Industrial Use of HiPIMS with Voltage Reversal: High Deposition Rate of Metal Nitrides and DLC Coatings

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HiPIMS with $V^+$

High density of ions in HiPIMS, so.....

.........any effect on plasma and coating properties?
HiPIMS with V+

A new ion extraction mechanism: acceleration from target surface.

Raise of plasma potential (bombardment of low V surfaces)
HiPIMS V+
Floating Potential

\[ E_i = E_0 + Qe \left( V_{\text{plasma}} - V_{\text{surface}} \right) \]
**HiPIMS with V+ H-free DLC**

6kW Hip-V 1200V – 500A.
Cr, WC and Graphite targets
40x10 cm² rectangular magnetrons.
Pure Ar atmosphere.
Deposition on Silicon + HSS coupons
HiPIMS V+ on graphite: IEDF

High energy ions are generated in the switching electric field.
Nanomechanical properties: H/E-t-a:C

More energetic ions → higher sp³ hybridization

Hardness = 36GPa
Young’s Modulus = 248GPa

Triboindenter TI950 from Hysitron equipped with a diamond Berkovich indenter.
Raman shift – Carbon Coatings

A.C. Ferrari, Chapter 2 in “Tribology of Diamond-Like Carbon films”
Getting close to t-a:C by filtered-arc

Reference commercial ta-C by Filtered Arc (60% sp3)

- G peak shift to higher wavenumbers
- D peak reduction

Raman excitation wavelength Argon 522nm (Green)
Double HiPIMS: Cr-doped DLC

Nanoindentation tests: Air, diamond Berkovich tip, Hysitron Xsol Stage and Tip

Stable up to 400°C

Hardness (GPa)

Temperature (°C)
Cr-DLC: Wear vs T in air

Lowest wear rate for Double HIPIMS Cr:DLC! $< 0.5 \times 10^{-15} \text{m}^3/\text{Nm}$ at $200^\circ\text{C}$

Low amount of Cr is sufficient to delay graphitization.
COF for Cr-DLC as low as 0.02 at 200ºC
(as compared to 0.08 for standard 30GPa DLC)

Pin-on-disk conditions: Air, Al2O3 ball, 5N, 10cm/s
Examples of ‘Hard’ DLC Coated Parts
Implementation on Industrial Tool

xPro4C
DLC - Coating System
HiPIMS with V⁺ TaN CFUBM

<table>
<thead>
<tr>
<th>Dep. rate [μm/hr]</th>
<th>0.51</th>
<th>0.42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness [GPa]</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>POSITIVE</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

25% increase of deposition rate (ion incorporation into the film)
CrN/ZrN in Industrial System
CrN/ZrN in Industrial System

3-fold rotation
2 x magnetrons
5kW average each
-60V bias
450 mm diameter x
650 mm height
CrN/ZrN in Industrial System

23-25 GPa
250 C

1μm/hr!! for CrN and ZrN
Summary

- HIPIMS with Positive Voltage Reversal can be used to control the degree of metal/gas ionization as well as ion energy
- 25% increase in deposition rate as compared to standard HIPIMS
- Self “Ion Assisted” deposition for coatings on insulating substrates
- Successfully implemented on several Industrial platforms
Thank you for your attention !!