



Influence of amorphous carbon layers on tribological properties of polyetheretherketone composite in contact with nitrided layer produced on Ti6Al4V titanium alloy

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ABSTRACT

The key issue in bone implants biomechanics is – besides using biocompatible materials – the optimization of tribological properties of friction pairs occurring in joint implants e.g. knee and hip endoprosthesis. Increasingly important role in these systems, alongside ceramics-on-ceramics and metal-on-metal, have metal-on-polymer friction pairs. Commonly used in orthopedics ultra-high molecular weight polyethylene (UHMWPE) does not meet the requirements of modern bone implants, mainly because of its harmful wear products which can cause inflammation and osteolysis of surrounding tissues after several years of using the endoprosthesis. Therefore, other polymer materials have been developed to replace UHMWPE, as well as several surface engineering methods are used for enhancing biocompatibility and tribological properties of applied materials. One of the materials to replace UHMWPE is increasingly used in medicine polyetheretherketone (PEEK) – a polymer material with a high biological indifference and mechanical properties.

The article presents characteristics of TiN + Ti₂N + αTi(N) nitrided layer produced on Ti6Al4V titanium alloy using glow discharge assisted nitriding process at the plasma potential, also known as the active screen plasma nitriding process and hydrogenated amorphous carbon doped with nitrogen layer a-C:N:H produced via RFCVD process on PEEK-based composite consisting of 10% graphite, 10% carbon fibers and 10% PTFE. Tribological properties of a-C:N:H – TiN + Ti₂N + αTi(N) friction pair using “ball-on-disc” and “block-on-roll” tests were examined in correlation with microstructure (TEM, SEM, Raman spectroscopy) and surface morphology and topography (SEM, AFM, optical profilometer).

The goal of this work is to present a new possibility of material solution for a ‘head-acetabulum’ friction pair in hip joint endoprosthesis using PEEK (PEEK T) as a replacement for commonly used UHMWPE and nitrided layer produced on Ti6Al4V titanium alloy using active screen plasma nitriding process.

Amorphous carbon layer, 200 nm thick, produced on PEEK composite significantly improved tribological properties of PEEK composite – TiN (nanocrystalline) + Ti₂N + αTi(N) layer friction pair, decreasing the friction coefficient by 2 times and minimizing wear of both used materials in the point contact (“ball-on-disc” method) and in surface contact (“block-on-roll” method).

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1. Introduction

Increasing demands with regard to the properties of medical implants and equipment are the driving force behind the rapid development of biomaterials. In recent years, a number of new metallic, ceramic, polymeric and composite materials have been developed, with each consecutive one demonstrating improved biological and mechanical properties [1–8]. It seems, however, that due to the very difficult conditions in which materials for implants are made to operate in, the future development of biomaterials will mainly be shaped by

surface engineering technologies. The technologies permit the modification of the microstructure, chemical and phase composition, residual stress state, morphology and topography of the surface of the processed materials in a controlled manner, making it possible to broadly shape their functional properties such as frictional wear resistance, corrosion resistance, fatigue resistance, biological activity, biocompatibility as well as limit the so-called metallosis effect, i.e. the migration of the alloy elements to the human body [9–12].

The hip joint plays a key role in the kinematic system of humans by allowing loads to be transferred from the backbone, through the pelvis to the lower limbs. This joint often undergoes deformation and mechanical damage as a result of the heavy weights it is subjected to when walking, running or jumping. It is currently estimated that one in four

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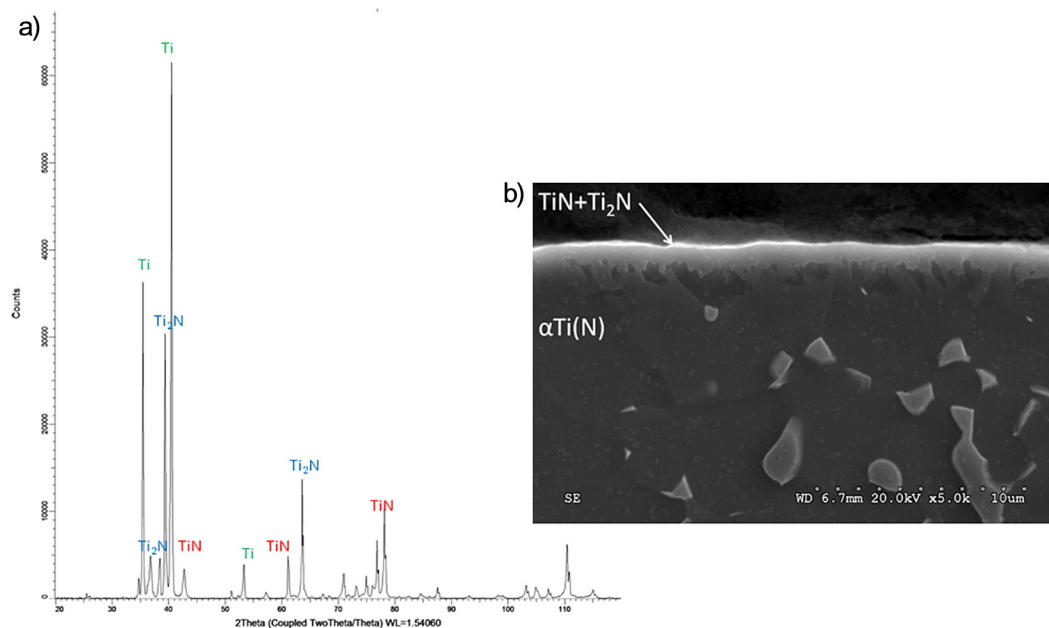


Fig. 1. XRD diffraction pattern (a) and microstructure (b) of the nitrided layer formed on Ti6Al4V alloy after active-screen plasma nitriding.

women and one in nine men over the age of 65 is at risk of suffering a fractured femoral neck resulting in the need for a hip replacement [13–14].

One of the main areas exposed to wear through friction in a hip joint implant is the contact area between the head and the cup. The materials currently used in this region include CoCrMo alloys, Al₂O₃ and ZrO₂ ceramics, ZTA (Zirconia Toughened Alumina) composites and ultra-high molecular weight polyethylene (UHMWPE) [15–24]. Additional inserts made of ceramic or metallic materials to limit the amount of wear debris which includes, in particular, polyethylene, metal or ceramic particles,

are used more and more often. The debris produced remains within the body accelerating the wear rate of the materials that come in contact with each other, leading, in extreme cases, to inflammation, osteolysis of the surrounding osseous tissue and even to the development of cancer cells [25–29].

Titanium and its alloys are one of the most biocompatible metallic materials. The metal demonstrates very good corrosion resistance properties, a high specific strength and a relatively low Young modulus, make it a very good material for use in bone implants. However, its low hardness and wear resistance, as well as the metallosis effect

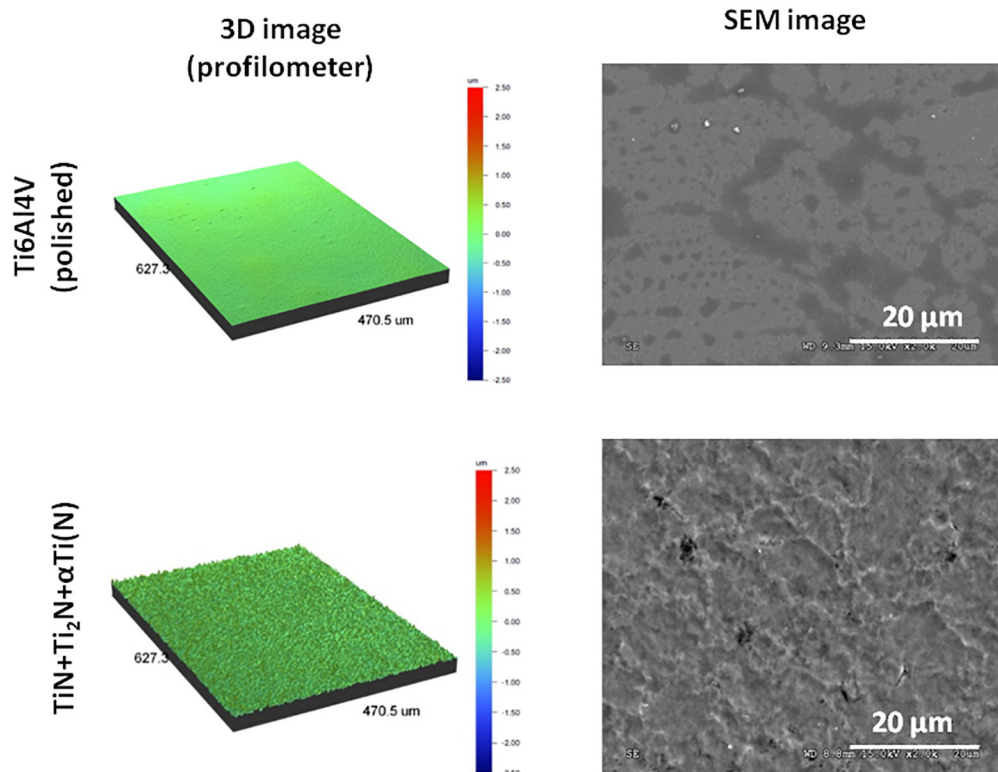


Fig. 2. Surface topography and morphology of a polished Ti6Al4V titanium alloy surface and of the nitrided layer formed thereon.

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