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Editorial

Special Issue: Surface Topography Effects on the Functional Properties of PVD Coatings

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The tribological contact between the moving components of each mechanical system degrades their performance and reliability due to friction and wear [1]. The tribological interactions of moving components depend on the properties of the materials in contact, contact conditions, as well as on the surface topography of both components [2]. In the majority of cases, the failures of moving components in mechanical systems are surface-initiated. Therefore, most engineering components are enhanced by surface treatments, which can improve their tribological properties. One of the most common and effective approaches involves the application of coatings deposited by physical vapor deposition (PVD) techniques. An important factor influencing the tribological properties of PVD coatings is their surface topography. Different topographical imperfections on the coating surface degrade its quality, which in some cases can even cause catastrophic failure in the mechanical system [3]. The knowledge of the surface topography of the PVD coating is therefore crucial. However, in the literature, the relationship between the surface topography and the functional properties of the coating has only been partially investigated.

This book provides a comprehensive overview of the surface topography of PVD coatings and their role in different tribological contacts. We show that the topography of the coating depends on the topography of the bare substrate, the substrate pretreatment (mechanical pretreatment and ion etching), and especially the deposition process. During the mechanical pretreatment of a substrate surface, it is impossible to achieve a perfectly smooth surface because each manufacturing technique (e.g., turning, milling, grinding, polishing, electro-discharge machining) leaves its own »fingerprint« on the surface. Most substrate materials are inhomogeneous. For instance, steel is composed of a ferrous matrix and different types of carbide inclusions as well as nonmetallic inclusions. During the ion etching procedure of such substrate, additional irregular surface topography is developed, because different phases have significantly different etching rates.

During the deposition process, all these irregularities on the substrate surface are transferred onto the coating surface. At the same time, additional irregularities still appear which are the result of the intrinsic coating morphology and the formation of growth defects. Although the role of growth defects in many thin-film applications is crucial, a comprehensive review of this area in the literature is still missing. The present book is intended to fill this void and provide information on the role of growth defects, especially in the tribological application of hard coatings.

This Special Issue contains ten papers that are intended for readers interested in topics related to the topography of PVD hard coatings. A brief summary of the papers in each category is provided below.

The review paper titled »Review of growth defects in thin films prepared by PVD techniques« summarizes our studies of the growth defects in PVD coatings [4]. The historical development in this research area is followed by a description of the mechanisms of the formation of growth defects. The authors described the types of defects in more detail as well as how their formation depends on the different deposition processes. They also described how growth defects affect their functional properties, such as friction, wear, optical properties, wettability, corrosion and oxidation resistance, and gas permeability, in more detail.

The paper titled »Surface topography of PVD hard coatings« presents a study concerning the surface topography of various PVD hard coatings prepared in various types of industrial deposition equipment, which differ in both the method of ion etching and the method of deposition [5]. The authors investigated how the coating topography depends on the topography of the substrate surface, intrinsic coating morphology, and growth defects.

In the paper titled »Microstructure and surface topography study of nanolayered TiAlN/CrN hard coating« [6], the authors focused on the microstructure, surface topography, layer periodicity, interlayer roughness, and formation of growth defects in the nanolayer TiAlN/CrN hard coating. They explained how these properties depend on the substrate rotation mode, the type of substrate material, and the method of ion etching. They showed that multilayer structures are very suitable for the topography study of coatings because the contours of individual layers clearly show the formation of any microstructural or topographical change.

In the paper titled »Contamination of substrate-coating interface caused by ion etching«, the authors described the problem of target surface contamination in an industrial magnetron sputtering deposition system with the residual products from the etching process [7]. They also described the mechanisms that cause the contamination of the target surface during the ion etching process and the contamination of the substrate–coating interface in the early stage of the deposition process in more detail.

In the paper titled »Comparative study of tribological behavior of TiN hard coatings deposited by various PVD deposition techniques«, the authors correlated the tribological behavior of TiN hard coatings prepared by different deposition methods, to their surface topography, microstructure and mechanical properties [8]. They also investigated how tribological properties depend on the roughness of coatings and the surrounding atmosphere (ambient air, nitrogen, and oxygen).

In the paper titled »Influence of growth defects on the oxidation resistance of sputter-deposited TiAlN hard coatings«, the authors studied the influence of growth defects on the oxidation behavior of TiAlN hard coatings sputter deposited on D2 tool steel substrates [9]. They carried out high-temperature oxidation in air at temperatures of 800 and 850 °C for 15 to 120 min. They found that pinholes and pores at the rim of nodular defects that extend through the entire coating thickness enable the fast diffusion of oxygen towards the substrate and elements of the substrate towards the coating surface.

The surface topography of orthopedic and dental implants is very important in the integration and biological response of soft and hard tissues. The paper »Laser-assisted surface texturing of Ti/Zr multilayers for mesenchymal stem cell response« deals with the surface functionalization of the Ti-base alloy in terms of improving the osteoblast cell response [10]. The authors irradiated the Ti/Zr multilayer structure using femtosecond laser irradiation in order to form the laser-induced periodic surface structure and ensure the intermixing between the titanium and zirconium layers. They found that the modification of surfaces significantly improves the adhesion of cells and their growth.

In the paper titled »Metallurgical soldering of duplex CrN coating in contact with aluminum alloy«, the authors described the performance of duplex CrN coatings used for the protection of high-pressure die-casting tools used in aluminum alloy processing [11]. Duplex CrN coatings with different roughness were evaluated by modified ejection tests with conventional (CS) and delayed (DS) casting solidification. In the case of CrN coating without a chromium oxide top layer (CS test), the ejection force increases with decreasing surface roughness. In DS tests, considerably lower values of the ejection force were recorded. A reduction in the ejection force could be attributed to the formation of a chromium oxide layer on the CrN coating after being preheated to 650 °C.

The paper titled »Properties of tool steels and their importance, when used in a coated system« describes the influence of tool steel properties (such as fracture toughness, hardness, compressive and bending strength, wear resistance, and surface roughness) on hard coating performance [12]. The tribological properties of the hard coating specifically depend on its surface topography, which is largely determined by the roughness of the substrate surface. Thus, for example, low and stable friction, as well as the excellent galling resistance of coated tools in a broad load range, can be achieved if a highly polished substrate and the post-polishing of coating are used.

The last paper, titled «Distribution of the deposition rates in an industrial-size PECVD reactor using HMDSO precursor», deals with the problem of non-uniform deposition rates in commercial plasma reactors to prepare thin films from organic precursors using the PECVD technique [13]. The plasma was formed by an asymmetric capacitively coupled radiofrequency (RF) discharge. They found that the radicals from plasma adhere to any object surface exposed to the plasma and form a thin film. Therefore, the deposition rates of hexamethyldisiloxane far from the powered electrodes strongly decreased for a fully loaded chamber. In order to achieve a homogenous film thickness distribution, a planetary substrate holder system was used.

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