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Investigation of (Ti, Al)N Based Coatings Grown by Physical Vapor Deposition

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Hard (Ti, Al)N based coatings were deposited by means of physical vapor deposition (PVD) arc ion-platting PLATIT unit on top of the stainless steel AISI 304 and hard metal substrates. The crystal structure, morphology, hardness and adhesion of coating were under investigation. (Ti, Al)N based coatings with the high hardness and smooth surfaces were obtained.

Keywords: hard coatings, XRD, SEM, hardness, adhesion.

1. INTRODUCTION

Hard coatings have been widely used to increase the wear resistance of a number cutting and forming tools. Various methods of coating deposition found industrial application. One of successful approach is physical vapor deposition (PVD) techniques.

TiN coatings deposited by PVD show a variety of positive properties such as high electric and thermal conductivity, low friction coefficient, relatively high wear and corrosion resistance [1]. The arc ion plating combines arc evaporation process with ion bombardment during coating deposition, which facilitates more stoichiometric balance within coating. However some drawbacks, namely limited oxidation resistance, rather high temperature of deposition to achieve sufficient adhesion restrict TiN coatings from wider technical application. (Ti, Al)N-based coatings find a continuously increasing interest due to high hardness, wear resistance and low oxidation rate. Especially, for high performance cutting tools these compounds show a high efficiency. In the past, the properties of (Ti, Al)N coatings grown on HSS and cemented carbides, which represent actual industrial tools, were intensively investigated [2]. Moreover, it is expected that (Ti, Al)N coatings will be eventually supplemented or even replaced by nanocomposites [3]. The corrosion properties of (Ti, Al)N coatings were investigated in a number of works [4, 5]. It was shown that (Ti, Al)N coatings are nobler than the untreated steel substrates. The presence of defects within of coatings may lead to a breakdown of the barrier properties of coatings and the development of localized corrosion, which is considered as a major corrosion. A nature of the coating/substrate interface plays significant role [4], among a number of parameters and causes influencing to the corrosion resistance, for example a thickness of coatings, buffer layer, and so on.

For our knowledge, there are no publications, concerning the deposition and properties of (Ti, Al)N based coatings on stainless steel AISI 304. This study of specific interest for the purposes of using in aggressive environment.

The present work aims to systematically study of the basic properties of (Ti, Al)N coatings on AISI 304 stainless steel and hard metal substrates, respectively.

2. EXPERIMENTAL

The deposition of TiN, TiAlN, AlTiN and nanocomposite was carried out in the arc plating PVD-unit PLATIT, LAteral Rotating ARC-Cathodes (LARC) technology. The following abbreviations are used to denote the coatings: TiAlN and AlTiN were obtained from 50/50 at.% and 30/70 at.% of Ti/Al cathodes, respectively. Nanocomposite (nc-$Ti_{1-x}Al_xN$)/(a-Si_3N_4) was deposited from two cathodes Ti and AlSi, respectively. The deposition temperature was 450 °C. The thickness of coatings was 2.5 μm.

The AISI 304 (Avesta Sheffield Inc.) and hard metal specimens were used as substrates. Before deposition the specimens were polished on emery paper, and finally with 1 μm diamond suspension, after that cleaned in ultrasonic bath with detergent. Immediately after the cleaning procedure, the samples were placed into the vacuum chamber and mounted on the sample holder. Finally, the samples were sputter-cleaned in argon plasma. A thin metallic Ti layer was deposited to substrates prior to coatings.

The X-ray measurements were performed in the Philips PW 3710 diffractometer using monochromatized Cu-Kα radiation and Bragg-Brentano goniometer. The morphology of the deposited coatings was investigated by scanning electron microscope, Jeol JSM-840A. The hardness was measured by Fischerscope H 100 VP, with 70 mN load. Adhesion testing was conducted on commercial CSM scratch tester.

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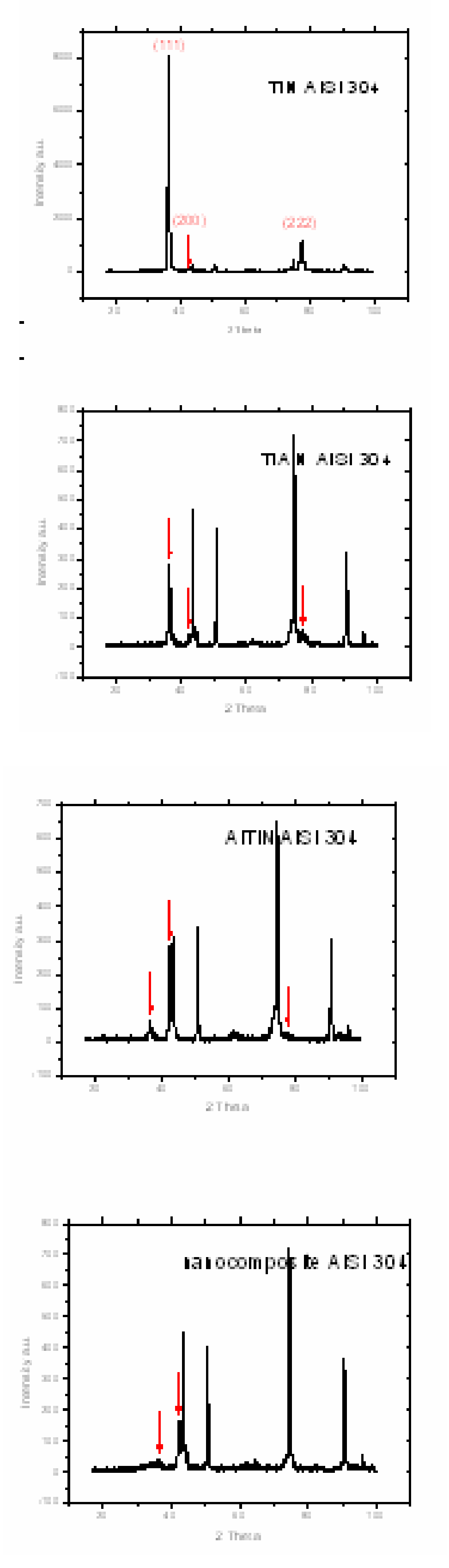


Fig. 1. XRD spectra obtained from the hard coatings deposited on AISI 304. The (111), (200) and (222) peaks correspond to the cubic NaCl-type of structure

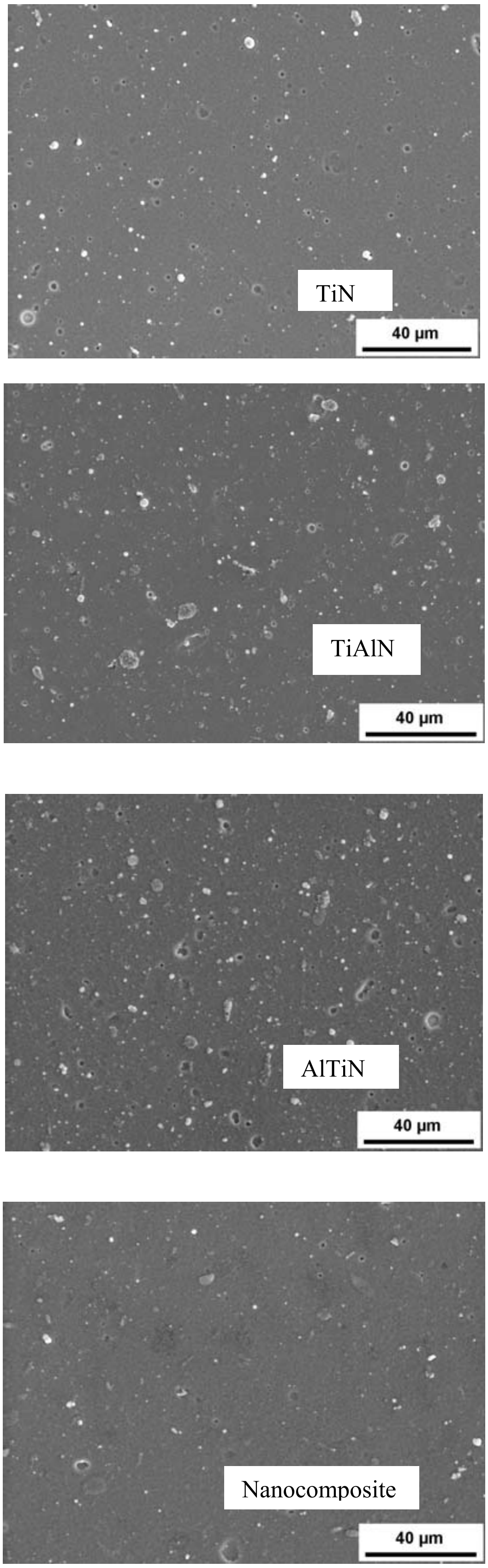


Fig. 2. SEM images taken from the hard coatings deposited on AISI 304

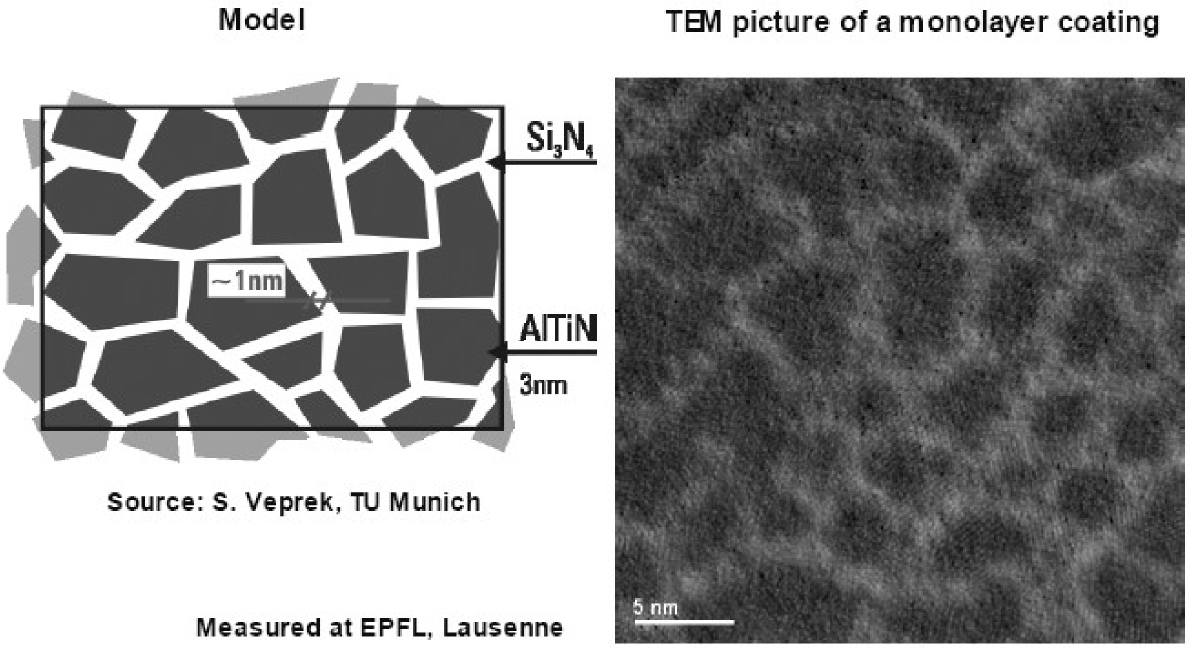
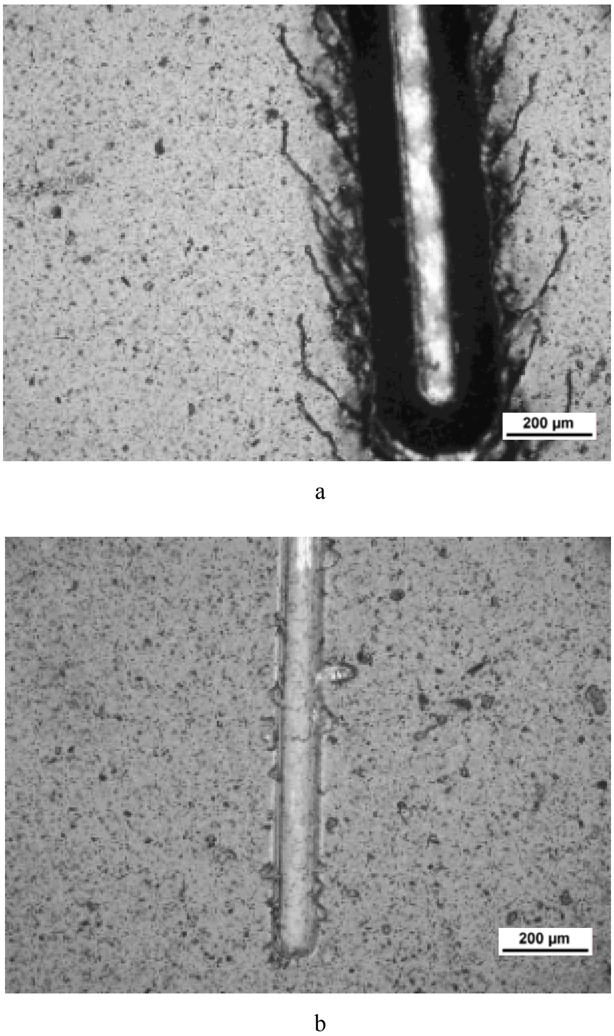


Fig. 3. Nanocomposite structure (nc-$Ti_{1-x}Al_xN$)/(a-Si_3N_4) and a model [3]



a

b

Fig. 4. A scratch track observed on top of AlTiN coating deposited: a – on AISI 304; b – on hard metal

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

Fig. 1 shows X-ray diffraction patterns obtained from TiN and (Ti, Al)N based coatings. The TiN exhibits NaCl-type of structure with strong (111) and (222) peaks meaning preferential orientation of (111) plane parallel to the coating surface. Other peaks are attributed to AISI 304. With increasing Al content the intensity of the (111) peak decreases, in contrast to the (200) peak, which becomes more intense. This phenomenon was also observed in some other works, namely within of 50 – 70 at.% of Al in coatings, the intensity of the (200) peak is dominantly high in spectrum [6], or, alternatively, steadily increases with the increase of Al content [7]. Interesting to point out that independent of type of coatings the crystal structures are identical. It is believed that Ti atoms in the TiN lattice are substituted by Al atoms, along with N content leaves constant [2, 7]. Up to 70 at.% of Al in (Ti, Al)N based coatings the structure shows NaCl-type, altering to ZnS-type (wurtzite structure) for higher Al content [7]. An similarity observed between XRD spectra of AlTiN and nanocomposite could indicate a structural identity of the (Ti, Al)N phase of the both coatings.

Fig. 2 shows SEM images obtained from coatings grown on top of AISI 304. The coatings with smooth and a low number of defects on top were grown. The best surface morphology was found for TiN and nanocomposite. However, with increasing Al content the roughness of the surface increases. The melting point of Al is relatively low, in comparison with Ti, therefore it could enhance a droplet formation. An increase in the number of defects on top of the coatings could activate localized corrosion and therefore the corrosion resistance of AlTiN could suffer from it to a greater extent than that of other coatings.

The hardness of coatings showed no dependence on the type of substrates. In the case of AISI 304, as well as hard metal the hardness increased from 31.7 GPa for TiN to 40.7 and 44.8 GPa for TiAlN and AlTiN, respectively, and, finally, reached a value of 45 GPa for nanocomposite.

It is worth nothing that the high hardness of nanocomposite is due to a nanostructure and not due to a high compressive stress [8, 9]. The structure of nanocomposite is shown in Fig. 3, a darker area corresponds to a nanocrystalline AlTiN, embedded into amorphous Si_3N_4-matrix, see whiter area. This structure enables to maintain the high hardness upon annealing up to 1100 °C [8]. However, on the other hand, this type of structure could be vulnerable in aggressive environment. One could propose an existence of the centers of corrosion along phase boundaries. It was mentioned in Introduction that corrosion mainly starts at the defects. A porosity of the coating [4], pinholes and cracks could enhance corrosion, however, in the case of nanocomposites these assumptions need further research.

The scratch test revealed low scratch adhesion of coatings on AISI 304 in comparison with hard metal, namely the first critical load was about 10 N, in contrast to about 100 N for hard metal.

Scratch tracks on top of AlTiN coating deposited on AISI 304 and hard metal are shown in Fig. 4, a and b. The corresponding scratches on all coatings were similar in appearance. Different failures of coatings can be observed along scratch track borders. In the case of coating deposited on AISI 304 cracks extend from the track, in contrast to the deposition on hard metal, where detachments of the coating from the substrate take place. The scratch test is widely used method for adhesion evaluation, in spite of the fact that many parameters could influence to the scratch results [10, 11], for instance, the hardness of the substrate. Present results could be treated as an indication of a difference between coating/substrate interfaces for AISI 304 and hard metal, respectively. The coating/substrate interface is of importance in an understanding of corrosion [4].

3. CONCLUSIONS

The (Ti, Al)N based coatings deposited on AISI 304 show high hardness, reasonable low number of imperfections on the surface of coatings and relatively low adhesion. An increase in the number of defects on top of AlTiN and cell-like structure of nanocomposite could lead to reduced corrosion resistance.

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