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Enhancement of Corrosion, Mechanical, and Tribological Properties by Using a $[CrN/AlN]_n$ Multilayer System

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Abstract – $[CrN/AlN]_n$ non-isostructural multilayered systems with various periods (λ) have been synthesized by reactive magnetron sputtering and deposited on AISI D3 steel. Five CrN/AlN systems with n=1, 10, 20, 40, and 50 bilayers were made. The minimum period reached was 60 nm (50 bilayers). All the systems were evaluated in terms of corrosion resistance, mechanical and tribological properties. A Multilayered structure is shown in Fig. 1. The multilayer system with 50 bilayers revealed the best combination of properties. Conclusions of this study were relevant for our national manufacturing industry in wear-resistant cutting, forming tools, and mechanical devices.

The first generation of single-layer hard coatings such as TiN, CrN, AlN, WC, and DLC played an important role in the past, because of their enhanced mechanical and tribological properties. CrN, especially, has been used as a protective coating material because of its excellent mechanical and thermal properties, but the application of CrN films is restricted since CrN tends to oxidize rapidly at high temperatures above 700 °C. To meet environmental demands, the material´s properties should be improved to overcome related deficiencies. A way to upgrade the properties of CrN coatings is to deposit two kinds of nitride coatings alternately to create multilayers or superlattices like TiN/CrN, WC/CrAlN, and CrN/NbN [1].

Enhancement of corrosion, mechanical, and tribological properties by using a $[CrN/AlN]_n$ multilayered system with various periods (λ) via magnetron sputtering method was studied in this work. The coatings were characterized in terms of crystal phase; micro-structural, electrochemical, mechanical, and tribological properties by X-ray diffractometry (XRD), Fourier transform infrared spectroscopy (FTIR), atomic force microscopy (AFM), scanning electron microscopy (SEM), electron dispersive spectrograph (EDS), Tafel polarization curves, electrochemical impedance spectroscopy (EIS), nanoindentation, pin-on-disc, and scratch test. Corrosion evolution and the failure modes mechanism were observed via optical microscopy. Results from XRD analysis revealed that the crystal structure of $[CrN/AlN]_n$ multilayered coatings has an NaCl-type lattice structure and hexagonal structure (wurtzite-type) for CrN and AlN, respectively, *i.e.*, we made non-isostructural multilayers. The AlN coating revealed the poorest behavior in all tests, while the best behavior was obtained when the multilayered period (λ) is 60 nm (50 bilayers), showing maximum corrosion resistance (polarization resistance of 1.18 KΩ, and corrosion rate of 1.02 mpy), the highest hardness and elastic modulus (28 GPa and 280 GPa, respectively), optimum tribological behavior, critical load (friction coefficient of 0.18 and critical load for the adhesive failure of 43 N, respectively), that meant enhanced corrosion resistance, hardness, friction coefficient, and adhesion with respect to the AlN single-layer coating at 98%, 84%, 46%, 24%, 58%, 44%, respectively. These enhancement effects in multilayered coatings could be attributed to different mechanisms for layer formation with nanometric thickness due to the Hall Petch effect. Because of this effect, originally used to explain the increase in hardness with decreasing grain size in bulk polycrystalline metals, it has also been used to explain the hardness enhancements in multilayers. Other effects could be attributed to the number of interfaces or relaxation stress between layers.

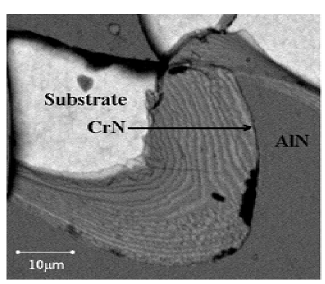

Figure 1: SEM micrograph for $[CrN/AlN]_{20}$ coating after scratch test in a top view.

[1] B.S. Kim, G.S. Kim, S.Y. Lee, B.Y. Lee. Surface and Coatings Technology 202 (2008) 5526-5529.