Mechanisms and dynamics of unipolar arcs in magnetized plasmas

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Mechanisms and dynamic of unipolar arcs
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Introduction
• Unipolar arc = arc between a plasma and a surface in contact with it [1]
• Main cause of wall erosion & impurity formation in fusion devices with metal PFCs [2,3]
• Impact of unipolar arcs on tungsten surfaces not well known [4]
• Many difficulties in the experimental investigations: spatial/temporal scales involved
• In this presentation: our first experimental results on the triggering of unipolar arcs
• Our aim: to provide more reliable input parameters & to assess the validity of models⇒
  better understanding of the mechanism/dynamic & consequences of unipolar arcs

Experimental device
• Experiments carried out in the ALINE device [5]
• Stainless steel cylindrical magnetized chamber
• 100cm long, 30cm in diameter
• Tunable RF plasma (10kHz-250Mhz, up to 600 W)
• Equipped with rotatable and biasable manipulators by Cryscan©
• Possibility of heat pulses (45W IR Laser)

Target manipulator installed on ALINE

Experimental conditions

<table>
<thead>
<tr>
<th>Gas</th>
<th>Ar, He</th>
<th>D2, D3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working pressure</td>
<td>10¹⁸ - 10¹⁹ mbar</td>
<td></td>
</tr>
<tr>
<td>Plasma densities</td>
<td>10¹⁰ - 10¹¹ m⁻³</td>
<td></td>
</tr>
<tr>
<td>Magnetic Field</td>
<td>up to 0.1 T</td>
<td></td>
</tr>
<tr>
<td>ρAr (mm)</td>
<td>0.03 - 0.3</td>
<td></td>
</tr>
<tr>
<td>h (mm)</td>
<td>0.03</td>
<td></td>
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<tr>
<td>R (mm)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Tc (eV)</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td>Te (eV)</td>
<td>0.002</td>
<td></td>
</tr>
</tbody>
</table>

Examples of plasma density and potential profiles obtained in ALINE for different angles between the cathode and the magnetic field

Conclusions & Perspectives
• Versatile and well-diagnosed experiment for the investigation of unipolar arcs
• Various ways to trigger arcs on different surfaces: excitation by plasma pulse, laser pulse, biasing
• Experiments have just started: statistical investigation to come
• Modelling: 2D PIC code under development (see PBO27, this conference)
• Participation to WEST C4 campaign for investigations in more fusion-relevant conditions
• Application to various PFC’s, including mirror cleaning applications with Univ. Basel.

Experimental set-up
• 2 inches target samples mounted on rotatable manipulator
• Several kinds of target material (W, Mo, Ti, Al/Fe…)

Preparation of samples:
• Manual deposition of W micron-sized dust samples
• Microtexturing (Fe/Au and soft metals) by surface nitriding
• W, Mo... depositions in HiPIMS (possibility to trap various gases: Ar, He, D)
• W fuzz, Ti nanoparticles (provided by Univ. Basel)

Post-mortem analysis:
• sample Degradation/Erosion (SEM, profilometry, FIB)

Experimental Results
• Only preliminary results, low statistics: 107 arcs
• Wide distribution of arc lifetime (best time resolution so far: 3.8 µs, 250 ns in close future)
• Influence of plasma & surface properties going to start after improvements in the set-up
• Preliminary observations suggest that dust rates are correlated with arc lifetime

References