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DIAMOND COATING ON TITANIUM ALLOYS AND THE TRIBOLOGICAL CHARACTERISTICS DIAMOND COATINGS

This paper presents diamond coatings on titanium alloys and tribological characteristics of the surface. The coating morphology has been investigated Raman spectroscopy. Friction and wear characteristics have been studied with tribometer as a function of the applied load, the sliding speed of the interacting surfaces.

Key words: titan, diamond coating, wear, tribology, CVD.

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АЛМАЗНОЕ ПОКРЫТИЕ ТИТАНА И ЕГО СВОЙСТВА В ПРОЦЕССЕ ТРЕНИЯ

В данной работе представлены трибологические характеристики алмазного покрытия титанового сплава. Были исследованы морфология и качество покрытия при помощи спектроскопии комбинационного рассеяния. Характеристики трения и износа были изучены с помощью трибометра в зависимости от скорости скольжения и материала.

Ключевые слова: титан, алмазное покрытие, износ, трибологические свойства, CVD.

CoCr and ultra-high-molecular-weight polyethylene (UHMWPE) are now a promising implant pair, because both materials exhibit low friction coefficient, and consequently less wear. CoCr alloys with UHMWPE are widely used in artificial hip and knee joints. The important factor affecting the longevity of hip joint and knee implants is the wear rate, but UHMWPE may be too soft, that limits the time of use of the implant. Biocompatible appears as the most important parameter when choosing implant material. However, the cobalt can cause allergic reactions. Titanium alloys also are biocompatible, making them suitable for prosthetic applications, but Ti-alloy has a high friction coefficient. The diamond coating on titanium alloys films is can to find applications in the medicine because of the unique combination of excellent mechanical and tribological properties, wear resistance and low friction coefficient.

Diamond coatings were deposited onto titanium alloy by plasma-assisted chemical vapor deposition (CVD), with both hydrogen (98,6 %) and methane (1,4 %) feedgas mixtures. The microstructural specifications of the coating, such as graphite concentration and residual stresses, can be influenced by process parameters such as the pressure, the temperature, and the hydrogen and methane concentrations in the vapor. The grain size of the coating can be influenced by varying the temperature of the filaments (2200 °C), the methane concentration in the gas atmosphere, and the substrate temperature (800 °C) [1]. By varying the temperature of the filaments, the number of hydrogen radicals can be altered and lower process pressures of 10 mbar lead to a fine diamond microstructure at the boundary. In the deposition processes, many complex surface reactions take place and a change in deposition parameters leads to change in morphology [2].

The purpose of the study was to evaluate the tribological properties of the diamond coatings of the titanium alloys and to compare the results to polyethylene-on-CoCr (CoCr/UHMWPE) and Ti/Ti. Investigations are required to better understand the process, that can arise when using implants. Deposition time for specimens was 10 h. The surface morphology and quality of the deposited films are observed by scanning electron microscopy (SEM) and analyzed by Raman spectroscopy (RS). In this study used the friction device a pin-on-disc tribometer. During testing, the samples were contained in a single, large well submerged in the lubricant — distilled water.

Fig. 1 shows the SEM images of rubbing surfaces (CoCr/UHMWPE, Ti/Ti and diamond coatings of the titanium alloys). The SEM images revealed noticeable differences in the surface morphology. After wear tests, protuberances were visible on the surface that was in contact with CoCr. Under higher magnification, these elevated regions were revealed as accumulations of polyethylene atop areas of pulled out fibers. CoCr/UHMWPE showed less adhesion compared with Ti/Ti. The CoCr/UHMWPE samples: the abrasion damage to the UHMWPE, these results are attributed to the high hardness CoCr. (fig.1, *a*, *d*). The simulator studies have shown the wear of Ti/Ti coatings to be more to that of diamond coatings (fig.1, *b*, *e*). Solid diamond coatings showed no evidence of abrasion damage and produced the least amount of surface wear. These results are attributed to the high hardness and excellent wear resistance in comparison to Ti/Ti and CoCr/UHMWPE (fig. 1, *c*, *f*). The diamond coating shows the lowest constant wear value, followed by the CoCr/UHMWPE sample, indicating a superior behavior against the microabrasion wear. The Ti/Ti sample has more wear mechanisms in comparison with CoCr/UHMWPE or diamond coating. The hard particles, that adhered to the back surface of the titanium surface, probably abrade the surface, causing abrasive wear.

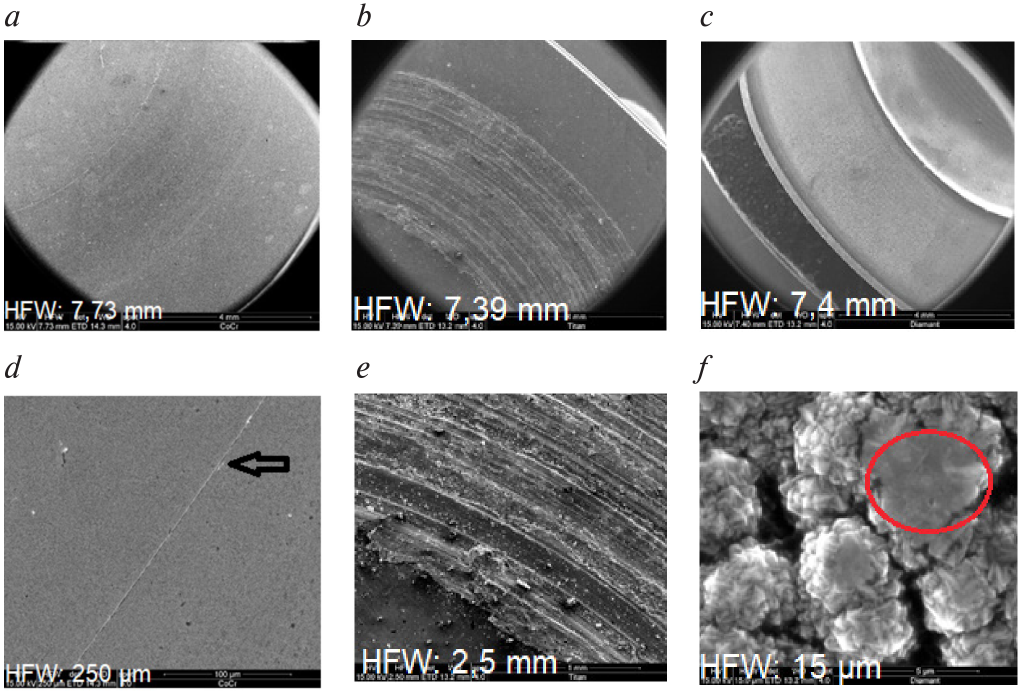


Fig. 1. The SEM micrographs of the surface;
a, d — Co-Cr/UHMWPE, *b, e* — Ti/Ti, *c, f* — diamond coatings

On the other hand, all samples showed the greatest wears at the beginning experiments (fig. 2). The surfaces of the samples are located on top of each other, obviously, first the surface irregularities are smoothing and then wear rate will be constant. The curvature of the Ti/Ti sample is stronger than that of the samples Co-Cr/UHMWPE or diamond coating. This is considered to result due to the formation of chips on the Ti surface, amplifying abrasive wear.

Fig. 3, *a* shows how much force was needed to move two pairs of friction. The diamond coating have the smallest frictional moment of a specimen, that as the resistance to the movement of friction pairs were minimal. Titanium sample has the greatest friction, this is manifested in the oscillation of the curve, where adhesion provides additional resistance. In addition, chips increased resistance.

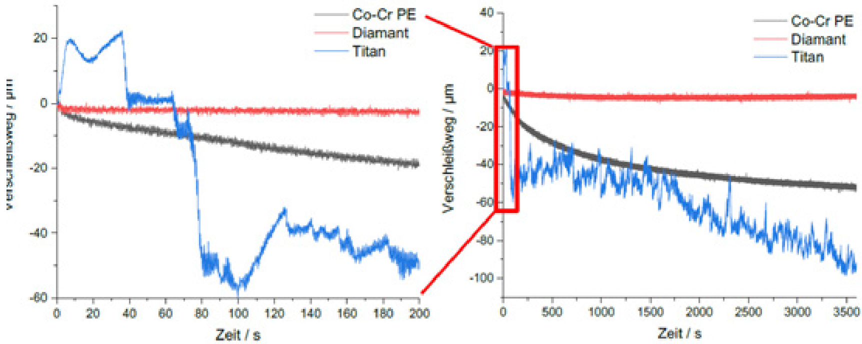
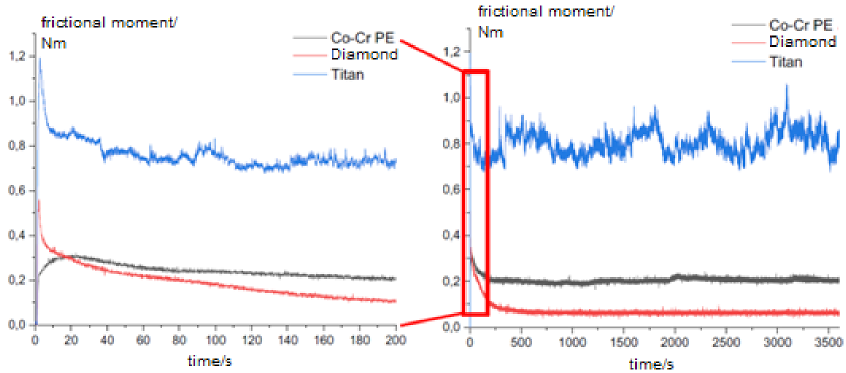


Fig. 2. Wear trajectory for Co-Cr/UHMWPE, Ti/Ti, diamond coatings

a



b

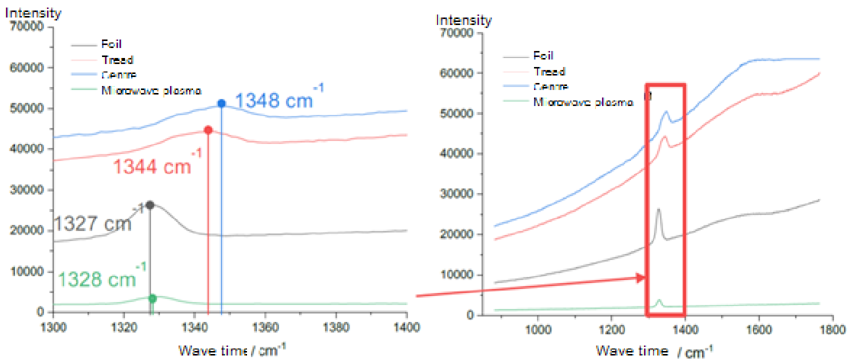


Fig. 3. Frictional moment of friction pairs (*a*); Raman spectroscopy diamond coating (*b*)

The quality of the diamond coating depends on the ratio of sp2 — and sp3-bonded parts, the residual stresses can be analyzed on Raman spectroscopy. Fig. 3 shows the Raman spectroscopy of microcrystalline CVD diamond coatings. The broadening of the peak centered at 1332 sm^{-1} is characteristic of diamond. The broadband centered at 1355 sm^{-1} and 1575 sm^{-1} are primarily associated with graphite [2]. The areas were taken both within and outside the wear track. Fig. 3 shows the results of the Raman spectroscopy of microcrystalline CVD surface. This shift of the peak is shown in more detail on the left side of fig. 3. There was applied only in the range from 1300 sm^{-1} to 1400 sm^{-1}, this makes the position more recognizable. The shift of the peak to greater value to be due to residual stresses within the coating material and diamond quality. The two sharp peaks revealed at 1340 sm^{-1} или 1350 sm^{-1}. The sharp peak, located at 1573 sm^{-1} is the most intense peak. Consequently, the diamond area would not be accurately measured.

The proportion diamond in the coating can be examined using Raman spectroscopy before and after the test (fig. 3). The software uses values that are determined at 1332 sm^{-1}, which leads to errors in the determination. The diamond quality can be determined from the ratio between the sp3 and sp2 peak areas. The microcrystalline coating showed a diamond quality 99 %. The spectrum of the microcrystalline diamond coating in figure 3b shows an obvious peak a 1573 sm^{-1}, therefore, graphite indicates a decrease in the part of the diamond (on tread — 89 %, in centre — 84,3 %). Which confirms the strong presence of graphite in the grooves between the polished edges of the diamond.

Surface characterization involving SEM and Raman spectroscopy shows that because of high hardness and chemical inertia, associated with both low friction and wear, the tribological performances of diamond coating on titanium alloy exceptional, and thus would be a better alternative than CoCr/UHMWPE. The diamond coating exhibited less wear against other samples in each respective test. Along with that, in reference samples showed a significantly higher proportion of sp3 graphite in the surface coating (the diamond quality can be determined from the ratio between the sp3 and sp2 peak areas). As a result, the diamond coating is formed on the backing and also graphite. This adversely affects the quality of the coating and impairs the tribological properties. Hence, improvements in the surface technique are needed. When using coatings must pay attention to coating adhesion and ensure the coating is uniform for successful use.

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