

DECORATIVE PVD COATINGS AS AN ENVIRONMENTALLY CLEAN ALTERNATIVE TO CHROME PLATING

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Abstract – *The objective of this work is to conduct applied research and development to demonstrate that metal or ceramic coatings deposited by Physical Vapor Deposition (PVD) are equivalent or superior in performance and are a cost-effective alternative to chrome plating in decorative applications. Chromium plating is commercially used to produce wear-resistant and decorative coatings, but the plating bath contains hexavalent chromium, which has adverse health and environmental effects. The present study describes and compares the mechanical and tribological properties of TiN, AlTiN, ZrN and ZrCN coatings deposited by CAPVD (cathodic arc plasma physical vapor deposition), on nickel plated aluminium substrates. The properties of the above mentioned PVD coatings have been compared with the properties of conventional chromium plating.*

Keywords – *Physical vapour deposition, Decorative coating, Mechanical properties, Tribology, Adhesion.*

INTRODUCTION

The increasing environmental and worker safety pressures on chrome plating are leading many industries to adopt alternatives. Chromium plating is commercially used to produce wear-resistant and decorative coatings, but the plating bath contains hexavalent chromium and produces large volumes of chrome-contaminated toxic waste, which have adverse health and environmental effects. For this reason, the use of hexavalent chromium is being limited. It has not been until the last decade that strong activity aimed towards systematically replacing this “dirty” technology with high performance dry coating “clean” methods. Engineers faced the difficult problem of finding an appropriate alternative coating technology, which would offer quality and cost-effective production coatings according to the available standard in each case. Among the many available technologies the processes that are most widely viewed as being capable of replacing chrome plating are the physical vapour deposition (PVD) and chemical vapour deposition (CVD) techniques, which are used to produce functional hard coatings or decorative thin films. Deposited PVD coatings can have a wide colour range, for example, titanium nitride (TiN) is gold coloured, and titanium carbonitride (TiC_xN_y) can vary in colour from gold to purple to black depending on the composition. Zirconium nitride (ZrN) has the colour of brass and is much more wear and scratch resistant than brass. Decorative/wear coatings are used on door hardware, plumbing fixtures, fashion items, marine hardware, and other such applications.

EXPERIMENTAL DETAILS

Coating deposition

The coatings studied in this research were TiN, TiAlN, ZrN and ZrCN deposited by PVD/CAPVD (cathodic arc plasma physical vapour deposition) on a nickel plated aluminium 6063 substrate with a thickness around 0.5 μm. A compact MIDAS 450 system (Millennium Coatings S.L.) equipped with three advanced controlled arc cathodes in a chamber volume of 1 m³ was used for coating deposition. PVD decorative coatings are by their nature very thin, and do not act as a corrosion barrier. Therefore, the decorative PVD coatings should be applied on top of the corrosion resistant nickel electroplated coating. The properties of the above mentioned PVD coatings have been compared with the properties of conventional chromium plating on a nickel plated aluminium substrate.

Coating characterisation

The mechanical properties of the coatings were determined with an ultra-microhardness testing system, capable of measuring force versus displacement, using a Vickers diamond indenter (DIN 50359). Tribological evaluation was performed using a pin on disc tribometer, according to ASTM wear testing standard (G-99). Furthermore, the scratch tests technique was employed for adhesion evaluation of the coatings.

RESULTS

Table 1 shows the average results of the plastic hardness and specific wear rate (Pin on disc tests under lubricated conditions) for the studied coatings. The hardness values obtained for the AlTiN coating were the highest among the PVD coatings under study. The hardness of the TiN, ZrN and ZrCN coatings were quite

close to each other, and hence the differences between them could be considered to be within the standard deviation interval. Furthermore, all studied PVD coatings presented higher hardness and elastic properties than conventional chromium plating.

Table 1: Mechanical and tribological properties and coating adhesion

	chromium plating	TiN	AlTiN	ZrN	ZrCN
Plastic hardness (GPa)	8.4	16.1	29.2	15.7	16.1
Specific Wear Rate ($m^3/m.N \times 10^{-16}$)	4,24	1,1	5,27	1,27	0,44
Critical load failure (L_c) (Scratch test) (N)	9	15	11	25	23
Coating colour	Silver coloured	Golden yellow	Grey anthracite	Brass coloured	Golden coloured

Despite having the highest hardness, the AlTiN coating presents a high specific wear rate, probably as a consequence of residual stresses within the coating that lead to a higher adherence loss. On the other hand, it can be observed that studied PVD coatings, with exception of the AlTiN coating, have better tribological performance than the conventional chromium plating.

The Coating adhesion was evaluated by the critical load, i.e. the normal load at the first coating failure, was found to increase in the following order: conventional chromium plating, AlTiN, TiN, ZrCN and ZrN (see Table 1). In all coatings, the critical load corresponded to semicircular cohesive failures, which are typical for brittle materials. For loads higher than the critical load the coatings showed large cracks, on both sides of the scratch. For all PVD coatings the level of the critical normal load is probably sufficient for many applications.

CONCLUSIONS

The studied PVD ceramic coatings are better than the traditional chromium electroplated coating due to their superior hardness, adhesion and wear resistance. The PVD coatings can replace the decorative wear resistant coatings; in addition a wide colour range is available.

The introduction of PVD processes as a substitute for chromium plating in decorative applications represents a development towards an environmentally clean technology. Future successful applications of PVD coatings, as alternative to chromium plating, should considered collectively many factors like wear resistance, friction coefficient, costs and environmental issues.