Structural Characterization and Corrosion Performance of Super Hard Composite Coating: An Overview

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Abstract

This study is focused on super hard materials in terms of their characteristics assessment, super-hardness coating techniques and super-hardness coatings as corrosion inhibitors. However, plasma cladding showed good and effective technique for surface performance enhancement. Taper abrasion tests revealed enhanced good mechanical wear resistivity of the coatings which was the result of applying the magnetron sputtering technique. Also the study showed the importance of super-hard coatings techniques as corrosion inhibitors in roofing materials in protecting the roofing sheet from corrosion or rust due to the influence of moisture content of the air as well as rainfall.

Keywords Coating, Corrosion, Super hard, Hardness

1 Introduction

The quest for super hardness in materials by researchers is important because proper combination of material hardness value which can exceed the hardness value of diamond provides a better material for advance manufacturing purposes. Hardness therefore is the measure of the ability of a material to resist failure when subjected to load. Further definition of theoretical hardness, is a measure of the resistance of a material to deformation under isostatic stress (Vepr, 1999). According to (Fischer-cripps, 2016), in measuring hardness of a material, the area of projection of the indent performed in a significant pattern when the indenting device is withdrawn which invariably led to an immense rise in the measured hardness value by a factor of two. Therefore, from finite element analysis approach measurement of hardness by indentation revealed that the Meyer measure of abrasion of diamond is greater compared to that of the controlled quality when the indentation is used as a fundamental calculation. However better hardness values in materials such as Zn-Sn-Ti coating of mild steel can be obtained by applying laser technology. A laser power application of 750W and 900W together with a scanning speed of 0.6 and 0.8 m/min produced a better hardness value as well as better corrosion resistance and microstructure of the mild steel. It can be deduced therefore that surface hardness values and better corrosion behavior can be improved using that laser alloy of Zn-Sn-Ti on UNS G10150 steel (O.S. Fatoba, A.P.I. Popoola, 2016). Application of non-direct proportion FEM and "Bückle rule", to investigate the failure of softer underlying layer during impression of hard and super hardness materials revealed that thickness ratio of the coatings to the depth of impression rises with improving abrasion of the coatings more than the control value given by Bückle's rule (Veprek-heijman & Veprek, 2015). The aim of this study is to assess the super hard coating characteristics, performance as well as corrosion inhibition ability.

2 Super hardness Coatings and Characteristics Assessment

Plasma cladding is a good and effective technique for surface performance enhancement. Microstructure of with concentrated-entropy alloy composition can be developed using plasma cladding technique. However a comparative study of microstructural behavior and thermodynamic evaluation revealed that combined FeCoNiAl Cu resulted to a structural analysis which composed of an FCC1 phase doped with Fe and Cu, and FCC2 phase doped with Cu and a BCC phase doped with Fe. However the thermodynamic behavior and experimental analysis of the phase composition agreed to a greater extent (Cai et al., 2017).

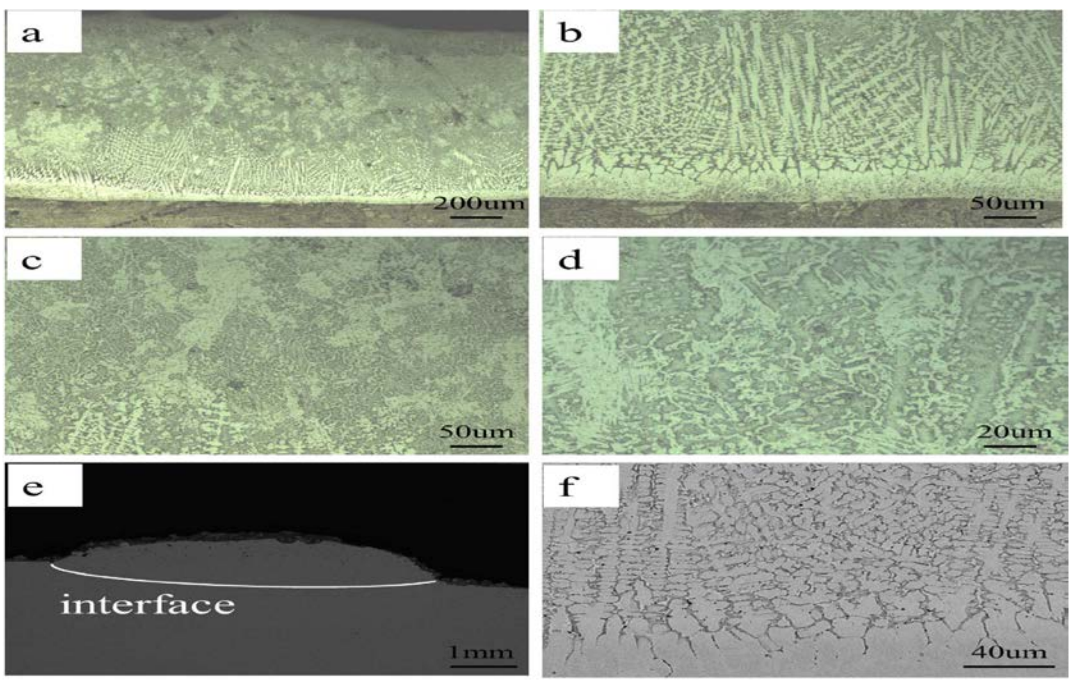

Figure 1. OM images and SEM micrographs of FeCoNiAl Cu coating (a) the entire coating, (b) the interface region of substrate and coating, (c) the central region of the coating and (d) the topside region of the coating, (e) low magnitude and high magnitude (f) SEM micrographs of the entire coating. [Source: Z. Cai et al., Surface & Coatings Technology 330 (2017) 163–169]

Furthermore surface adhesion as well as quality improvement of diamond drill can be achieved by coating the surface with microcrystalline and nanocrystalline diamond. However optimization with nanocrystalline sized diamond grains is better in performance such as force reduction, improvement of the hole quality, reducing tool wear and increasing the tool life (X. Wang, Shen, Yang, & Sun, 2017).

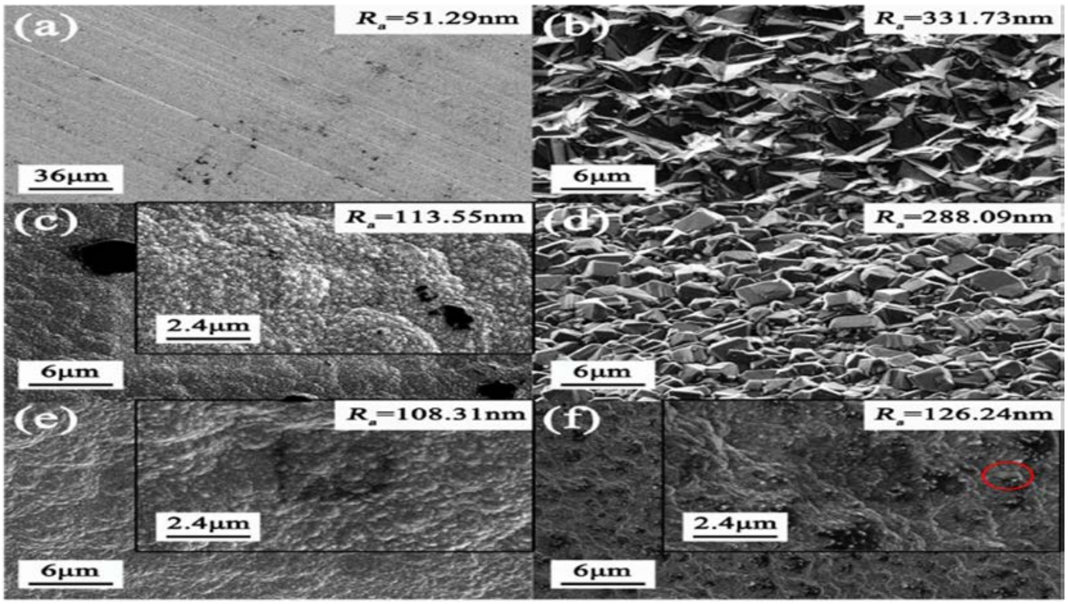

Figure 2. Surface morphologies of (a) uncoated, (b) MCD, (c) NCD, (d) BDMCD, (e) BDNCD and (f) 2-BDMC-NCD coated drills [Source: X. Wang et al., (2017). Surface & Coatings Technology 330 149–162]

According to (Zhou, Yang, Wang, & Pang, 2017), annealing a coated aluminum surface at different temperature and studying the phase characteristics, morphology, diffusion element using scanning electron microscope and X-ray diffraction, revealed that tiny openings and drops on the face of the coating slowly varnished with increase in annealing temperature. However chromium spread to the top surface of coating. However application of duplex coating techniques and electrochemical analysis had shown the importance of the techniques in enhancement of corrosion resistance, synthesized corrosion attack of uniform and pitting corrosion. Though the best corrosion protection of the duplex coatings was achieved when the coatings were laser annealed (Liu & Liu, 2017) (Fayomi, Joseph, Popoola, Popoola, & Ferrão, 2017).

(Moreira, Costa-barbosa, Mariana, Sampaio, & Carvalho, 2017) carried out a comparative study on tantalum and tantalum oxide as bioactive coating agents because of their cell activation, adhesion and proliferation. The coating effects of tantalum and tantalum oxide on a 316L stainless steel revealed that tantalum showed a mixture of the α-Ta and β-Ta phases, whereas tantalum oxide appeared nanocrystalline in structure. Also the two bioactive agents do not have any inflammatory response from macrophage cells.

(Safonov et al., 2014) investigated the importance of effective coatings on the surface of man-made joints because of their greater hardness, the force of adhesion and the low coefficient of friction of the oxide magnetron sputtered coatings. The result of this study showed that thin film deposition had great improvement on the corrosion resistance of 10 for both titanium alloy substrate and steel. Observation of the nanocrystalline oxide coatings showed enhanced biocompatibility. CYSZ/Al_2O_3 ceramic TBCs were produced in double layered and FGed design having 4, 8 and 12 layers by high-velocity oxy-fuel and atmospheric plasma spraying processes. Cross sectional examination of the microstructure showed that the bond coat showed zero porosity and perfect adhesion of the substrate and the ceramic top coat was equally achieved. Variation in thermal conductivity values were observed and found that functional graded coatings had lesser thermal conductivity than single layered CYSZ and double layered CYSZ/Al_2O_3 due to interfaces between them (Kirbiyik, Guven, & Goller, 2017).The effect of powder injector distance on the microstructure and characteristic of TiCN revealed that TiCxN1 − x (0≤ x ≤1), Ti2O and/or residual graphite phases, and the amount of residual graphite and Ti_2O phase increases with the increase of distance. However the coating sprayed at 3mm distance showed an improved mechanical and wear properties which are likened to the high Vicker micro hardness and strong bonding strength (Qin, Zhu, He, Yin, & Nan, 2017). Various methods have been used to analyze hydroxyapatite coatings on nanotubes of Ti–25Ta–xZr alloys which was prepared using electro-chemical deposition for dental implants. The result observed from optical microscopy, scanning electron microscope, X-ray diffraction as well as image analyzer showed that Microstructures of the Ti–25Ta–xZr alloys changed fromα″ phase to β phase, and the phases changed in morphology from a needle- like to an equiaxed structure with increasing Zr content. more so the nanotubes pattern changed from irregular pattern of distribution to a high level of ordering guarded by few tubes (Kim, Jeong, Choe, & Brantley, 2014).

3 Super hardness Coating Techniques

One of the techniques used in improving the oleophobic behavior of glass deposited with Zn–Sn–O–N and Si–Al–O–N is the magnetron sputtering which can be done at various nitrogen-to-oxygen ratios. Mechanical wet sheening, Taper abrasion tests revealed enhanced good mechanical wear resistivity of the coatings. Stability of chemical and mechanical resistivity of the oleophobic films were achieved at temperatures, air humidity and time (Bernt, Ponomarenko, & Pisarev, 2017). However, according to (Choy et al., 2017), the use of the recent laser microwave technique to produce titania/hydroxyapatite/tricalcium phosphate (TiO_2/HA/TCP) complex coating on titanium alloy (Ti_6Al4V) substrate, proven to be one of a better technique for coating as it provide a useful improvement in the osteoconductive property over the uncoated sample. The laser-microwave hybridization provides a better route to synthesize HA/TCP based coatings for bioactivity enhancement, and serves as an effective sterilization tool for implant materials.

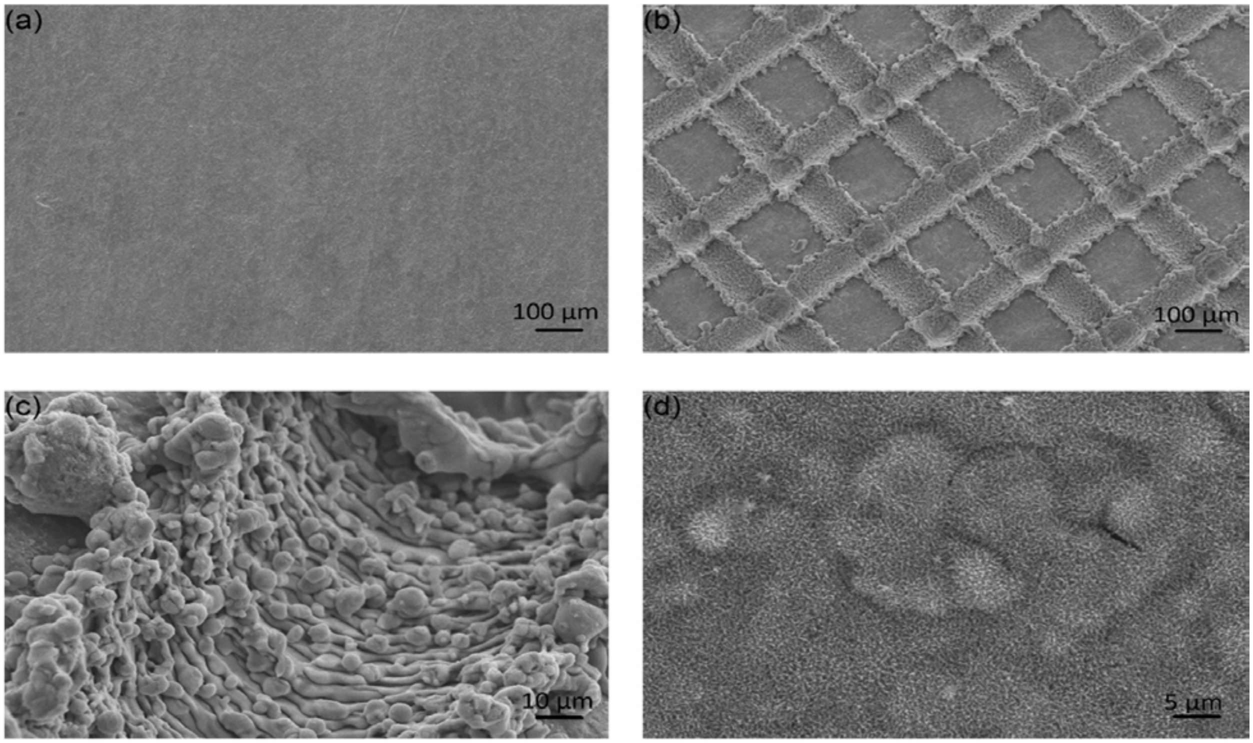

Figure 3. Morphology of (a) pure Ti6Al4V, (b) linear groove micro-patterns, (c) micro-pillars created by laser ablation, and (d) porous network created by NaOH etching (Source X. Wang, Shen, Yang, & Sun, 2017).

(Shari, Pugh, Moreau, & Dolatabadi, 2016) applied the atmospheric plasma spraying and suspension spraying techniques to determine their effectiveness on micro/nano morphologies of super hydrophobic coatings with high degree of water repellence and mobility. The analysis of the results showed that coatings deposited by atmospheric method reached water contact angles of 145°, but with a low water mobility due to heavy morphological feature. But on the other hand coatings developed by suspension spraying technique showed a better water repellence as well as improved mobility. More so the atmospheric plasma spraying and suspension plasma spraying techniques were equally used (Aghasibeig, Dolatabadi, Wuthrich, & Moreau, 2016) to create Nickel-based terminal coatings for hydrogen generation by antacid water electrolysis. However this reason, two work screens with various wire sizes and work densities were utilized to cover the substrates amid APS process. Therefore, extraordinary full scale and minute levels of surface harshness were made by assembling three-dimensional blade clusters. The outcomes indicated diverse harshness esteems and smaller scale structures on the highest point of the blades, inclines of the balances and under the work wires. (Belei, Fitseva, Santos, Alcântara, & Hanke, 2017) reinforced Ti-6Al-4V with TiC using friction surface coating technique. Coating behavior of this technique showed irregular structure in deposition especially for low distances to the rod centre and ejected particles lying loosely on the substrate adjacent to the coatings. With increasing hole distance to the center, the detrimental effects of the particles on the process behavior and the resulting coatings' appearance diminished. (Y. Wang et al., 2017) also studied the effects of pack cementation technique on the coating of an Al-Ti. The multilayer structure of this coating was "α-Al2O3/TiO2/transition layer". The oxidation behavior of Al-Ti coating changed with the nitridation pretreatment, and a better α-Al2O3/TiO2 composite coating was obtained. According to (Li et al., 2017) production of an antibacterial with extensive life span for implant development involved the combination of hydroxyapatite (HA)-gentamicin sulfate (GS) composite powder deposited on titanium substrate using the vacuum spraying technique at room temperature. The result from trans- mission electron microscopy (TEM), field-emission scanning electron microscopy (FE-SEM), Fourier transform infrared spectroscopy (FTIR) and X-ray photoelectron spectroscopy (XPS) analysis showed that effective loading of coating with antibiotic gave an extensive antibacterial capacity and the developed HA-GS composite coatings showed excellent biocompatibility. Application of radio frequency plasma gave a better chemical vapour deposition (RF PECVD) technique during carbon coating had shown a great improvement on the hardness behavior, refractive index as well as density of coating deposited (Jedrzejczak et al., 2017).

Atomic layer deposition has an excellent result when used to compare the coating effectiveness of Al_2O_3 and TiO_3 films on polyethylene terephthalate (PET) substrate. Al_2O_3gave the highest efficiency compared to TiO_3 on substrate (Edy et al., 2017).

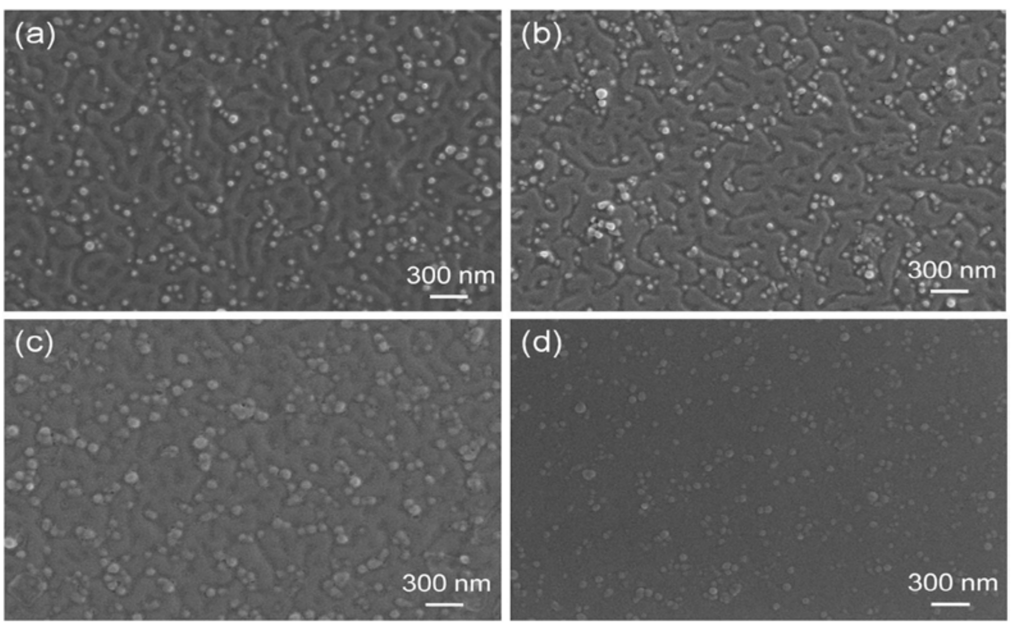

Figure 4. SEM images of (a) uncoated PET and the PET surface coated (b) TiO_2, (c) Al_2O_3 by ALD with 100 cycles (d) Al_2O_3/TiO_2 bilayer with both materials of 100 ALD cycles (Source: Zuo, Li, Zhao, & Tang, 2017)

Pd-Co gradient coating always gives a uniform, compact as well as grain size reduction from the inside of the interface to the outer layer when prepared on stainless steel using electro-deposition density in the same electrolyte bath. Also, greater micro-hardness, improved adherence strength, lower internal stress and porosity were achieved (Zuo, Li, Zhao, & Tang, 2017).

4 Super hard Coating as Corrosion Inhibitor

Coatings techniques have been widely used in the industry most especially in roofing materials to protect the roofing sheet from corrosion or rust due to the influence of moisture content of the air as well as rainfall. (Jantaping, Schuh, & Boonyongmaneerat, 2017) presented a study on the influence of microstructure on the corrosion characteristics of coatings using fabricated galvanized coatings with coating additives. The result of the study revealed that additives enhanced the microstructure of the galvanized coatings and the chromate layer. However the corrosion resistance of the coatings can be improved by reducing the crystallographic planes and also reducing the defects substrate interface.

Application of cobalt super hydrophobic samples on aluminum substrate would produce an excellent catalytic properties as well as enhanced corrosion resistance of aluminum substrate (Wu et al., 2017).

Further to this, (Fayomi & Popoola, 2015) improved balance in the corrosion behavior of Zn–Al–SnO_2/TiO_2 developed from chloride coating can be achieved by investigating the corrosion behavior using the linear polarization technique in a NaCl media. However the corrosion resistance behavior on the functioning substrate is a function of the development of unified and regular precipitation from the integrated particulate. In an effort to predict the effects of synthesizing and application of the coating techniques, hybrid technique (PVD and chemical heat treatment) was used to deposit titanium nitride coating on the AZ91D magnesium alloy and the result showed a great improvements on the corrosion resistance of the developed substrate (Tacikowski, Banaszek, & Smolik, 2014). However, more hybrid techniques can be adopted to improve corrosion resistance in coated materials. For instance the addition of Triton X-100 and D-maltose (DM) to TiAl7Nb alloy to develop polypyrole films showed a great increase in the corrosion resistance as well as stable electrochemical films (Mindroiu, Ion, Pirvu, & Cimpean, 2013). To further investigate on how the wear properties and corrosion resistance of artificial joint can be improved in order to enhance their performance while in operation, (Safonov et al., 2014) observed the effect of oxide coating on stainless steel and titanium alloy and the result showed that the effect of oxide coating on the stainless steel had improved the corrosion resistance greatly. More so measurement of coating levels using electrochemical equipment of treated steel materials with polyacrylic acid and Mo based layer revealed that polyacrylic acid improved the corrosion resistance of steel to a desirable height (Gao, Li, & Ma, 2017).

5 Conclusion

Super hard coatings refers to the treatment of the surfaces and the near-surface zones of material to allow the surface to efficiently carry out operations that are quite excellent from those functions demand from the whole of the material. It is however important to treat engineering surfaces in order to improve the corrosion resistance, oxidation, frictional energy losses, wear resistance as well as mechanical properties.

The study therefore focused on the characteristics assessment, techniques and corrosion resistance of super hardness coatings. Various techniques of super hard coatings were studied as well as the various techniques of improving the corrosion resistance of super hard materials. Plasma cladding and magnetron sputtering have been established as good coating techniques.

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