Instabilities in High Power Pulsed Magnetron Plasmas

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High power pulsed magnetron plasmas may show instabilities in the form of rotating emission structures. They are associated with a corresponding modulation of the floating potential and/or ejection of charge particle beams. Rotation velocities are of the order of 10 kms-1, of the order of the ion drift speeds. The azimuthal mode number depends on current. Fast Fourier Transform (FFT) analysis of the frequency spectra suggest transition from chaotic to periodic behavior. These instabilities may lead to strongly modulated high heat fluxes on the target surface and influence the plasma-surface- interaction.

This paper deals with the investigation of instabilities in High Power Pulsed Magnetron Sputtering (HPPMS) plasmas, which we have recently observed [1].

High power pulsed magnetron sputtering (HPPMS) combines high voltage / high current glow discharges with conventional magnetron cathodes to achieve high deposition rates and highly ionized sputtered particles flux. Heat flux management is achieved by pulsing the discharge at durations of a few 100 µs and frequencies of a few 100 Hz. The deposition environment of HPPMS has a characteristic high surface ad-atom mobility and can produce fully dense thin films with high adhesion. The ionization degree can be controlled by the peak power in the discharge and allows the tailoring of a number of different properties of the film properties.

Observed with a low time resolution, the optical emission from HPPMS discharge may appear to be homogeneous during the pulse. However, as we have shown recently [1], the HPPMS plasma may develop instabilities which are characterized by well defined regions of high and low plasma emissivity along the race track of the magnetron. They are also associated with periodic shifts in floating potential and/or the existence of ejected charged particle beams. The emission structures rotate in ExB direction at velocities of ~10 kms^{-1} (close to the ExB ion drift velocity) and with frequencies up to 200 kHz. The azimuthal mode number m depends on plasma current, plasma density and gas pressure.

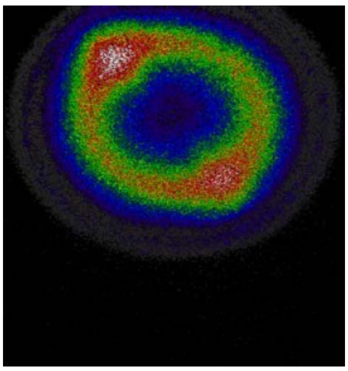

Fig. 1 : CCD image (frontal view) of the total light emission from the HPPMS discharge, showing an azimuthal mode number of m=2. Camera acquisition time: 150 ns

Optical sensors viewing a small area on the race track of the target allow to follow the evolution of the rotating structures during the entire discharge. Fast Fourier Transform analysis of the frequency spectrum of the modes indicate transitions from periodic to chaotic motion, depending on discharge parameters.

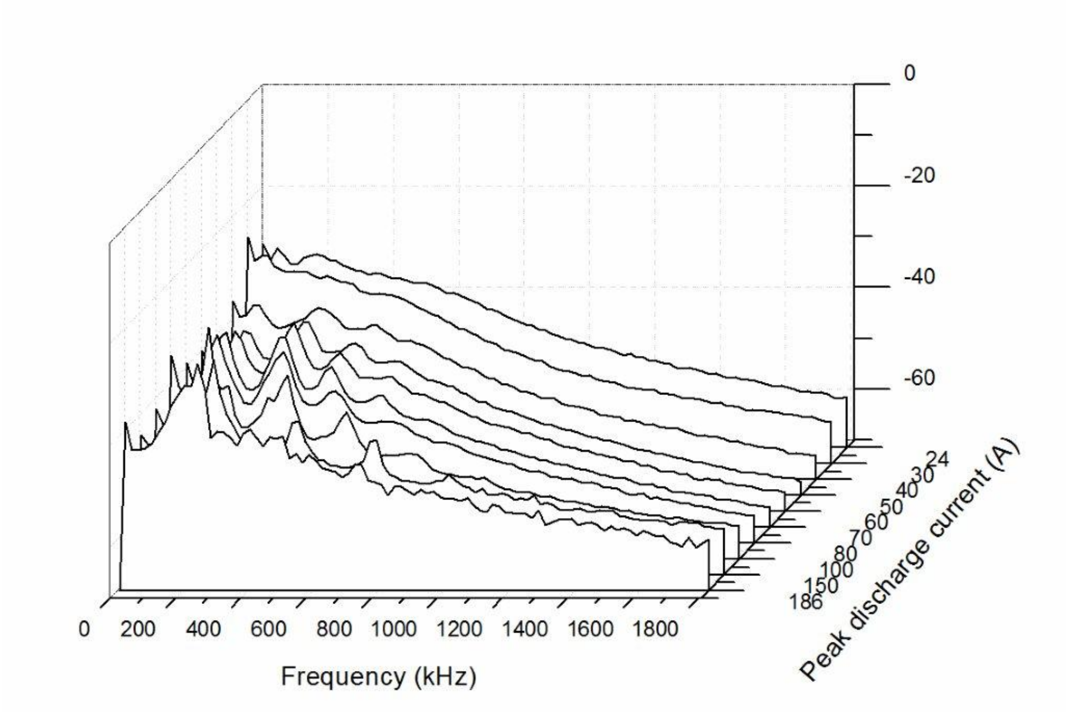

Fig. 2: FFT analysis of the frequency spectrum during a full discharge for different discharge currents (peak currents).

The optical measurements are complemented by magnetic probe studies. Furthermore electrostatic ring probe measurement showed the coexistence of another instability at about 2 MHz which is electron driven. It is most likely associated with the two stream instability due to the difference in confinement of electron and ions and the associated differences in particle fluxes [2].

These instabilities we observed may lead to strongly modulated high heat fluxes on the target surface. This would significantly influence the plasma-surface-interaction and possibly impact on the lifetime of the targets.

References

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