Plasma-surface interaction during High-Power Impulse Magnetron Sputtering

A. Balhamri [1], S. Konstantinidis [1], M. Palmucci [1], J.P. Dauchot [1,2], M. Hecq [1,2] and R. Snyders [1,2]

adil.balhamri@umh.ac.be

[1] Laboratoire de Chimie Inorganique et Analytique, UMons - 20, Place du Parc, B-7000 Mons, Belgium

[2] Materia Nova Research Center - Parc Initialis - 1, Avenue Nicolas Copernic, B-7000 Mons, Belgium

1° Frame of the work

High-Power Impulse Magnetron Sputtering (HiPIMS) is a thin film growth technique that offers an extended range of possibilities compared to conventional dc magnetron sputtering (dcMS).

→ High-current (power) pulses which duration is typically <20 µs (peak current ~A/cm² and peak power ~kw/cm²)

→ Strongly ionized sputtered metallic vapour [1] ([M⁺]>>>)

→ Intense ion bombardment of the growing films

⇨local epitaxial growth [2], low surface roughness [3], high film density [3].....

But : deposition rate (HiPIMS) ≤ deposition rate (dcMS)

Why? Is the plasma-surface interaction in HiPIMS ≠ than in dcMS ?

2° Hypothesis

a) Kinetic Energy tranfer through and gas heating sputtering wind

$$dE = \frac{4M_G M_M}{(M_G + M_M)^2} \quad \text{(A)} \qquad dE_{Ti-Ar} = 99\% \qquad dE_{Ti-Ne} = 83\%$$

b) Sputtering rate

$$\Theta \propto I \times \gamma(Energy \overbrace{, M - G}^{\text{Combination}})$$

$$\propto I_{G^+} \times \gamma_{(M-G^+)} + I_{M^+}\left(\gamma_{(M-M^+)} - 1\right) \quad \text{(B)}$$

$$\left.\begin{array}{ll} \gamma_{(Ti-Ar^+)800V=0,84} & \gamma_{(Ti-Ne^+)900V=0,91} \\ \gamma_{(Ti-Ti^+)800V=0,75} & \gamma_{(Ti-Ti^+)900V=0,78} \end{array}\right\} \quad \text{(C)}$$

High current (A/cm²) + "long" pulse

$M_M \cong M_G$ → Efficient transfer of kin. E between M and G → dE = 1 → T_G ↑↑↑ → $[G]$↓↓↓ → Sput. Rate ~ $I_{G^+}\gamma_{(M-G^+)} + I_{M^+}\left(\gamma_{(M-M^+)} - 1\right)$

$[M^+]$↑↑↑ → Self-sputtering → If $\gamma_{(M-M^+)} < 1$ ⇨ Sput. Rate → 0

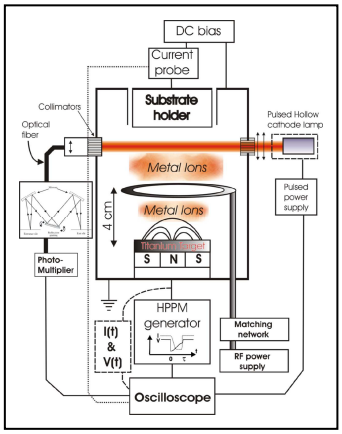
$M_M \neq M_G$ → Less efficient transfer of kin. E between M and G → dE < 1 → T_G ↑ → $[G]$↓ → Sput. Rate ~ $I_{G^+}\gamma_{(M-G^+)} + I_{M^+}\left(\gamma_{(M-M^+)} - 1\right)$ ⇨ Sput. Rate > 0

3° Experimental Strategy & Setup

- Target (Ti)
- Gas (Ar, Ne @ 5 / 10 mTorr)
- Dist. target – subst. : 8 cm
- <P> = 300 W @ 5 / 10 mTorr
- V_{Ar} = 800 V / V_{Ne} = 900 V

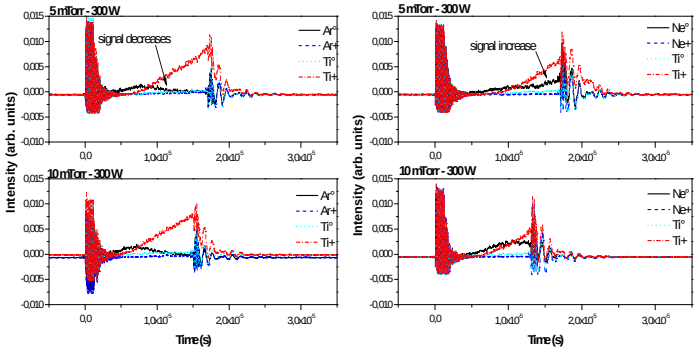
Variation of pulse peak current (through pulse duration)

1-X-ray fluorescence → amount of deposition material
2-Time-Resolved OES → plasma composition



4° Experimental results

a) Time-Resolved OES

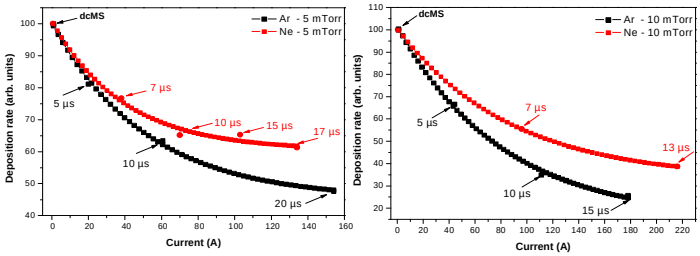


⇨ Ar : signal decreases ↔ T_{gas} >>> (see A) → [Ar]↓↓↓.

⇨ Ne : weak saturation → T_{gas} > (see A) → [Ne]↓

⇨ Ti^+ : intense emission → $[M^+]$↑↑↑

b) Deposition rate



⇨ The deposition rate in Neon decreases less than in Argon.

5° Conclusions

- Decrease of the Ar OES signal
- T_{gas} (Ar) ↑

  PV = nkT_{gas} → [Ar]↓↓↓
- [Ar] decreased + high $[M^+]$ → leads to self-sputtering (see B)
- Decrease of the deposition rate (see C)
- Heating of Ne gas less efficient (cfr OES)
- [Ne] still high and contribute to target sputtering → Deposition rate higher for Ne

⇨ The sputtering wind influences the transition between gas sputtering and the self-sputtering in HiPIMS experiments.

6° References

[1] S.Konstantinidis, J.-P. Dauchot, M. Ganciu, A. Ricard, M. Hecq, J. Appl. Phys. **99** (2006) 013307..

[2] A.P. Ehiasarian, W.-D. Munz, L. Hultman, U. Helmersson, I. Petrov, Surf. Coat. Technol. **163-164** (2003) 267.

[3] S. Konstantinidis, A. Hemberg, J.-P. Dauchot, M. Hecq, J. Vac. Sci. Technol. **B 25** (2007) L19.

Acknowledgements : Special thanks to Belspo (PAI – VI, « Ψ » program) and the FNRS for financial support.