GEC-57th-2004:

Plasma Dynamics in a Unipolar Pulsed Magnetron Sputtering Discharge

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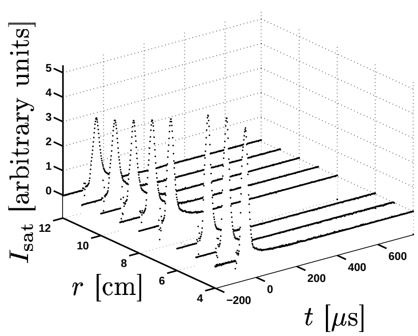
28. September 2004

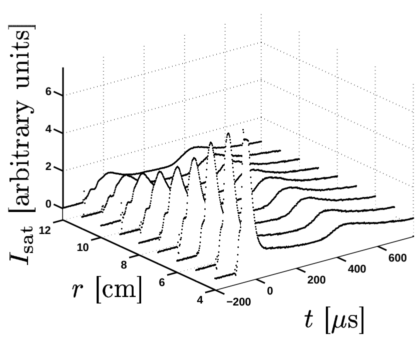
Introduction

- Two principal methods of pulsing a magnetron discharge have been proposed:
  - asymmetric bipolar pulsing
  - unipolar pulsing
- Unipolar pulsing utilizes a power supply operating at low (or zero) power level most of the time but pulsing to a significantly higher level for a short period each cycle
  - a high energy pulse (3 – 12 J) of length $\approx 50 - 100$ μs
  - a repetition frequency of 50 pulses per second
- A dense localized plasma
  - electron density $n_e \approx 10^{19}$ m^{-3}
- We report on ion-acoustic solitary waves in a unipolar high power pulsed magnetron sputtering discharge

Solitary waves



(a) 1 mTorr

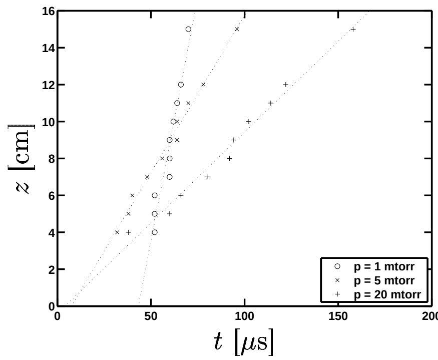


(b) 20 mTorr

Solitary waves

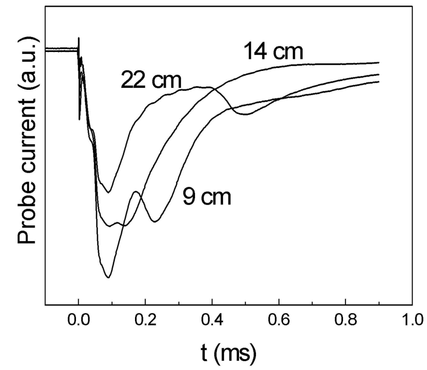
- The electron saturation current, measured by a Langmuir probe, as a function of time from pulse initiation and position below the target
- The argon pressure was (a) 1 mTorr and (b) 20 mTorr. The target made of titanium, pulse length was ≈ 70 μs, and pulse energy 8 J
- The peak electron density is in the range of $10^{18} - 10^{19}$ m^{-3} (Gudmundsson et al., 2001, 2002)
- At higher pressures ($>$ 10 mTorr) a second peak is apparent, hundreds of microseconds after the pulse is switched off

Solitary waves



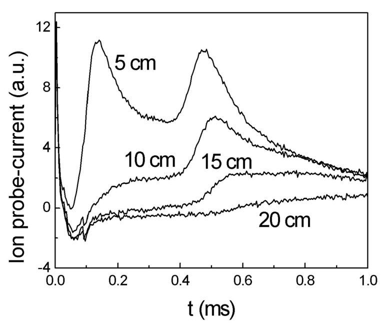
- The trajectories of the peaks
- Each peak travels with a fixed velocity
- A least squares fit shows that at 8 J the peaks travel with velocity of 5.3×10^3 m/s at 1 mTorr, 1.7×10^3 m/s at 5 mTorr, and 9.8×10^2 m/s at 20 mTorr
- The velocity of the peaks increases with decreasing pressure but is roughly constant with varying pulse energy

Solitary waves



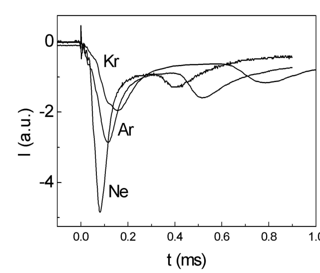
- Electron saturation current at various chamber radius 10 cm below the target
- The second peak moves closer to the first one as the chamber radius is decreased

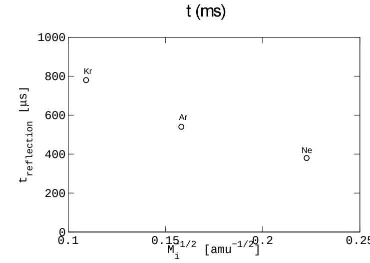
Solitary waves



- The ion saturation current shows similar temporal behavior as the electron current
- Ta target in argon discharge at 20 mTorr and pulse energy of 11 J
- The ion saturation current was measured with a flat probe at - 50 V

Solitary waves





- There is a linear relationship between reflection time and $1/\sqrt{M_i}$
- Measured 10 cm blelow Ta target in argon discharge at 20 mTorr and pulse energy of 11 J

Summary

- We demonstrate propagation of ion acoustic waves away from the magnetron target
- The first peak travels with a fixed velocity away from the target. The velocity of the wave depends entirely on the discharge pressure but is almost independent of the pulse energy
- The second peak is directly influenced by the chamber size and the mass of the working gas species
- We suggest this second peak to be an ion acoustic wave reflecting from the chamber walls

Acknowledgments

This work was partially supported by the Swedish Foundation for Strategic Research, the Icelandic Research Fund for Graduate Students, the University of Iceland Research Fund and the Icelandic Research Council. The company Chemfilt R & D is acknowledged for the use of the power supply.

References

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