

HiPIMS-Driven Innovations in Functional Oxide and Oxynitride Films

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Over the past decade, reactive high-power impulse magnetron sputtering (HiPIMS) has evolved from a laboratory technique into a versatile, industrially relevant tool for growing functional nitride, oxide and oxynitride films. Advances in reactive-gas control, design of pulsed power supplies, and new approaches to substrate biasing now allow formation of dense, well-adherent films with controlled composition and tunable properties. Several case studies below will be presented to illustrate the potential of this method.

i) Reactive HiPIMS of a Ta target in Ar+O₂+N₂ mixtures with pulsed reactive-gas-flow control tuned the composition of Ta-O-N films continuously between oxide-like and nitride-like extremes at high deposition rates [1]. The films evolved from a wide-band-gap, resistive oxide to a conductive nitride, with intermediate oxynitride compositions showing visible-light absorption promising for photocatalysis.

ii) Reactive HiPIMS of a Cu target tailored p-type Cu₂O-based films for two functions. A high-energy discharge regime led to effective dissociation of reactive molecules, enabling precise control of composition and reduced resistivity of Cu₂:N films [2]. Separately, optimized oxygen pressure, substrate heating and annealing gave densified, highly crystalline undoped Cu₂O films with photocurrent densities among the highest reported for a bare Cu₂O photocathode in water splitting [3].

iii) Reactive HiPIMS deposited thin bilayer Ti-Nb-O coatings on stainless steel for PEM electrolyzer bipolar plates and porous transport layers. Tuning oxygen pressure and the Nb/Ti ratio gave low-resistivity, corrosion-resistant coatings that, with only a very thin Pt overlayer, met demanding contact-resistance targets while sharply reducing Pt loading compared with conventional approaches [4].

iv) Shaping the HiPIMS pulse waveform itself was shown to control energy delivery to insulating surfaces. Comparing unipolar, bipolar and chopped configurations with a thermal probe showed that splitting the negative pulse into shorter segments increases ion flux, while a chopped bipolar pulse becomes effective once the surface capacitance is high enough that its charging time matches the pulse length. This provides a new route to controlling ion bombardment of films on insulating substrates [5].

Together, these examples demonstrate how controlling reactive HiPIMS discharge conditions and pulse architecture provides a single, scalable platform for tailoring the optical, electrical, electrochemical and functional surface properties of thin-film materials for applications in photocatalysis, transparent conductors, energy conversion and advanced coatings.

References

- [1] Rezek, J. et al. *Thin Solid Films* 566 (2014) 70–77.
- [2] Rezek, J. et al. *Appl. Surf. Sci.* 714 (2025) 164380.
- [3] Vosejpka, J. et al. *Sol. Energy Mater. Sol. Cells* 305 (2026) 114425.
- [4] Kolenatý, D. et al. *Int. J. Hydrogen Energy* 221 (2026) 153920.
- [5] Farahani, M. et al. *Plasma Sources Sci. Technol.* 34 (2025) 03LT02.

This work was supported by the project Quantum materials for applications in sustainable technologies (QM4ST), funded as project No. CZ.02.01.01/00/22_008/0004572 by Programme Johannes Amos Comenius, call Excellent Research.