Time-Resolved Ionisation Studies of the High Power Impulse Magnetron Discharge in Mixed Argon and Nitrogen Atmosphere

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Introduction

High power impulse magnetron sputtering (HIPIMS) is a new method for physical vapor deposition (PVD) based on magnetron sputtering [1, 2]. It utilises transient impulse (short pulse) grow discharges with very high power and current density (up to 3 kW/m² and 4 A/cm² respectively) at a duty cycle of ~5%. Under these conditions the plasma density near the target increases sufficiently to ionise a significant proportion of the sputtered metal ions [3,4] thus creating a high-efficiency metal ion source. The discharge has been up scaled successfully [4] and has found a number of applications. One example is substrate pretreatment under HIPIMS which benefits from double-free metal ion bombardment that provides a highly clean substrate interface where local optical growth is maintained [5]. This in turn enhances the coating adhesion. Another example are nitride [6] thin films grown by HIPIMS. C/N films grown by HIPIMS have a high density of the microstructure and demonstrate superior performance in corrosion and wear environments [6,7].

Experimental

Equipment:

• Ultra high vacuum (UHV) chamber, base pressure of < 10⁻⁹ mbar.
• One magnetron (Tornus, Kurt J Leeker) diameter of 675 mm Ti target
• HIPIMS Power Supply from Advanced Coatings AG Spezio, Italy

Energy-resolved mass spectroscopy at substrate position:

• PSM003, Hiden Analytical Ltd.
• Distance to target - 120 mm, Angle of 58° with respect to target normal.
• Plasma sampled through a ø200 µm grounded orifice, acceptance angle of 5°
• Ion collection gated with a TTL output from power supply.
• Measure a 70 µs window centred at the peak of the 150 µs pulse.

NEW: Quantitative Plasma Analysis of HIPIMS in REACTIVE ATMOSPHERE

Comparison:

• HIPIMS, DC and mid-frequency pulsed DC
• Identical average power = 200 W
• Pulsed DC frequency = 20 kHz
• HIPIMS Discharge:
  • Peak power = 20 kW, Peak current = 50 A
  • Pulse frequency = 100 Hz
  • Discharge voltage: -550 V for inert gas atmosphere
  • -480 V for reactive gas mixture

Results

The time-averaged ion distribution function (IEDF) for ions generated by different methods of sputtering in inert and reactive atmospheres are shown below:

HIPIMS of Ti

<table>
<thead>
<tr>
<th>Inert atmosphere: Ar</th>
<th>Reactive atmosphere: Ar + N₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ions were sampled with an energy-mass spectrometer PSM003 (Hiden Analytical Ltd)</td>
<td></td>
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<tr>
<td>DC &amp; MF pulsed DC Sputtering in Reactive Sputtering</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Ion</th>
<th>DC</th>
<th>MF pulsed DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ar²⁺</td>
<td>34</td>
<td>5</td>
</tr>
<tr>
<td>Ar³⁺</td>
<td>46</td>
<td>15</td>
</tr>
<tr>
<td>Ti²⁺</td>
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<td>Ti³⁺</td>
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<td>N²⁺</td>
<td>82</td>
<td>3</td>
</tr>
<tr>
<td>N³⁺</td>
<td>11</td>
<td>2</td>
</tr>
</tbody>
</table>

References