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Tribological performance of femtosecond laser-induced periodic surface structures on TiN and TiCN coated titanium for biomedical applications

Alaitz Zabala[1)*], Iñigo Llavori[1)], David Bruneel[2)], Jose A. Ramos-de-Campos[2)] , Jörn Bonse[3)], Dirk Spaltmann[3)], Unai Lizarribar[1), 2)], Andrea Aginagalde[1)]

1) Mechanical and Industrial Production department, Mondragon University, Spain
2) Process and modeling unit, LASEA, Belgique
3) Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany
*Corresponding author: azabalae@mondragon.edu

In this study TiN and TiCN coated titanium surfaces were functionalized adding laser-induced periodic surface structures (LIPSS) through femtosecond laser nanotexturing technology to enhance their tribological performance for orthopaedic implant applications. The processing parameters for the LIPSS generation and the surface modifications in terms of morphology and surface chemistry influencing the tribological properties are analyzed and discussed.

Keywords (from 3 to 5 max): tribology, LIPSS, implants, hard coatings, femtosecond laser

1. Introduction

Knee and hip prosthesis material's wear reduction is a major concern in the biomedical industry. Accordingly, the analysis of medical grade titanium alloy Ti6Al4V and ultra-high molecular weight polyethylene (UHMWPE) tribopair´s performance in biological media is of interest. One of the strategies to reduce the wear of the polymer material is the functionalization of the metallic component, either coating the titanium alloy to increase its hardness and decrease the friction, or texturing the surface to improve the lubrication performance.
In this context, physical vapour deposited (PVD) TiN and TiCN coatings have been widely studied and are used for orthopaedic applications [1]. Additionally, the response of LIPSS in hard PVD TiN films was previously analyzed for tool steels demonstrating the potential for coefficient of friction reduction [2]. However, little research is available that combines coated surfaces and nano-structured (LIPSS) at metal on polymer tribopairs for hip and knee implants. Thus, the objective of this work was to evaluate the tribological effect of the LIPSS in a TiN or TiCN coated Ti6Al4V-UHMWPE tribopairs.

2. Methods

2.1. Sample texturing
Laser texturing was carried out in LASEA, Liege, Belgium, through a commercial Yb:YAG femtosecond laser amplifier system (Satsuma HP2, Amplitude Systémes: τ =280 fs pulse duration, l = 1030 nm wavelength). Table 1 shows the process parameters followed to the generation of the LIPSS shown in Figure 1. As can be observed, similar periodicities of ~830 nm were obtained on both coating materials with more pronounced nanotextures for the TiCN coating.

Table 1: Experimental parameters used to create the nanostructures.

Coating material	TiN or TiCN
Pulse repetition rate (kHz)	5 - 50
Pulse energy (mJ)	0.0515 - 0.0276
Scanning speed (mm/s)	6.5 - 80
Hatch pitch (µm)	7.5 – 5.0

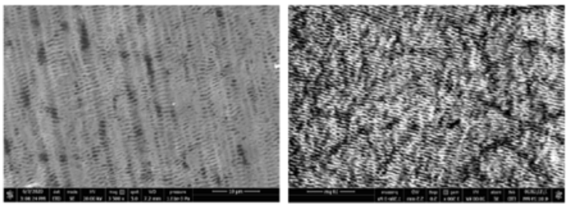

Figure 1: SEM images of the LIPSS on TiN (left) and on TiCN showing a more pronounced structure (right).

2.2. Tribological analysis
Tribological experiments were carried out with a pin-on-flat linear reciprocating sliding configuration. Test parameters were chosen based on orthopedic implant application working parameters. For an initial comparison study, 1 h long tests with 10 MPa contact pressure and 20 mm/s sliding speed were conducted. In order to analyze the impact of the textures on the lubrication regime, a Stribeck curve study was conducted with a sliding frequency between 0.1 - 3 Hz, and a contact pressure range between 3.5-10 MPa. In all cases, a stroke of 10 mm was imposed. The coefficient of friction (CoF) was calculated by the ASTM G203 standard for determining friction energy dissipation in reciprocating tribosystems.

3. Discussion

Non-textured TiCN coated samples presented larger CoF values compared to the TiN coating. The LIPSS influence also varied between the different coatings, presenting a moderate CoF decrease only for the TiCN coating. The present work analyses and discusses the effect of the femtosecond laser process parameters on the generation of LIPSS and its influence on the tribological behaviour for TiN and TiCN coated Ti6Al4V-UHMWPE metal on polymer tribopairs for orthopaedic applications.

4. References

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