High Power Impulse Magnetron Sputtering: The Age of Adolescence

High Power Impulse Magnetron Sputtering (HIPIMS) is a technology for the deposition of thin films using large volumes of dense plasma. The growth of films in such an environment benefits from a greatly enhanced degree of freedom of the system which diversifies the reactions in the plasma phase and opens unique pathways for film formation and tailoring film properties. To achieve this, plasma generation is carried out at significantly higher instantaneous power than conventional sputtering methods. The power is delivered in pulses on timescales that are sufficient to produce dense metal plasma of $10^{13} \text{ cm}^{-3}$ whilst avoiding heat buildup and transitions from glow to arc discharge on the target. In particular regimes, the plasma self-organises into waves which propagate in the $E \times B$ direction and build up localised plasma density spikes that shield the confining fields and increase pressure to generate intense particle emission in direction to the substrate.

Metallic plasmas containing rare earth ions were used to produce an implantation zone of a few nanometres to seal and protect the surface of substrates against oxidation. They also served to promote adhesion by providing conditions for local epitaxial growth inducing a crystalline interface and chemistry for better wetting during film nucleation. For metallic films of Mo, the ratio of double- to single- charged metal ions could be varied in a wide range through the peak current and charge exchange reactions with the process gas. The ratio correlated with the grain size and improved smoothness of the films due to the additional energy gained by the higher charge states through the sheath. It also shifted the crystallographic orientation from a highly textured to a random mix. ErNi films have improved crystallinity and heat lift capacity at cryogenic temperatures whilst Nb films have better superconducting properties. Better coverage of meshes and high aspect ratio vias is achieved.

In reactive sputtering conditions, the deposition flux comprises mainly ions of metal and dissociated nitrogen which change the dynamics of adatoms on the surface and promotes a (200) crystallographic texture which in turn sustains fully dense column boundaries in TiN monolithic films.

Nanolayered CrN/NbN and CrAlN/CrN developed with low waviness and enhanced density making them suitable for corrosion, wear, biological and high-temperature oxidation environments. Nanocomposites of CrAlN-SiN can be produced with different cluster size and corresponding hardness.

The deposition of oxides has benefited from controlling the current in the discharge pulse to produce high density TiO$_2$ films for architectural glass coatings and enabling the production of highly insulating materials such as SiO$_2$ for the glass and semiconductor industries.

Industrial uptake is rife in the fields of hard coatings and microelectronics with a number of vendors providing turn-key solutions.