

Introduction

Electroplated hard chrome is a common surface finishing approach in many engineering industries due to its high hardness and excellent corrosion resistance. However, environmental and health regulations on chromates drive the exploration of alternative coating methods, among which physical vapor deposition looks very promising.

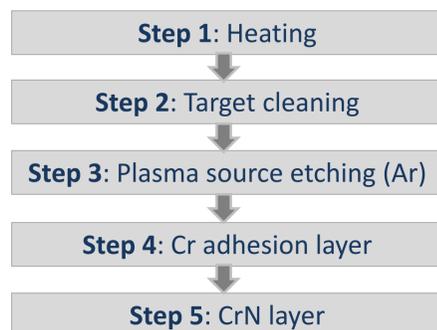
This study aims to evaluate PVD CrN as a viable replacement for hard chrome. A way to achieve an increased performance of PVD coatings in terms of wear and corrosion resistance is the use of High Power Impulse Magnetron Sputtering. The HIPIMS technology is believed to allow for coatings with superior mechanical, tribological and wear resistant properties compared to DC-MS. Also a combination of DC-MS and HIPIMS is evaluated. CrN coatings are deposited by means of DC-MS, HIPIMS and combined DC-MS/HIPIMS. Mechanical (Calo test, Nano indentation test, 3D Profilometry (Confocal microscopy), Taber Abrasion test) and tribological (Pin-on-disc test) properties of the different coatings are studied and compared to electroplated hard chromium.

Experimental

Hard chromium

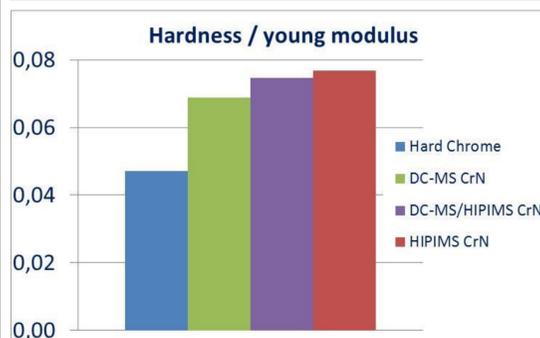
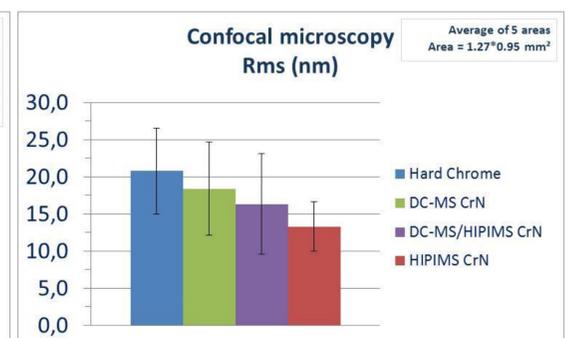
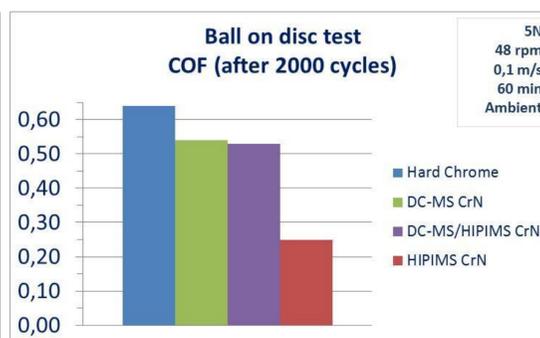
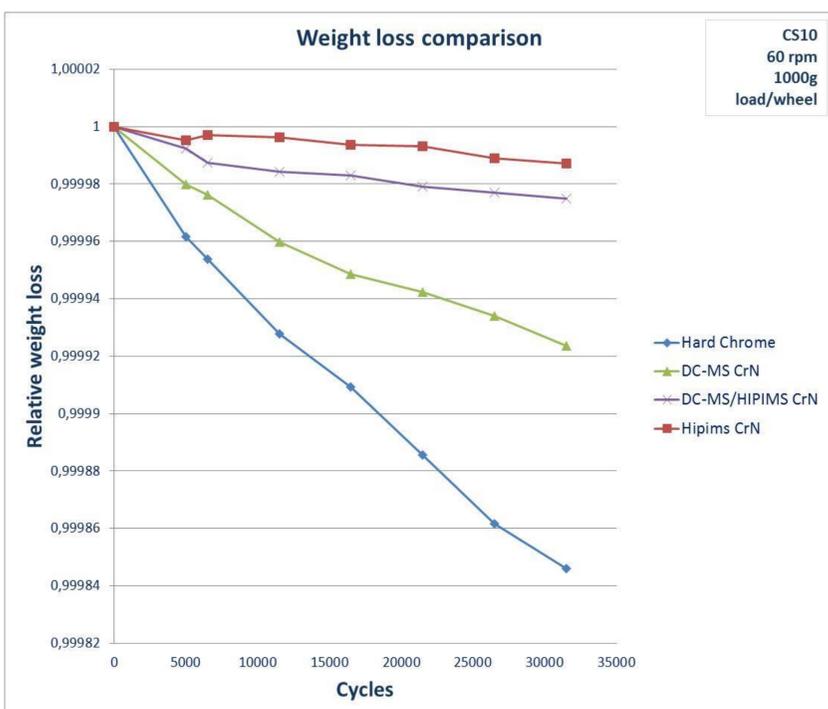
- Electroplated
- 25 μm thick
- Reference coating

PVD CrN coatings



	DC-MS	HIPIMS	DC-MS/HIPIMS
Step 4 : Cr adhesion layer	5' stationary	5' stationary	15' rotational
Step 5 : CrN layer	60' stationary	240' stationary	400' rotational

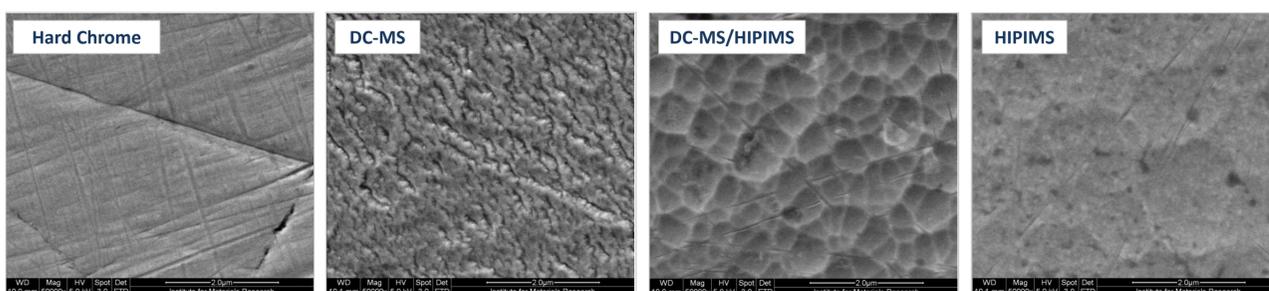
Results



Salt spray test (ISO 9227)

- 33-37°C
- [NaCl] = 5 ± 0.5%
- 1 to 2 ml/hour/80 cm²
- pH = 6.5 – 7.2

➔ After 300 hours no corrosion detected for all coatings



Conclusions

- PVD coatings perform better than thick hard chrome layer (25 μm)
- HIPIMS coating shows:
 - ☺ Highest abrasion resistance
 - ☺ Highest hardness / young modulus ratio
 - ☺ Lowest coefficient of friction
 - ☺ Lowest surface roughness
- DC-MS/HIPIMS allows higher deposition rate, while maintaining high abrasion resistance
- No corrosion detected after 300 hours for all samples

	Hard Chrome	DC-MS	DC-MS/HIPIMS	HIPIMS
Thickness (μm)	24.9	3.4	4.8	6.1
Hardness (GPa)	11.6 ± 0.9	20.0 ± 1.0	24.0 ± 4.0	26.0 ± 4.0
Young Modulus (Gpa)	246 ± 11	291 ± 13	322 ± 35	339 ± 37

General conclusions

From this study it can be concluded that PVD CrN can serve as an alternative for hard chrome. The thin (3,5 – 6,0 μm) PVD CrN coatings perform better than a 25 μm thick hard chrome layer in terms of abrasion resistance. Furthermore, a tribological study, using an Al₂O₃ counter body, shows that all PVD coatings exhibit a lower COF compared to hard chrome, making them more favourable for anti-stick applications. Best results are obtained for the HIPIMS CrN, showing the highest hardness (26.0 GPa) and abrasion resistance in combination with the lowest surface roughness and coefficient of friction (0.25). Furthermore, the desirable condition of a high hardness with a relatively small Young's modulus, which is a measure for the coating's toughness, is seen for this layer.

It is known that a lower deposition rate is inherent to the HIPIMS technology. However by combining the DC-MS and HIPIMS technology we were able to increase this deposition rate, while maintaining the desired mechanical properties (high abrasion resistance, high hardness/young modulus).

To evaluate the corrosion resistance all coatings were subjected to a salt spray test. After 300 hours still no signs of corrosion were seen for all coatings with the PVD CrN samples having only a thickness of 1/5th of the thickness of hard chrome. Further corrosion tests are still on going. Results are expected in the near future.