Laboratoire Plasma et Conversion d'Energie

Effect of the operating parameters on aerosol-assisted atmospheric pressure plasma thin film deposition

R. Magnan, R. Clergereaux, P. Raynaud and N. Naudé

romain.magnan@laplace.univ-tlse.fr

Context

In this study, a **non-thermal atmospheric pressure plasma torch** from AcXys Plasma Technologies **is coupled with an aerosol injection**

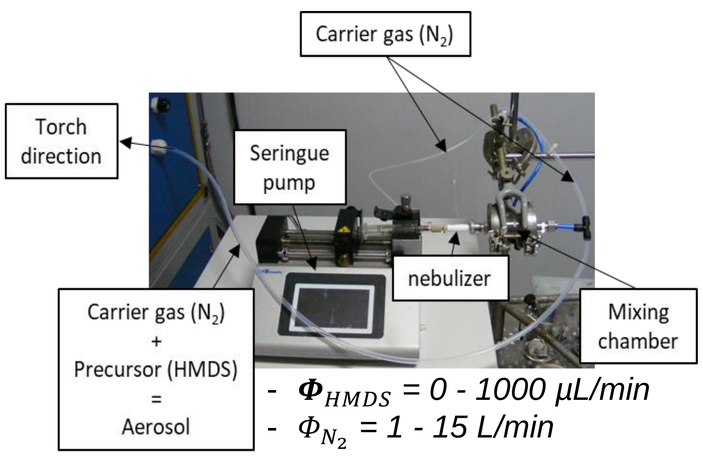
This process offers an easy and robust solution to generate **low temperature post-discharge in air or nitrogen**

It is suitable for surface activation and **for thin film deposition** on flat or 3D complex substrates for in-line production

The influence of process parameters (carrier gas and precursor flow rate) on the thin film properties are investigated

Experimental set-up

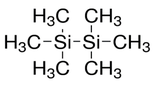
Aerosol production



- Φ_{HMDS} = 0 - 1000 µL/min
- Φ_{N_2} = 1 - 15 L/min

Precursor

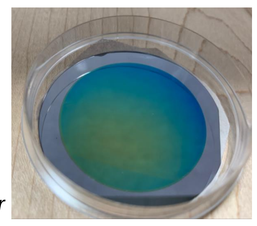
Hexamethyldisilane **(HMDS)**



Aerosol

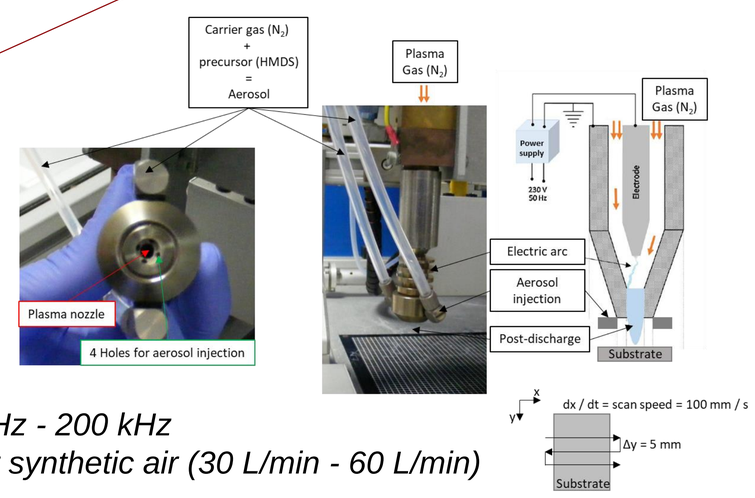
Aerosol + post-discharge

Thin film



$SiO_xC_yH_z$ on Si wafer

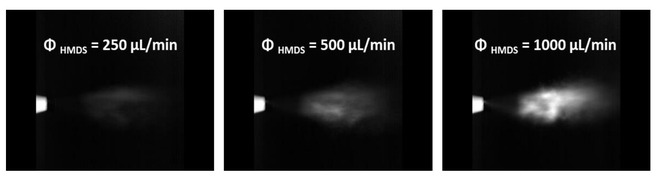
Cold plasma torch

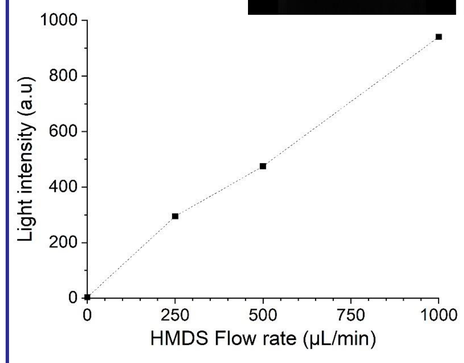


- *80 kHz - 200 kHz*
- *N_2 or synthetic air (30 L/min - 60 L/min)*

Influence of precursor flow rate (HMDS)

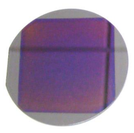
Photo of the aerosol at the nebulizer exit





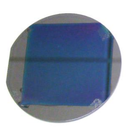
Due to Mie diffusion, the linear increase of the light intensity as a function of Φ_{HMDS} suggests that:

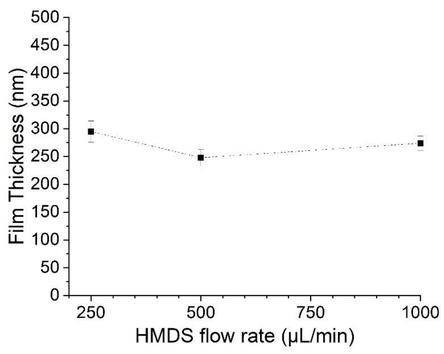
- **The size of the droplets doesn't change**
- **Increasing the flow rate increase the amount of precursor**

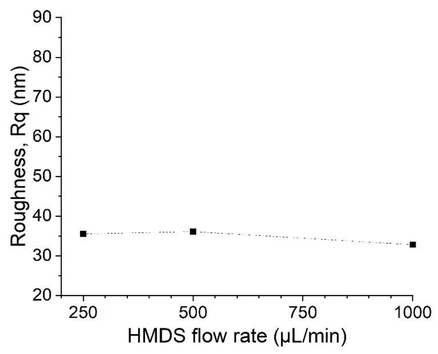


***Thin film properties** for Φ_{N_2} = 15 L/min*

the number of torch plasma passes is set as 3
The distance between the substrate and the nozzle is 1 cm



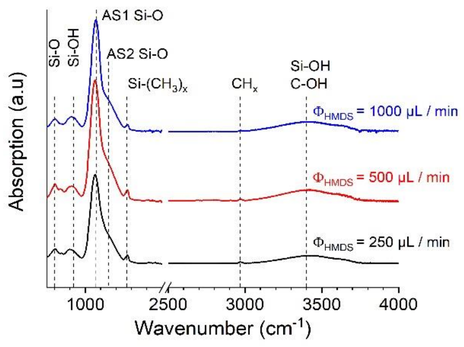




The thin film thickness and roughness are faintly affected by Φ_{HMDS}

Hypothesis:
- Mass balance ↓ (reactivity or adhesive problems ?)
- Plasma/droplet interaction

FTIR spectra

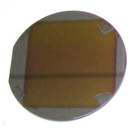


Identical band structure
$SiO_xC_yH_z$ thin films

Elipsometry fit with 2 phases (SiO_2 + void)

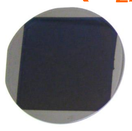
Fit optimum for Φ_{HMDS} = 500 µL/min
→ SiO_2-like thin film

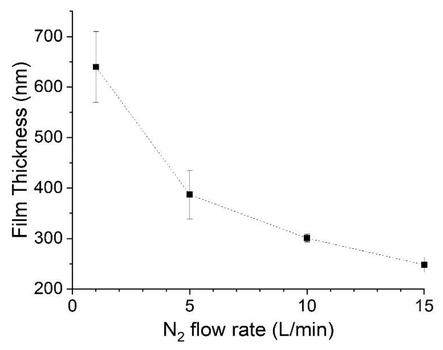
Influence of carrier gas flow rate (N_2)

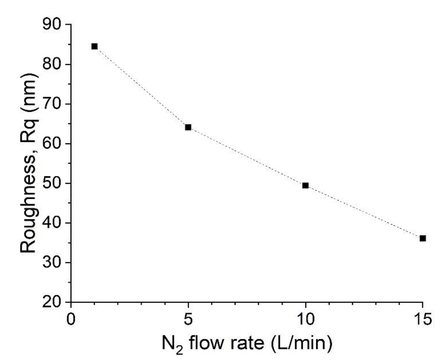


***Thin film properties** for Φ_{HMDS} = 500 µL/min*

the number of torch plasma passes is set as 3
The distance between the substrate and the nozzle is 1 cm



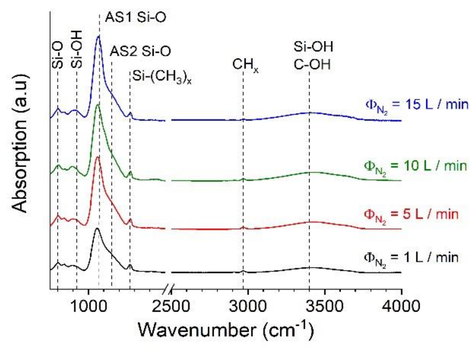




The thin film thickness and roughness decrease with Φ_{HMDS}

Hypothesis:
- Densification of the thin film
- Modification of the aerosol density and/or higher precursor dissociation at the center of the plasma post discharge

FTIR spectra



Increasing Φ_{N_2} → defined the Si-O band at 1200 cm^{-1} from Si-O-Si environment

Elipsometry fit with 2 phases (SiO_2 + void)

Increasing Φ_{N_2} → tend toward SiO_2-like thin film

Conclusion

- **Elaboration of $SiO_xC_yH_z$ thin films from aerosol-assisted atmospheric pressure plasma**
- **High deposition rate** (from ≈80 to 200 nm/passing at 100mm/s)
- **Increasing the precursor flow rate (HMDS):**
  - **Increase the amount of the droplets precursor but not their size**
  - **Faintly modified thin film properties**
- **Increasing the carrier gas flow rate (N_2):**
  - **Densify the thin film (↓ thickness and ↓ roughness)**
  - **Modify the film chemistry ($SiO_xC_yH_z$ → SiO_2-like)**

Paper in preparation for submission

This set-up open up news perspective for various precursors

UPS
118, route de Narbonne, 31062 Toulouse cedex 9, France