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Plasma regimes in high power pulsed magnetron sputtering[1]

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High Power Pulsed Magnetron Sputtering (HPPMS) is a relatively recent variation of magnetron sputtering where high power is applied to the magnetron in short pulses. The result is the formation of dense transient plasmas with a high fraction of ionized species, ideally leading to better control of film growth through substrate bias. However, the broad range of experimental conditions accessible in pulsed discharges results in bewildering variations in current and voltage pulse shapes, pulse power densities, etc, which represent different discharge behaviors, making it difficult to identify relevant deposition conditions. The complexity of the plasma dynamics is evident. Within each pulse, plasma characteristics such as plasma composition, density, gas rarefaction, spatial distribution, degree of self-sputtering, etc. vary with time. A recent development has been the discovery that the plasma emission can self-organize into well-defined regions of high and low plasma emissivity above the racetrack (spokes), which rotate in the direction given by the E×B drift and that significantly influence the transport mechanisms in HPPMS. One seemingly universal characteristic of HPPMS plasmas is the existence of well defined plasma regimes for different power ranges. These regimes are clearly differentiated in terms of plasma conductivity, plasma composition and spatial plasma self-organization. We will discuss the global characteristics of these regimes in terms of current-voltage characteristics, energy-resolved QMS and OES analysis, and fast imaging. In particular we will discuss how the reorganization of the plasma emission into spokes is associated only to specific regimes of high plasma conductivity. We will also briefly discuss the role of the target in shaping the characteristics of the HPPMS plasma, since sputtering is a surface-driven process.

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