HiPIMS with positive voltage reversal: widening the process window

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HiPIMS with positive V reversal

I_{peak}
HiPIMS with positive V reversal

Serial switching in Asymmetric Bipolar Pulsed-DC!


Thomas Welzel, PhD thesis. “Time resolved characterization of pulsed magnetron discharges for the deposition of thin films with plasma diagnostic methods”
Bipolar Pulsed HiPIMS (BHP)

Time resolved Ti+ ground state density above the cathode.

Laser induced Fluorescence (LIF) imaging.

Baohua Wu et al., “Cu films prepared by bipolar pulsed high power impulse magnetron sputtering” Vacuum 150 (2018) 216-221
J.A. Santiago et al, “The influence of positive pulses on HiPIMS deposition of hard DLC coatings” Submitted to SCT
Hardness $= 36 \text{GPa}$
Young’s Modulus $= 248 \text{GPa}$

More energetic ions $\rightarrow$ higher sp$^3$ hybridization

Triboindenter TI950 from Hysitron equipped with a diamond Berkovich indenter.
‘Passive’ voltage reversal: shorter pulses (<5us) and delay time (<1us)

Tests performed in different batch coaters

Presented at SVC 2016
TaN coatings in a CFUBM

Rectangular magnetron 550x125 mm²
Ar + N2 atmosphere
RT deposition

50 cm
1. New technology launched at 2016.
2. Demonstrated >25% increase in deposition rate for Me-N and ta-C in different industrial machines (for example in PVT and Tekniker batch coaters).
3. Generate enhanced coating ion assistance → denser coating structure.
4. Reduced arc appearance in reactive sputtering.

<table>
<thead>
<tr>
<th>Deposition Rate [µm/hr]</th>
<th>0.51</th>
<th>0.42</th>
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<tbody>
<tr>
<td>Hardness [GPa]</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>Positive Pulsing</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

Setpoint [%] | 45 | 45
| Hardness [GPa] | 22.0 | 13 |
| POSITIVE | YES | NO |

25% increase in ion incorporation!! (deposition rate and hardness)
Change in morphology with HiPlus for Me:N
Example of Implementation on Industrial Tool

xPro4C
DLC - Coating System
It seems to be very convenient in large batch coaters (where parts to be coated are not continuously exposed to ion flux):

- Enhanced deposition rate
- Enhanced ion assistance (raise of plasma potential)

\[ E_i = E_0 + Qe (V_{\text{plasma}} - V_{\text{surface}}) \]
HiPlus \( ^+ \) for floated substrates

Nitch for positive pulsing
The implementation of magnetically guided anodes (or AC Dual) can boost the film ion incorporation.
Carbon on glass: AC Dual + HiPlus

HIPIMS DLC coated glass  Uncoated glass
Reflectivity improvement with high $I_{\text{peak}}$ & $V^+$
Reflectivity Improvement with V+

Worst Reflectivity
- 100A, +25V
- DC-Pulsed

Best Reflectivity
- 400A, +200V

- 400A, +300V
- 100A, +25V
- 200A, +225V
- 400A, +200V
- DC-Pulsed
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<tbody>
<tr>
<td>ON</td>
<td>8000</td>
<td>239</td>
<td>0.0149375</td>
<td>100.00%</td>
</tr>
<tr>
<td>OFF</td>
<td>8000</td>
<td>208</td>
<td>0.013</td>
<td>87.03%</td>
</tr>
<tr>
<td>NA</td>
<td>DC-Pulsed</td>
<td>5000</td>
<td>192</td>
<td>128.54%</td>
</tr>
</tbody>
</table>

**Diagram:**
- **Coil:** inductive power transmission
- **IR-LED:** data transfer
- **Electronics:** Multiplexing, ADC, Power management
- **Electrodes:** recording of cortical potentials

**Image:**
- A close-up view of a circuit board with labeled components.
With no plasma pre-treatment!
Denser films with no evidence of composition changes due when performing multiples passes.

All coatings performed at equal average power and deposition time.
Enhanced ion energy fluxes into insulating surfaces

Cada M, Bradley, J W Clarke G C B and Kelly P J 2007 ‘Measurement of energy transfer at an isolated substrate in a pulsed dc magnetron discharge’ J. Appl. Phys. 102 063301
Evidence of lower permeation at lower film thickness

Figure 8: Water vapour transmission rate of ZnSnOx sputtered on conventional PET film (DuPont Melinex 400) at 9.5 kW, with additional 10 sccm oxygen
Goal for next year (2019)...

10 and 20kW industrial HiPIMS with fully controlled positive pulse....

Up to +1200V
Delay time <1us
Longer pulses
Thank you for your attention!

nano4Energy