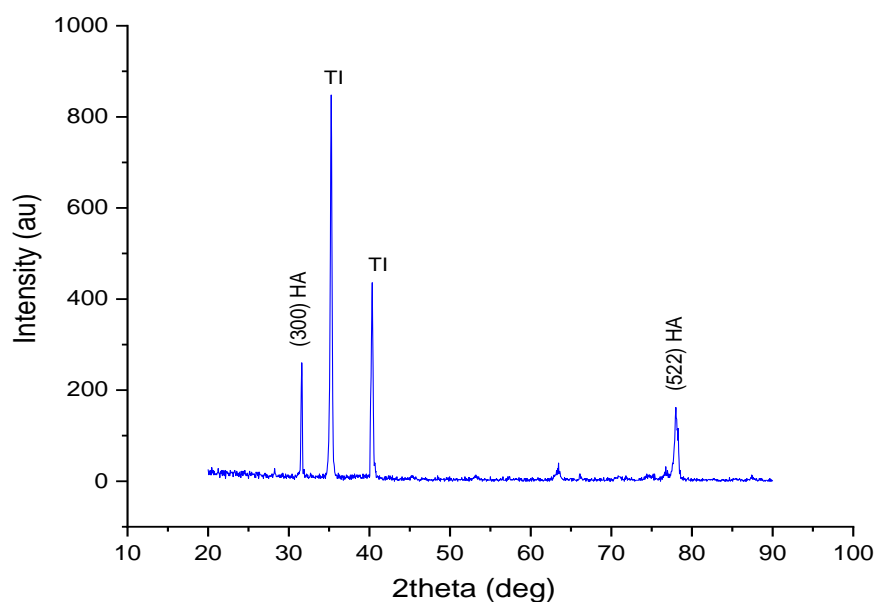
10×1.5 mbar). The voltage of the continuous power source is increased until the plasma is generated, and after the specified treatment time (5h), the system is turned off and left until the chamber temperature reaches room temperature. The valve at the top of the chamber is opened to equalize the pressure, extract the samples, place them in plastic containers, and repeat the process under the same conditions in Table (1) for the remaining samples, except that the time will change to (20, 15, 10 h). After the completion of these treatment periods, we notice that all samples have changed color from silver to golden, indicating the nitriding process. The longer the treatment period, the higher the protection result due to greater penetration of nitrogen into the sample and the thickness of the protective layer formed. We will also observe that the sample treated for (20h) has become better than the base sample, as well as the samples treated for (5h). In this study, Simulated Body Fluid (SBF) was prepared according to the concentrations specified in Table (1) by dissolving the contents in 1L of distilled water. The solution was stored at an acidic pH (7.4) at a temperature of 25 degrees Celsius. Samples were tested by immersing titanium samples in SBF for a month, and the growth of the hydroxyapatite layer was observed.

The substance	(Concentration g/l)
NaCl	8.035
NaHCO <sub>3</sub>	0.355
KCl	0.225
K <sub>4</sub> HPO <sub>4</sub> ·3H <sub>2</sub> O	0.231
MgCl <sub>2</sub> ·6H <sub>2</sub> O	0.311
CaCl <sub>2</sub>	0.392
Na <sub>2</sub> SO <sub>4</sub>	0.072
((HOCH <sub>2</sub> ) <sub>3</sub> CNH <sub>2</sub> )	6.118
1.0 M HCl	The appropriate quantity to make the pH 7.4

Table(1) [3]

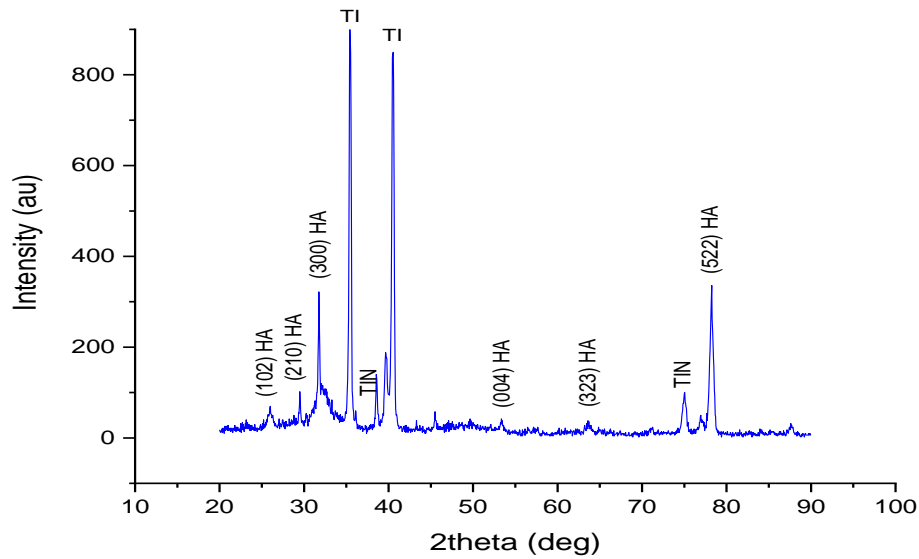
### Results and discussion:

The XRD diagram in Figure (1) illustrates the base sample after being immersed in a simulated body fluid for a month. In this pattern, we observe two distinct peaks of Hydroxyapatite (HA) at positions (522) and (300), aligning with angles (78.22) and (32.90) respectively, in accordance with the global card (ICDD#09-0432).



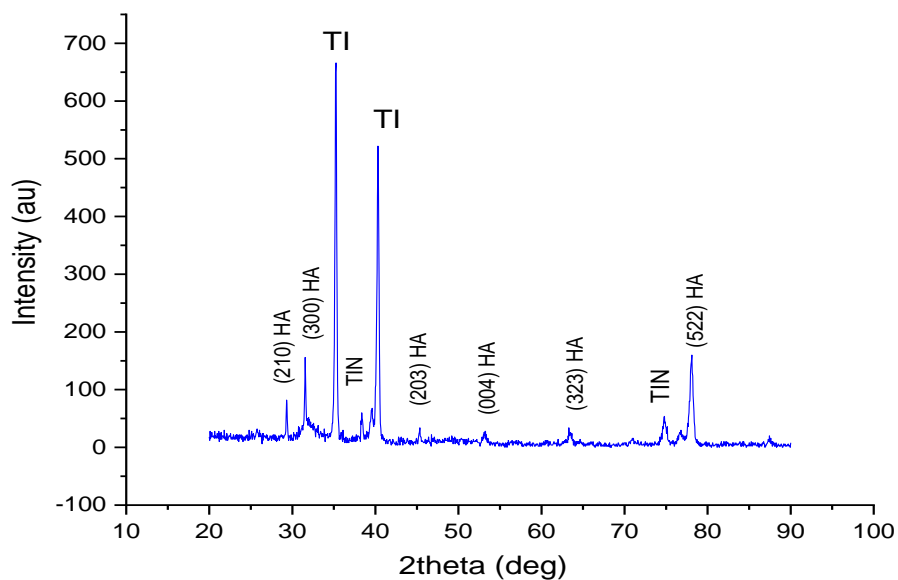
Figer(1)

In Figure (2), the XRD pattern of the sample processed for 5 hours is illustrated. This pattern reveals distinct peaks for hydroxyapatite (HA) located at positions (210), (300), (004), (323), and (522), aligning with angles (28.96), (32.9), (45.3), (64.07), and (78.22) as specified in card (ICDD#09-0432).



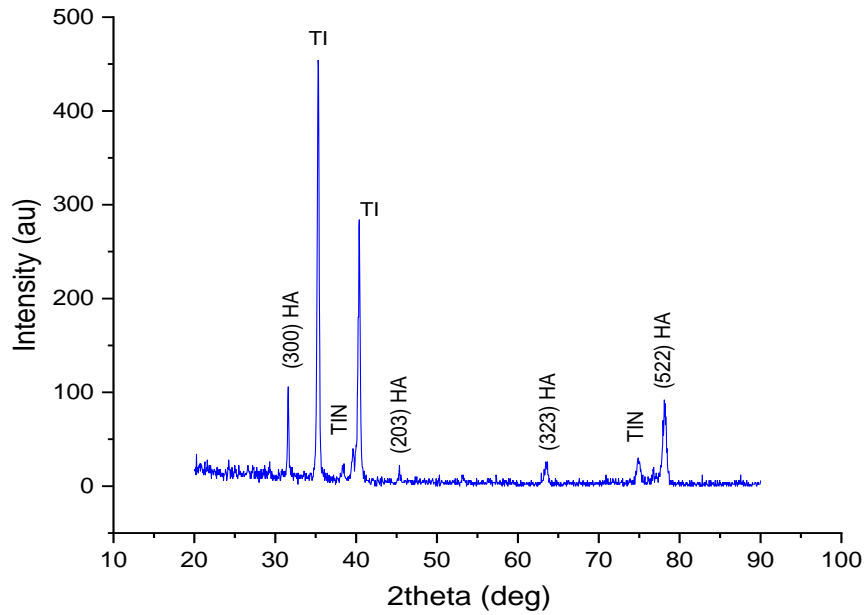
**Figer(2)**

Figure (3) shows the XRD pattern of the sample processed for 10 hours. From this pattern, we observe prominent peaks of hydroxyapatite (HA) at positions (210), (300), (004), (323), and (522), corresponding to angles (28.96), (32.9), (53.14), (64.07), and (78.22).



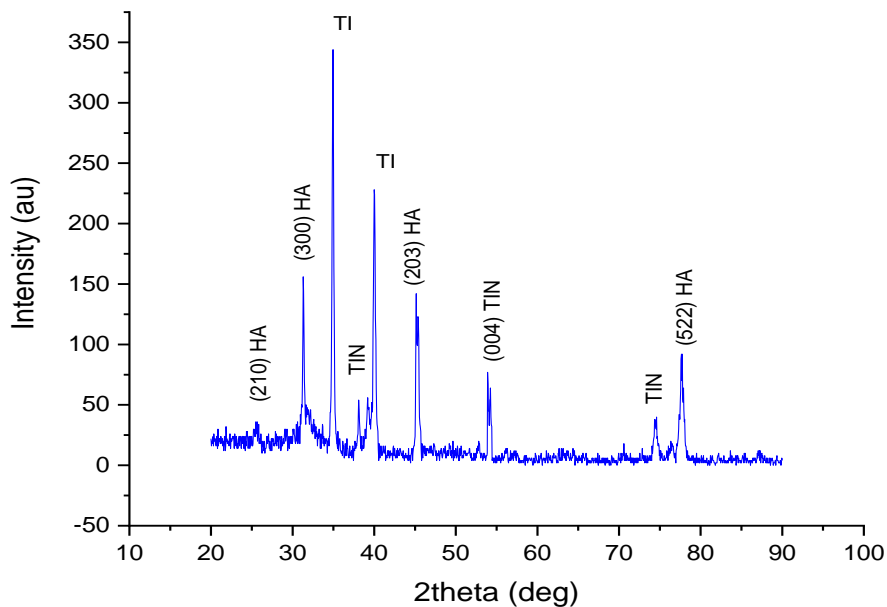
**Figer(3)**

Figure (4) displays the XRD pattern of the sample after a processing period of 15 hours. From this pattern, we can observe the presence of hydroxyapatite (HA) peaks located at positions (210), (300), (004), (323), and (522), corresponding to angles of (28.96), (32.9), (53.14), (64.07), and (78.22).



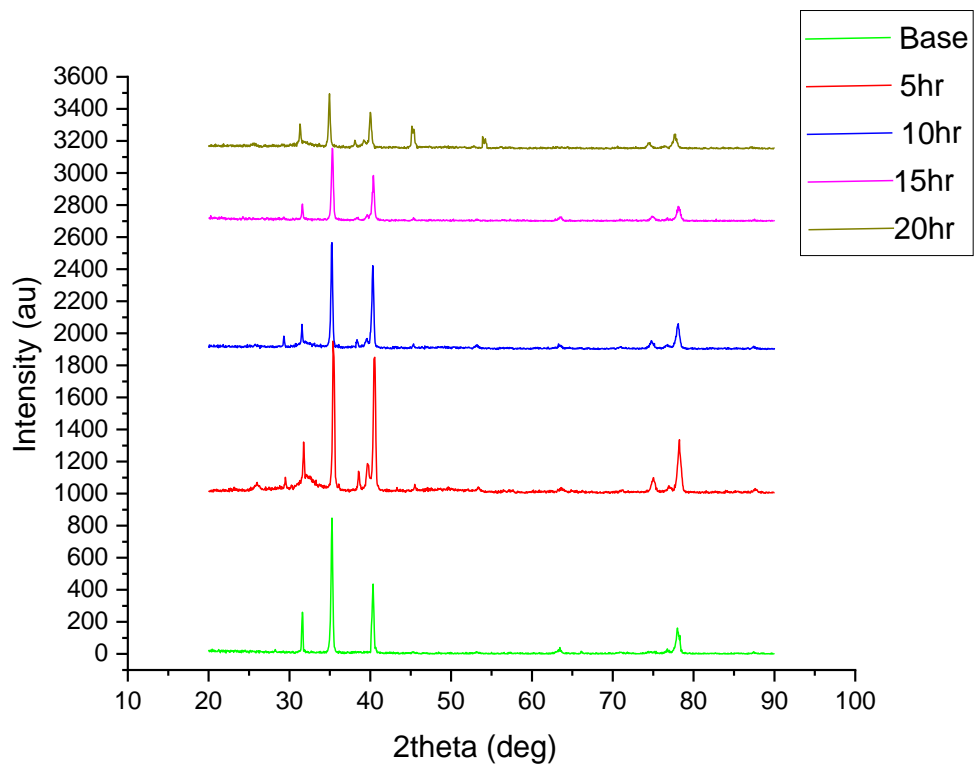
Figer(4)

The figure (5) shows the XRD pattern of the sample with a processing period (20hr) and from this pattern, we notice the appearance of peaks of hydroxyapatite (HA) where the peaks formed at positions (210), (300), (203), (004), and (522) which matched the angles (28.96), (32.9), (45.3), (53.14), and (78.22).



Figer(5)

From figure (6), we notice the growth of the hydroxyapatite (HA) layer on the samples increasing as the nitriding treatment period increases, with the peaks of HA rising, and the peaks of titanium (Ti) and titanium nitride (TiN) decreasing. This is because the hydroxyapatite layer formed above the alloy, and the thicker the treatment period, the thicker the formed layer. The growth of this layer during immersion in a simulated body fluid indicates bonding with the bones of the living organism and acceptance by the body tissues as part of the living organism's organs.

**Figer(6)****References**

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