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# Time-resolved Langmuir probe measurements during modulated pulsed power reactive magnetron sputtering of Cr/CrN

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In recent years modulated pulsed power magnetron sputtering (MPP) has become an alternative technique to high power impulse magnetron sputtering (HIPIMS) for the generation of highly ionised deposition fluxes. With the power supply employed in this investigation plasma parameters can be tailored by superimposing macropulse in the 100Hz range with micropulses in the kHz range. In the current study, non-reactive and reactive sputtering of a chromium target in argon and argon-nitrogen atmospheres were performed with an average power of 650 W, a macropulse frequency and length of 100 Hz and 750 µs, respectively. The temporal development of the electron density and temperature for various micropulse settings has been investigated using time-resolved Langmuir probe measurements. A two-step excitation of the plasma was used in this study, whereas the electron density and temperature obtained here revealed three distinct discharge regimes. Initially, long 'off'-times (34 µs) and short 'on'-times (6 µs) of the micropulses were used to excite the plasma. This first stable state is characterised by relatively low electron densities of 1 x $10^{11}$ $cm^{-3}$. In a second step, the 'off'-time was reduced to 8 µs and kept constant, while the 'on'-time was varied between 8 and 18 µs. A higher electron density of 3 x $10^{11}$ $cm^{-3}$ was recorded here. It is worth noting that the transition between these two stable states is accompanied by a maximum in the target voltage and the discharge current. At the same time, the electron density peaks up to 6 x $10^{11}$ $cm^{-3}$. After pulse termination the plasma decays with ultra-long time constants in the range of several hundred microseconds to milliseconds depending on the pressure. Further investigations will be carried out to explain the results in terms of the underlying physics.

**Keywords**
Modulated pulse power
High power impulse magnetron sputtering
Langmuir probe
Plasma diagnostics