Positive Voltage Reversal in HIPIIMS Discharges “Widening the Process Window”

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What’s important?

- Electron density
- Types of ions produced
  - Metal
  - Gas
  - Radicals
- Ion energy distributions
- Substrate potential

The distribution of ion energies at the substrate in an asymmetric bi-polar pulsed DC magnetron discharge

3 energy regimes are measured
IEDF’s HIPIMS

Ehiasarian et al

Ionization and Deposition Rate vs. Peak Current

Fig. 14. The rarefaction effect as manifested by optical emission spectroscopy measurements. At the lowest peak target current (a) an increase of the ionized species emission signal is detected. The increase continues for the Cr species when the peak target current increases but not for the Ar species (b). A further increase (c) shows that the Ar signal starts to decrease manifesting the rarefaction of these species. For the highest peak current (d) the rarefaction is well established. Note that the intensity scale is not the same for all parts of the figure (data taken from [34]).


FIG. 6. Influence of the pulse length on the deposition rates measured in HPPM sputtering (a) at 2 and (b) 10 mTorr and comparison with the mDC mode.

Magnetron sputtering
HIPIMS

- High peak powers (500-2000 W/cm²)
- Reasonable average power (up to 80kW)
- Low duty factors (0.5-5%)
HIPIIMS with Positive Voltage Reversal

Active V+

What does it look like?

Passive V+

hiPlus Option

no V+
Magnetron sputtering
HIPIMS with positive voltage reversal

- Increase in plasma potential
- Ion acceleration from target

Ion assistance as a consequence of:

- Target potential
- Floating potential

\[ \text{Target potential: } V_{\text{target}} = +450V \]
\[ \text{Floating potential: } V_{\text{floating}} = -25V \]
HIPIMS with Positive Voltage Reversal

\[ E_i = E_0 + Qe \left( V_{\text{plasma}} - V_{\text{surface}} \right) \]
IEDF’s for Carbon

- Hardness up to 22GPa on glass
- Hardness up to 35GPa on biased steel
TiN

TiN Planar rectangular magnetron (400x100mm)
Floating substrate, Room Temperature

<table>
<thead>
<tr>
<th>Hardness [GPa]</th>
<th>22.0</th>
<th>13</th>
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<tbody>
<tr>
<td>Positive V reversal</td>
<td>YES</td>
<td>NO</td>
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Deposition Rate for Ti/TiN

Net increase in Deposition Rate of about 20%
30% Gross increase in rate with 10% increase in power Positive pulse)
Strong influence of positive voltage reversal
Pushes crystal orientation to higher energy 111 plane
Al Deposition on Glass

Centurion System from Duralar Technologies
Table diameter = 950 mm
Cathodes – 152 mm Diameter
1200 mm Length
Average Power to Cathode = 5kW
Coating thickness approximately 1μm
Room Temperature
Work done in cooperation with
Von Ardenne North America

- 400A, +300V
- 100A, +25V
- 200A, +225V
- 400A, +200V
- DC-Pulsed
Al on Glass : Specular Reflectance

Spectra was taken with Ocean Optics CCD.

The light source was a combined deuterium and halogen light (from 400 to 800nm).
Al on glass: Specular reflectance

Reflectivity Improvement with High $I_{\text{peak}}$ & $V+$

- Worst Reflectivity
  - 100A, +25V
  - DC-Pulsed
- Best Reflectivity
  - 400A, +200V
Al on Glass : Specular Reflectance

Reflectivity improvement with high $I_{peak}$ & $V+$
Magnetron Ion Source
HIPIMS with positive voltage reversal

Pure O2 atmosphere

➢ No deposition – sputtered C will react with O\textsubscript{2} and be pumped away
➢ Can control density and energy of positive O\textsubscript{2} ions
➢ This together with control over average power allows for control over etch rate for various materials and line speeds
➢ Substrate is discharged every pulse cycle
Magnetron Ion Source
HIPIMS with positive voltage reversal

Glass etching with O2 and carbon target

Untreated glass substrate

RMS roughness : 2.6 nm

Oxygen treated glass substrate

RMS roughness : 1.4 nm
Summary

• Hipims with positive voltage reversal allows for precise control over ion species and energy for controlling coating properties

• Can “self bias” substrates whether they are insulating or conductive

• Improved coating properties for low temperature deposition

• Improved productivity due to higher rates
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Thanks for your attention!

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