Reactive HiPIMS and low duty cycle magnetron sputtering of durable active and passive optical coatings

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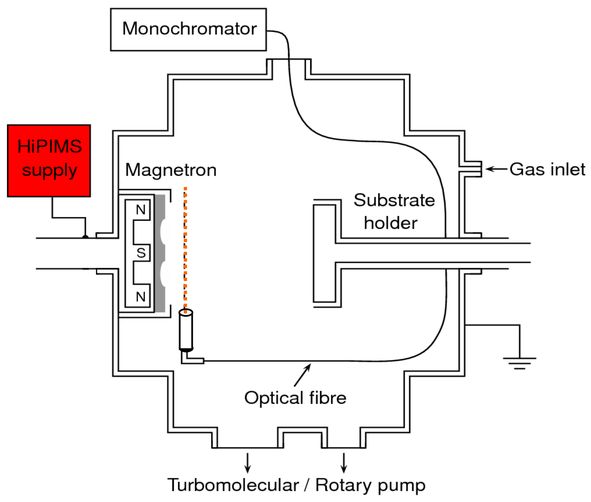
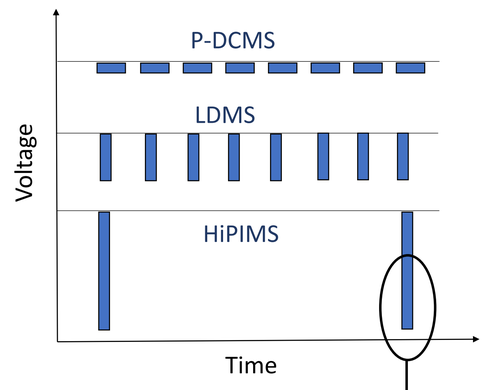
We have studied and developed pulsed DC magnetron sputtering approaches using pulse management to obtain high-quality durable active (thermochromic VO_2) and passive (hard protective AlN and Al_2O_3) optical coatings.

HiPIMS deposition system

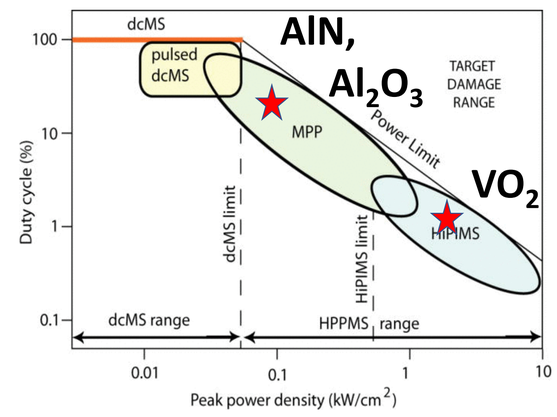


Pulse management strategies



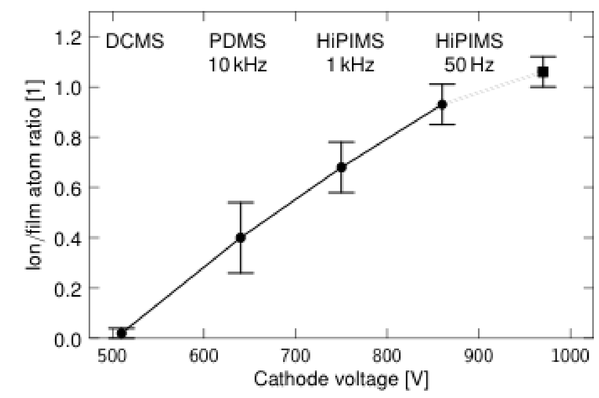
Voltage, current, frequency, duty cycle, pulse length

Categorization of pulsed discharges

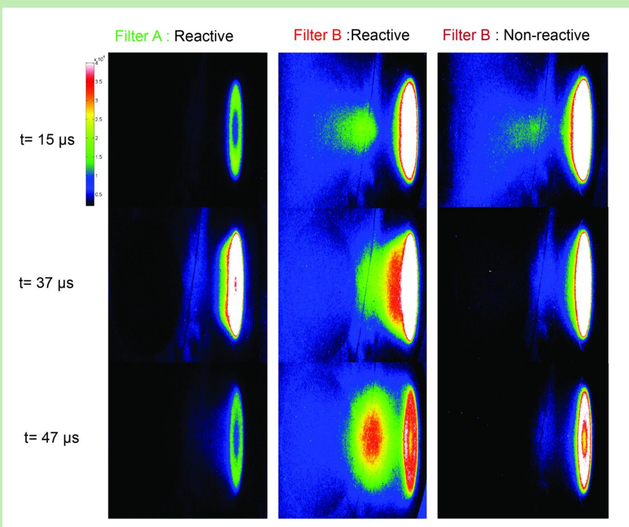


Adapted from [1]

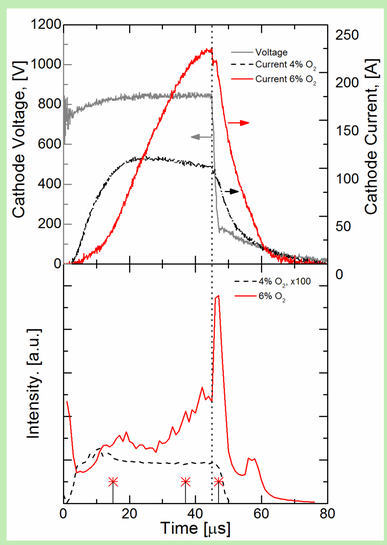
Ion/atom growth flux ratio



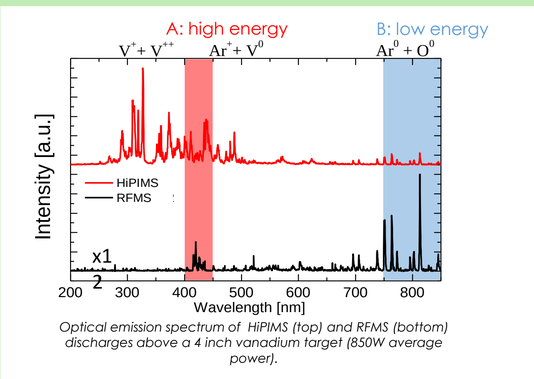
Reactive HiPIMS applied to VO_2



Time-, space-, species-resolved OES (Frequency: 1 kHz, pulse length: 45 µs)

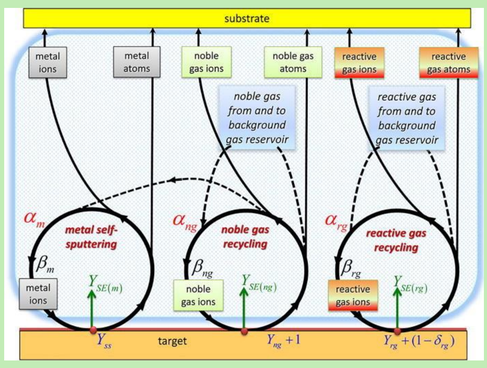


V(t) and I(t) waveforms, and post-pulse plasma flash



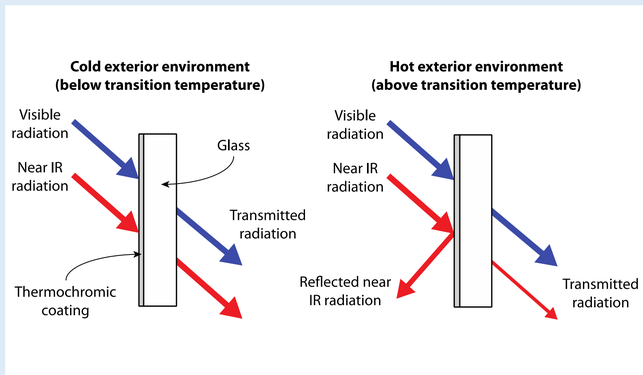
Optical emission spectrum of HiPIMS (top) and RFMS (bottom) discharges above a 4 inch vanadium target (850W average power).

Time-averaged OES spectra with optical filters

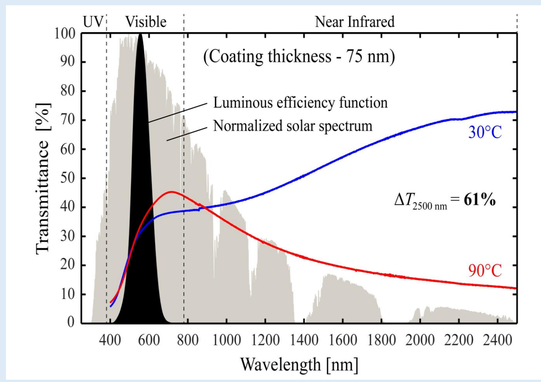


Simplified schematic of ion fluxes in reactive HIPIMS; from [2]

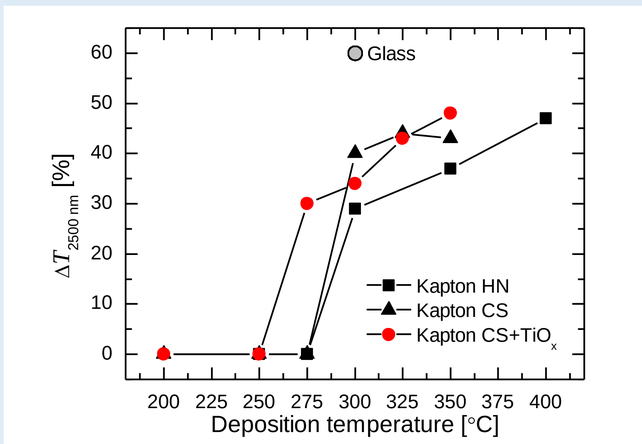
High performance thermochromic VO_2 films deposited at low temperature



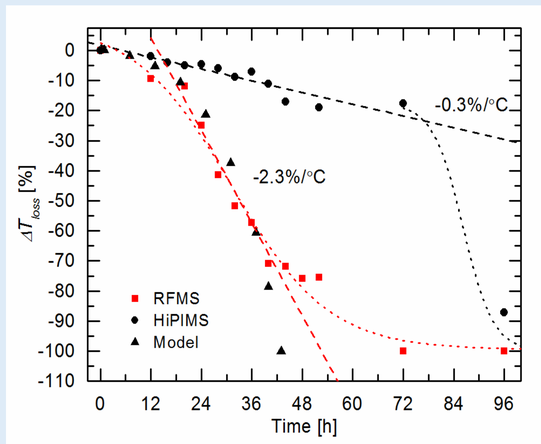
Principle of thermochromic smart windows



Transmission modulation in the NIR at high and low temperatures: ΔT

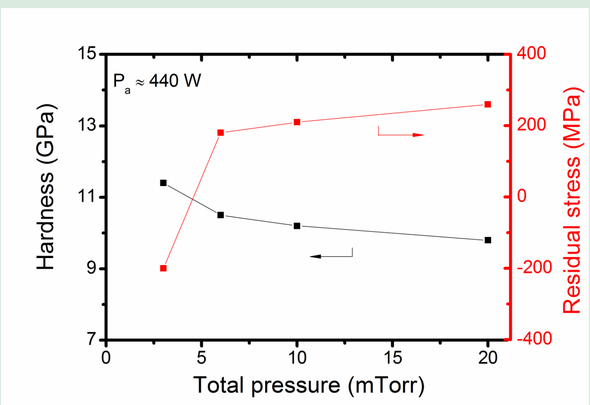


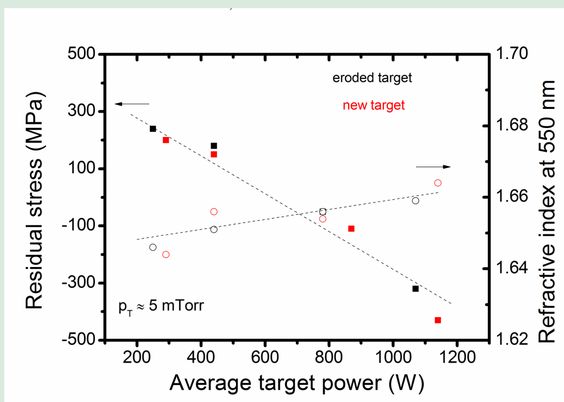
Deposition of VO_2 on plastics



High stability of HiPIMS VO_2

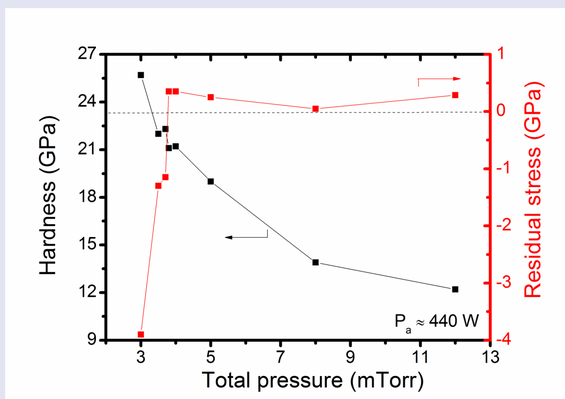
Hard transparent Al_2O_3 films

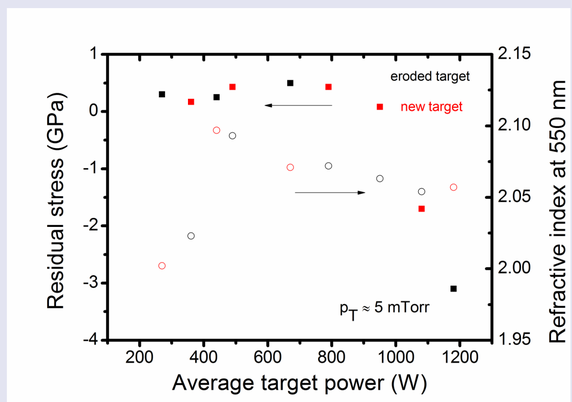




After optimization: H = 11 GPa, near zero stress, medium refractive index n = 1.66 @ 550 nm | Frequency: 10 kHz, pulse length: 10 µs

Hard transparent AlN films





After optimization: H = 23 GPa, near zero stress, high refractive index n = 2.08 @ 550 nm | Frequency: 10 kHz, pulse length: 10 µs

Perspectives

Energy control and savings (smart windows – glass and plastics, smart infrared radiators for satellites), protection of optical components - lens optics, windows, displays etc).

Traditional vs. New sustainable approaches

References

[1] J.T. Gudmundsson, N. Brenning, D. Lundin, U. Helmersson, "High power impulse magnetron sputtering discharge", *J. Vac. Sci. Technol. A* **30** (2012) 030801.

[2] A. Anders, "Tutorial: Reactive high power impulse magnetron sputtering (R-HiPIMS)", *Journal of Applied Physics* **121** (2017) 171101.

[3] J. Kohout, E. Bousser, T. Schmitt, R. Vernhes, O. Zabeida, J. Klemberg-Sapieha and L. Martinu, "Stable reactive deposition of amorphous Al_2O_3 films with low residual stress and enhanced toughness using pulsed dc magnetron sputtering with very low duty cycle", Vacuum **124** (2016) 96-100.

[4] J. Kohout, T. Schmitt, R. Vernhes, O. Zabeida, J. Klemberg-Sapieha and L. Martinu, "Pulsed magnetron deposition of hard AlN films – A comparison of different approaches and optimization of deposition conditions", Manuscript in preparation.

[5] S. Loquai, B. Baloukas, J.E. Klemberg-Sapieha, L. Martinu, "HiPIMS-deposited thermochromic VO_2 films with high environmental stability", *Solar Energy Materials and Solar Cells* **160** (2017) 217-224.

[6] S. Loquai, O. Zabeida, J. E. Klemberg-Sapieha, L. Martinu, "Flash post-discharge emission in a reactive HiPIMS process", *Appl. Phys. Lett.* **109** (2016) 114101.

[7] S. Loquai, B. Baloukas, O. Zabeida, J.E. Klemberg-Sapieha, L. Martinu, "HiPIMS-deposited thermochromic VO_2 films on polymeric substrates", *Solar Energy Materials & Solar Cells* **155** (2016) 60-69.