ELI USER MEETING 2026

24-26 JUNE

Nanofoam targets for laser-plasma interaction at Politecnico di Milano

Matteo Iaccarino

NanoLab
DIPARTIMENTO DI ENERGIA

POLITECNICO
MILANO 1863

26/06/2026

- Activities performed within the framework of a collaboration between:

- Our group from POLITECNICO MILANO 1863


M. Passoni
Principal Investigator


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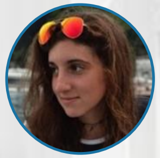
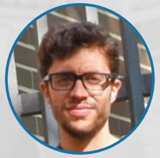
V. Russo


K. Ambrogioni


M. Iaccarino


M.S. De Magistris


D. Vavassori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F. Schillaci


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- And thesists


F. Piziali


M. Andreoni


L. Filippi

Why nanofoam
and
What is it?

1

2

How to produce
nanofoam - PLD

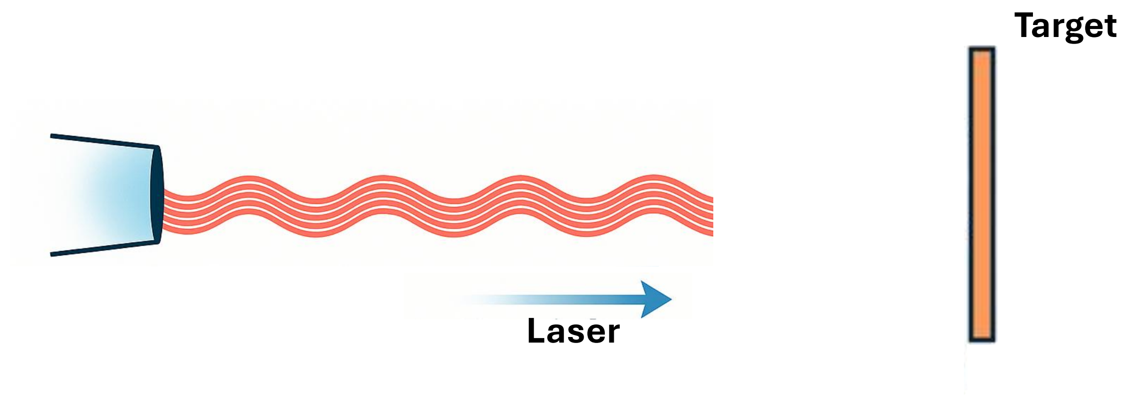
3

Some
applications

Nanofoam material for laser-plasma interaction

Nanofoam material for laser-plasma interaction

Laser-plasma interaction



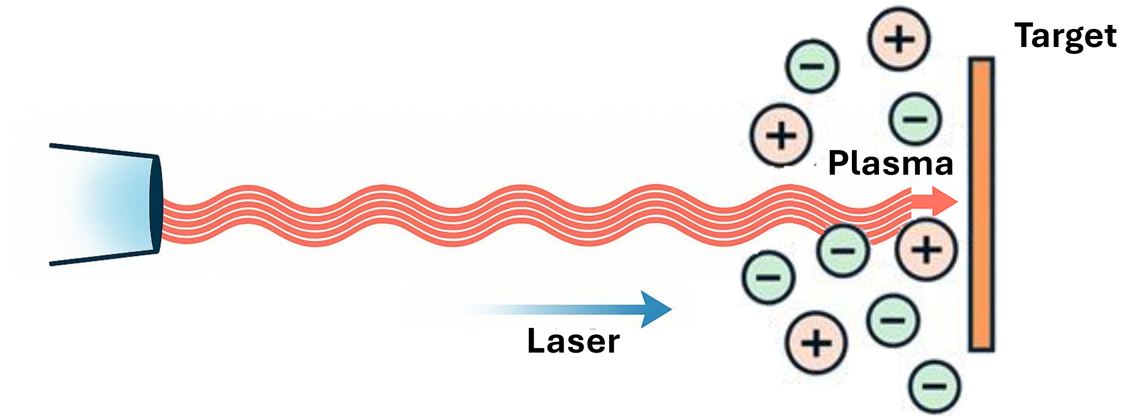
Laser

- Intensity ($I > 10^{13}\ W/cm^2$)
- Duration ($fs - ns$)
- Wavelength
- Energy ($mJ - MJ$)
- Repetition Rate

Target

- Density
- Thickness
- Composition

Laser-plasma interaction



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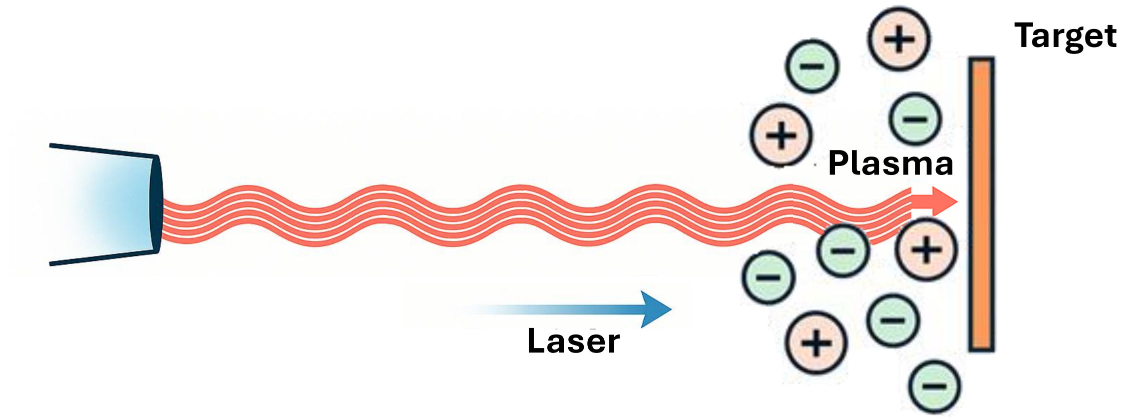
Plasma formation

Laser-plasma interaction



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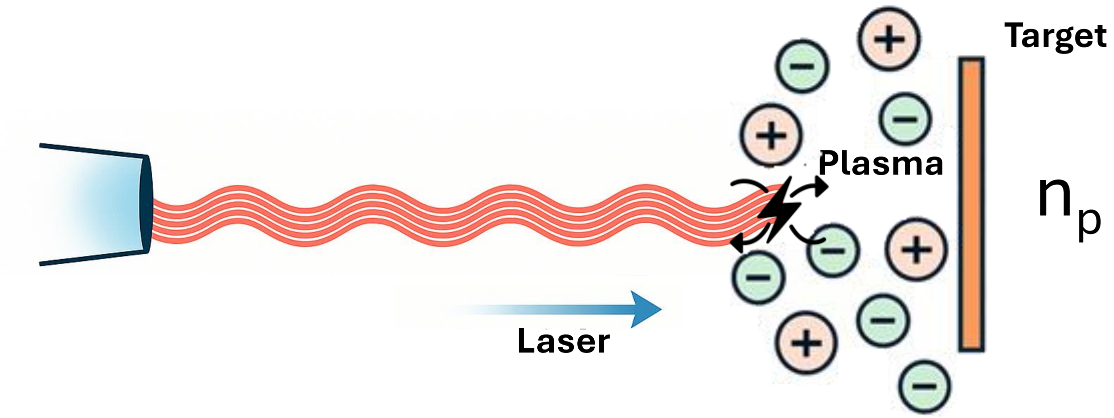
Plasma formation

Regimes of interaction depending on plasma density (n_p) with respect to the **critical density (n_c)** ⇨ $n_c = \frac{m_e \cdot \omega_L^2}{4\pi \cdot e^2}$

Laser-plasma interaction



$n_p \sim n_c$

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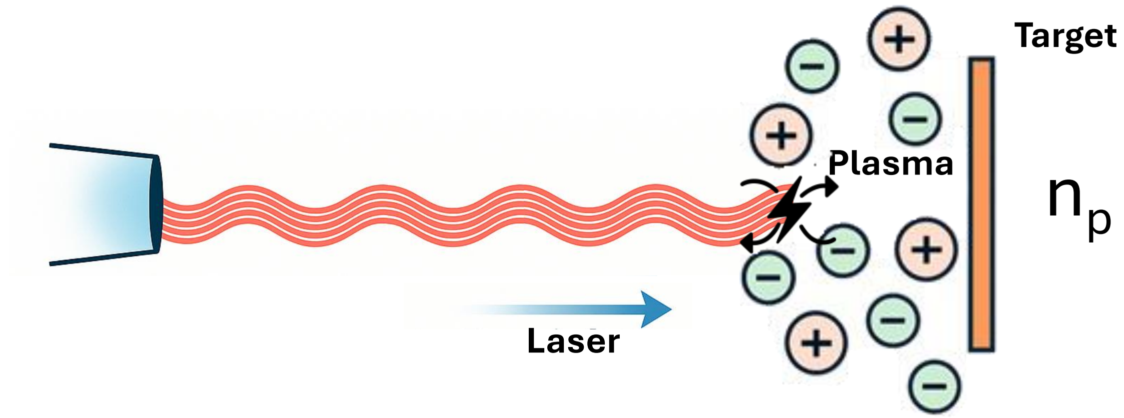
Optimized near-critical material!

$n_p \sim n_c$ ⇨ **↑ Laser-plasma coupling**

Laser-plasma interaction



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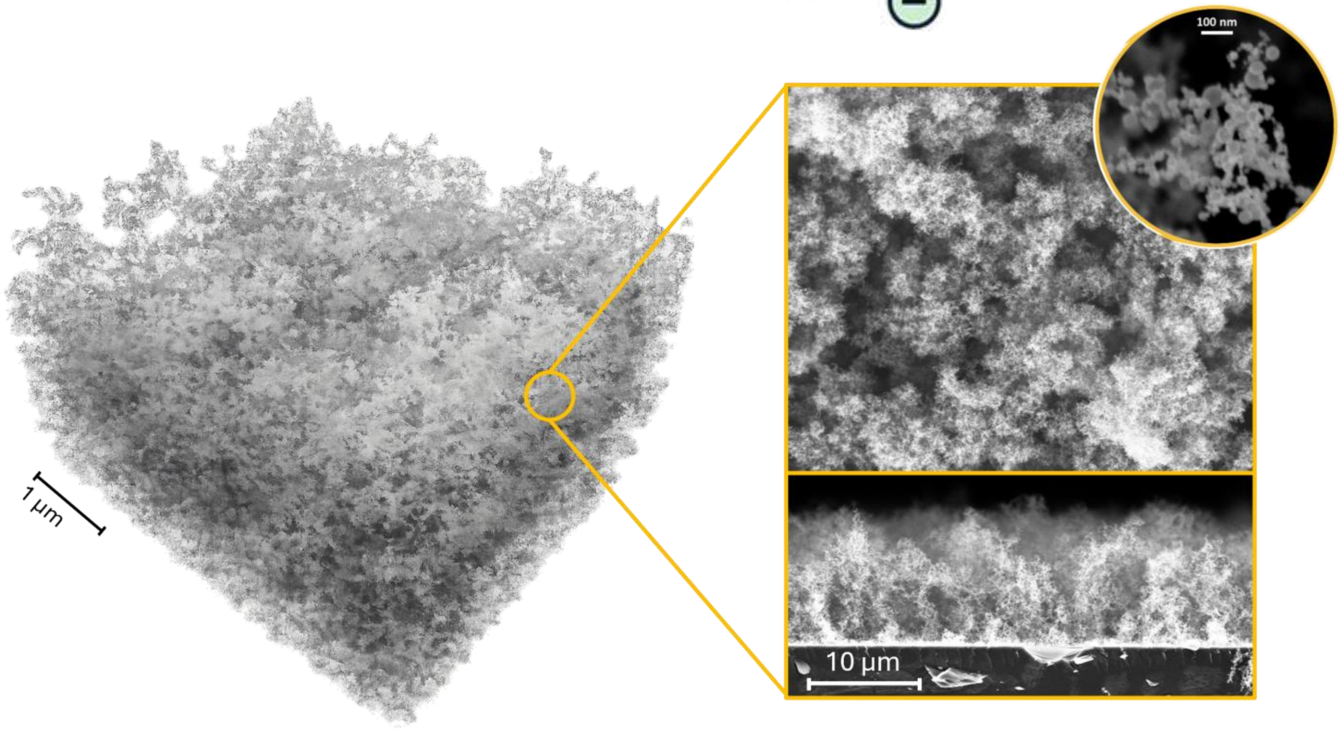
→ **Plasma formation**



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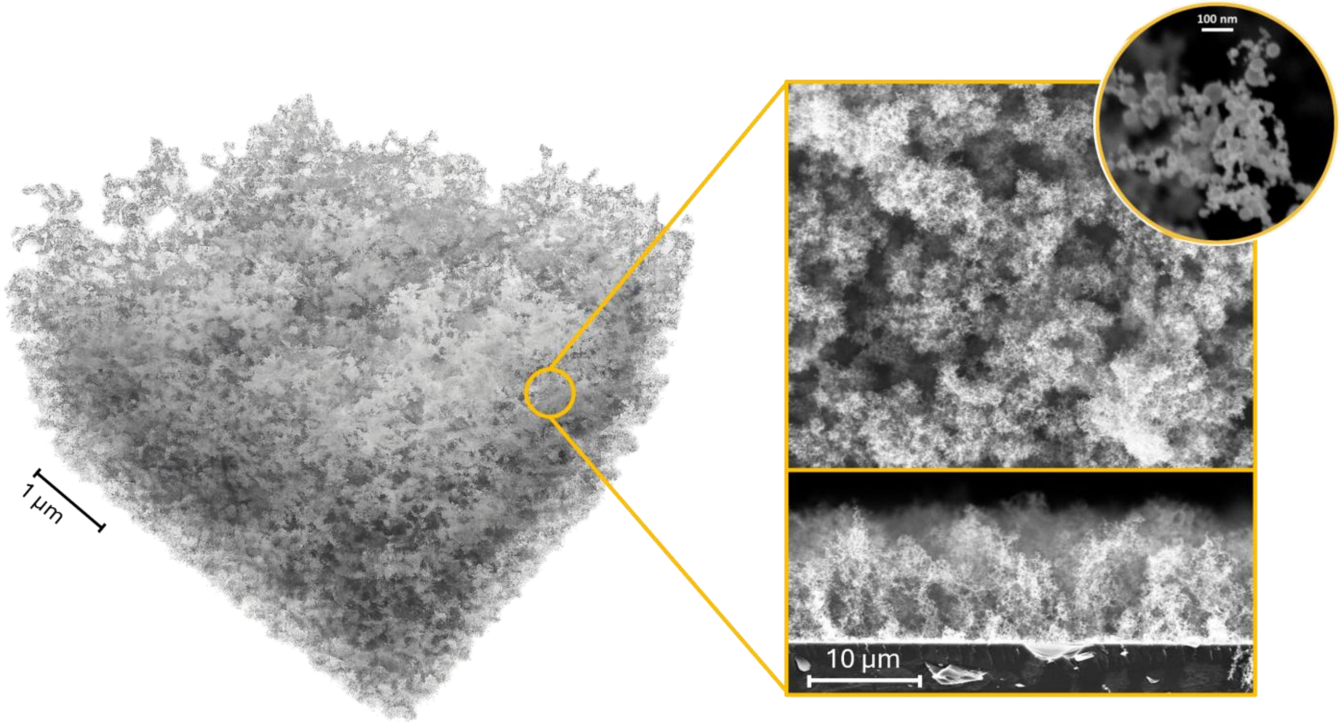
Nanofoam @PoliMi

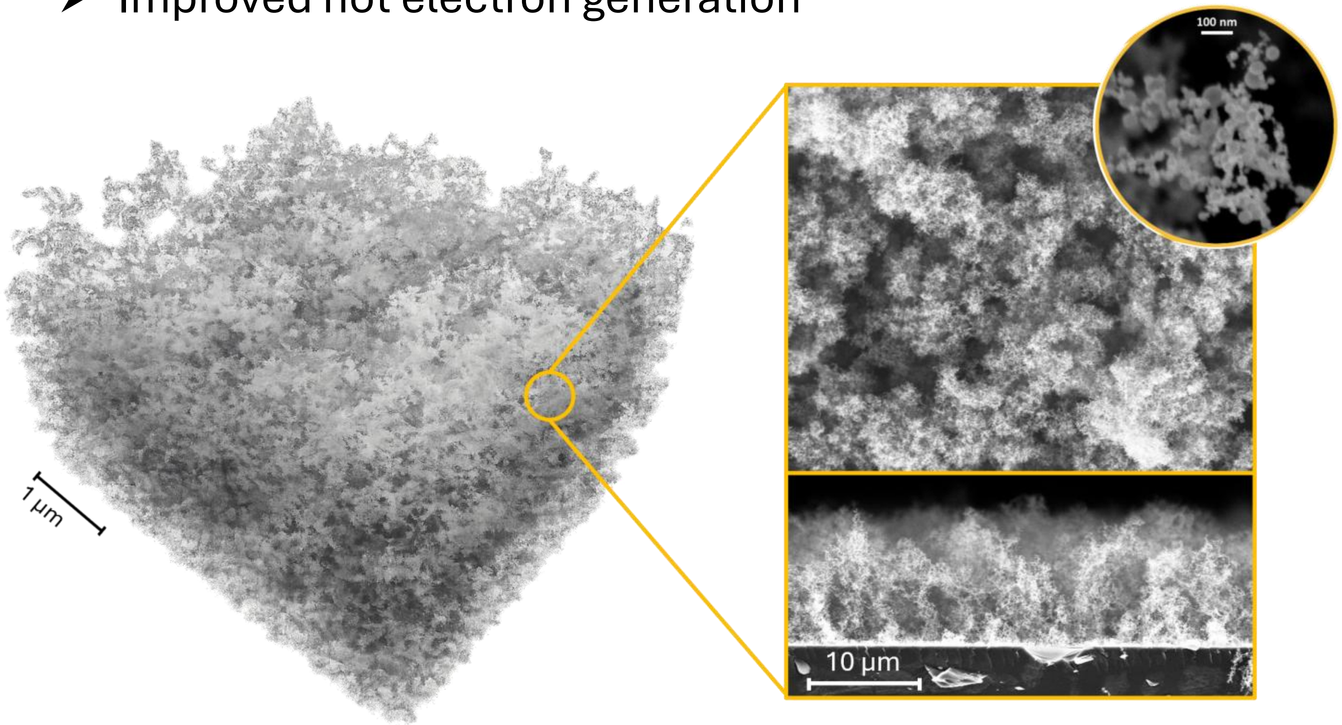
What is a nanofoam?



A. Maffini, et al. Plasma Physics and Controlled Fusion 68 (2026): 035007
A. Maffini et al., Applied Surface Science 599 (2022) 153859

What is a nanofoam?

- **Fractal-like aggregates of nanoparticles** forming a highly porous disordered network
- **Ultra low-density (few mg/cm^3)**
- Large effective surface area → **volumetric laser absorption**
- Improved hot electron generation



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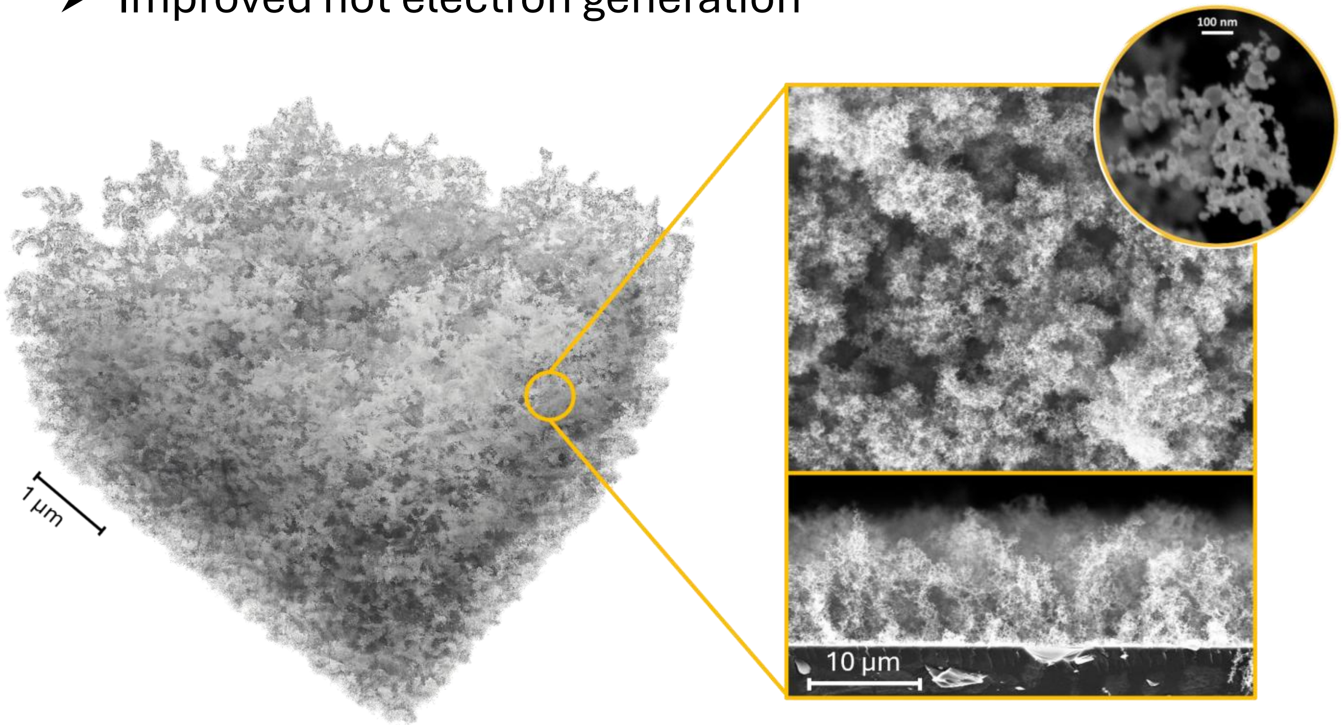

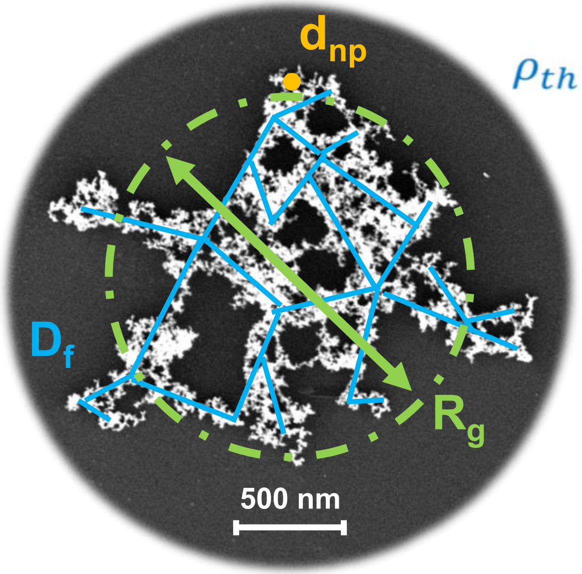

$$\rho_{th} \cong k\rho_{np}\left(\frac{d_{np}}{2R_g}\right)^{3-D_f}$$

Diffusion-Limited Cluster Aggregation (DLCA) mechanism

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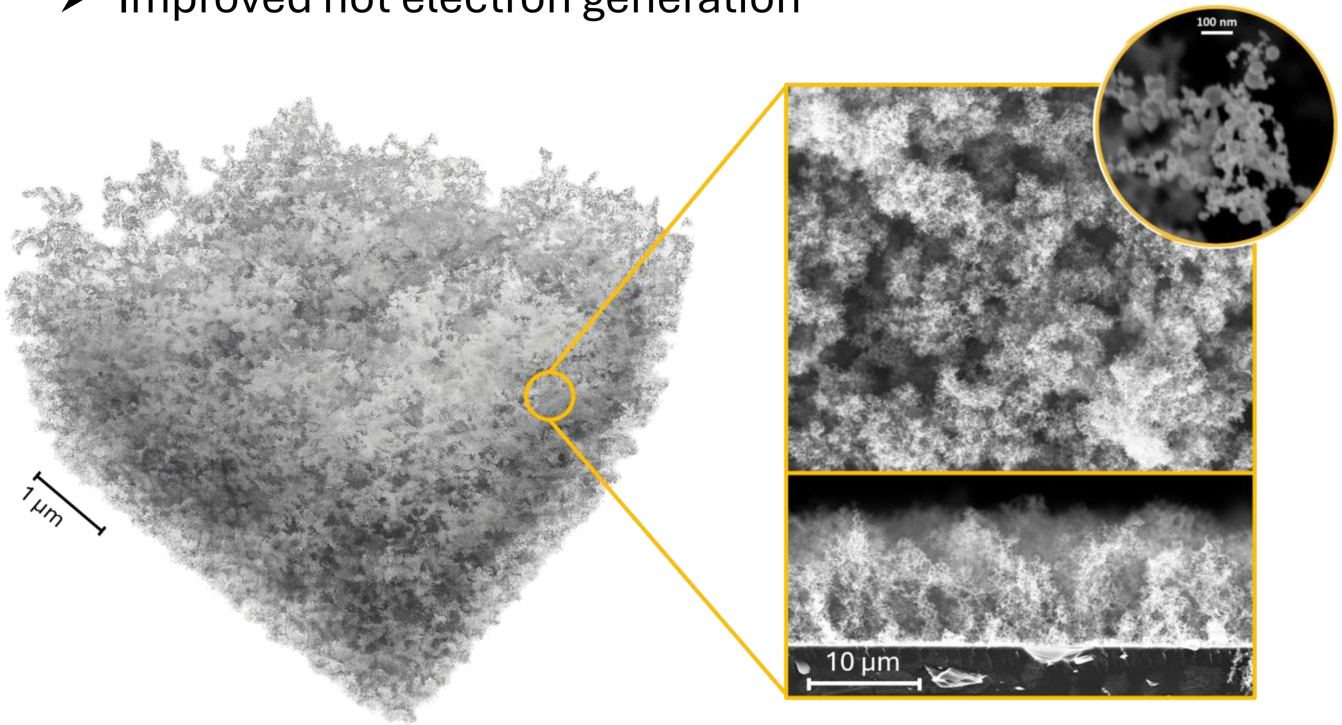

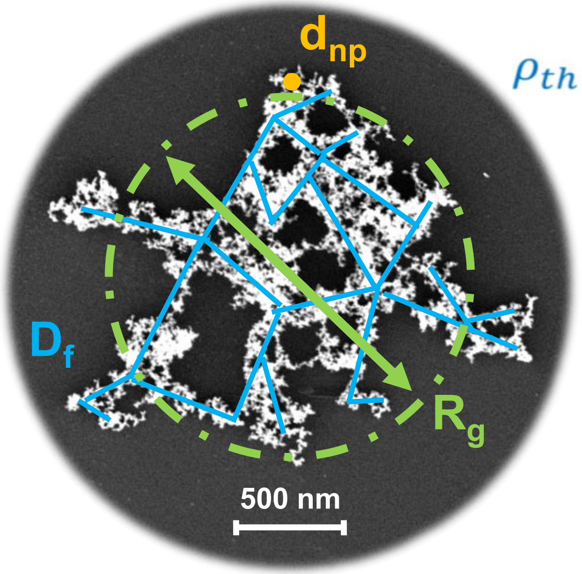

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Diffusion-Limited Cluster Aggregation (DLCA) mechanism

d_{np}

Nanoparticle diameter: **5 nm - 40 nm**
Nanoparticle density: ~ 50% - 100% of bulk
Nanoparticle composition: any!

D_f

Fractal dimension: **~ 1.8 - 2.2**

R_g

Gyration radius: **0.1 μm - 5 μm**

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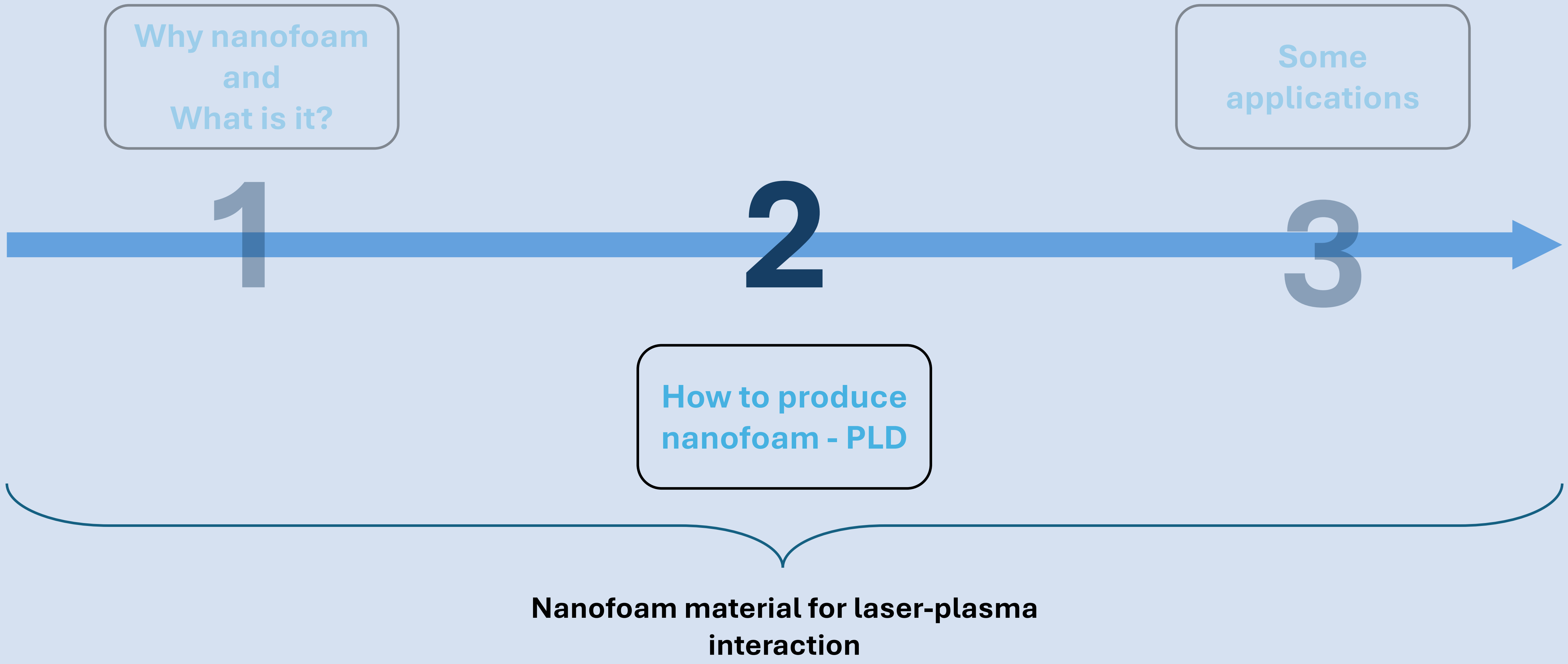
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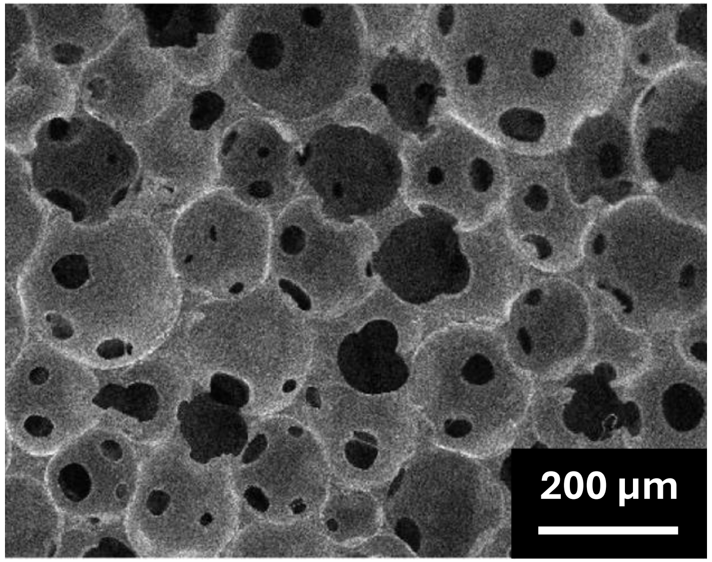
Nanofoam production methods

Chemical Synthesis

- ✓ Cheap & easy manufacturing
- ✓ Easily scalable
- × Limited control over properties



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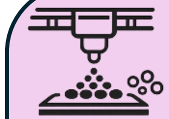
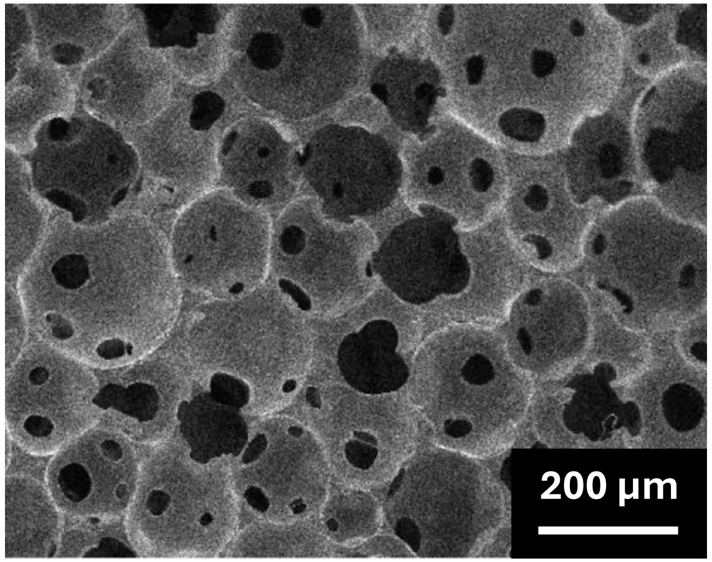
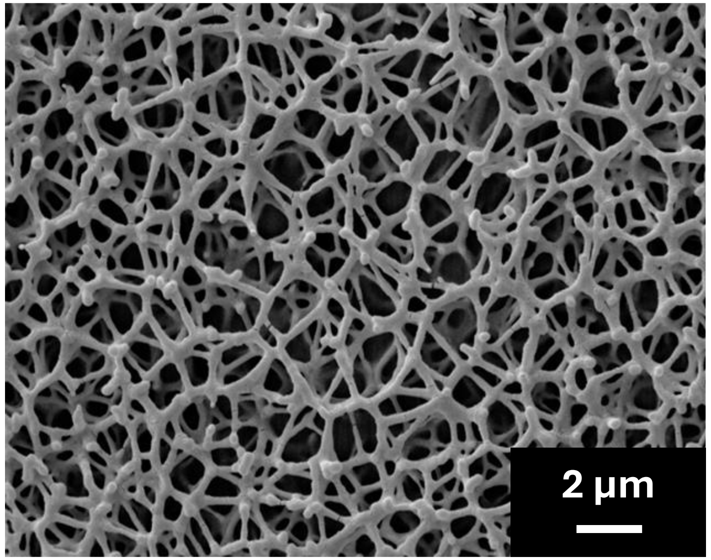


Additive Manufacturing

- ✓ Precise & reproducible
- ✓ High control over properties
- × Micrometric scale (10-100 μm)





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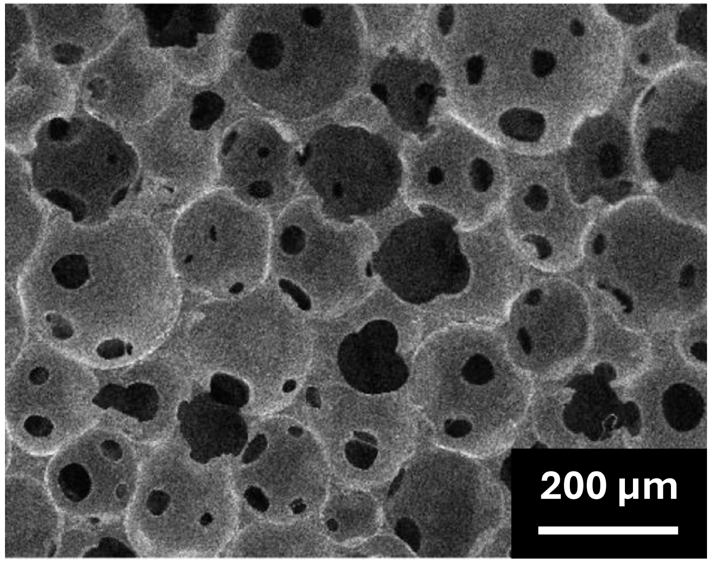
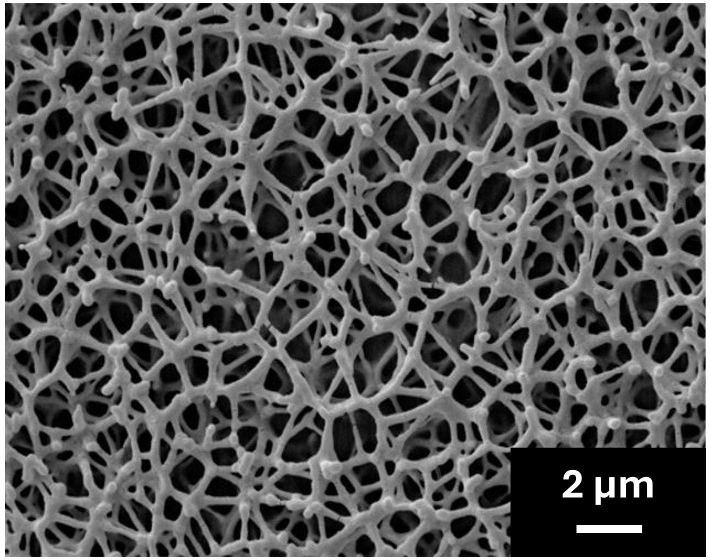
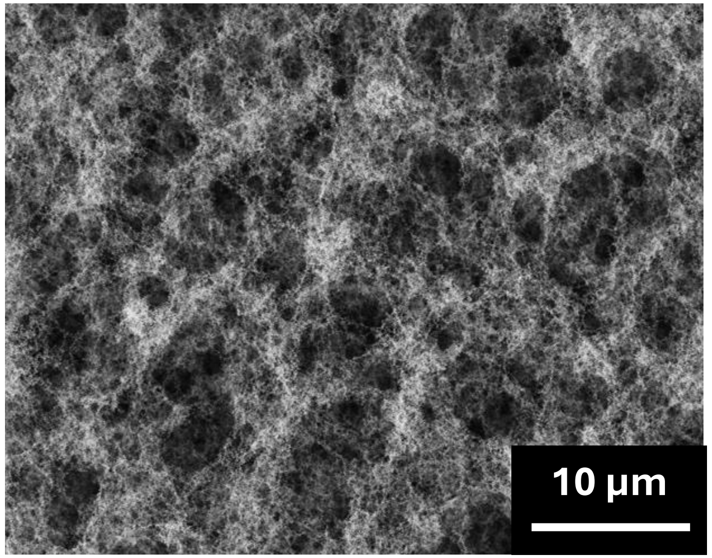
Physical Vapour Deposition
- ✓ Extreme versatility
- ✓ High control over properties
- ✓ Nanostructured layers







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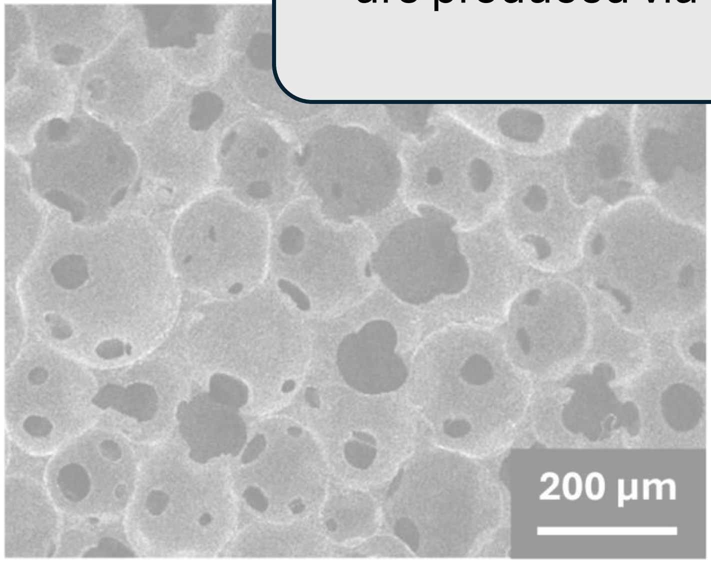
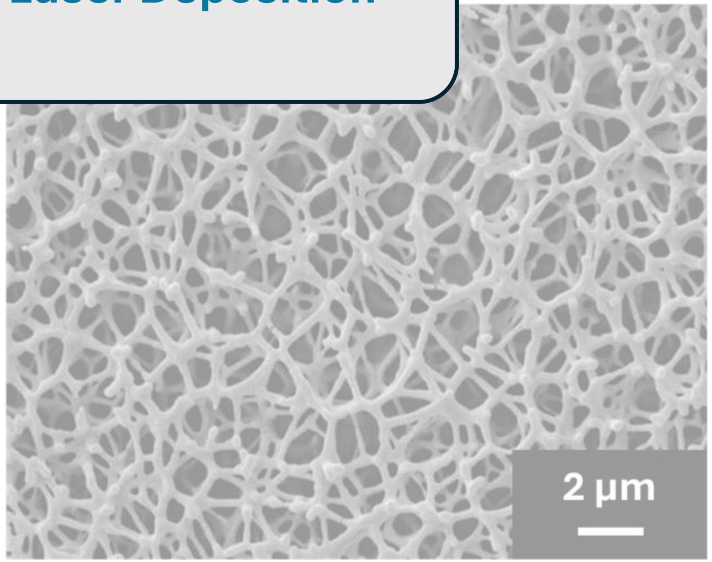
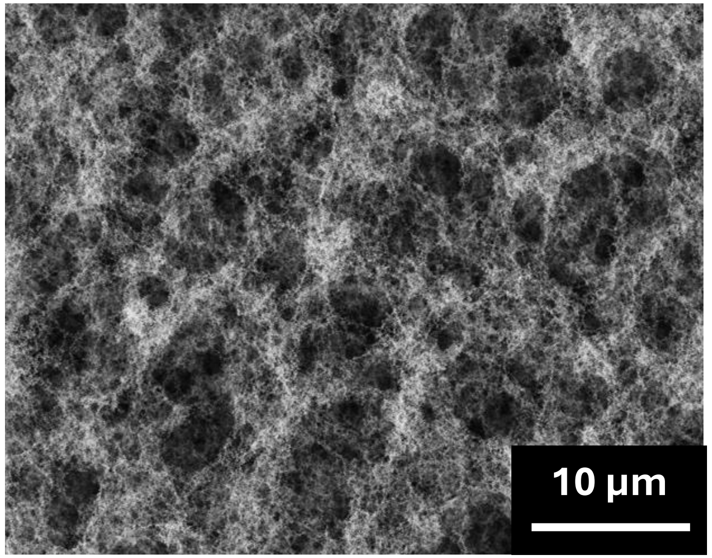
@ Politecnico di Milano Nanofoam materials are produced via **Pulsed Laser Deposition (PLD)**







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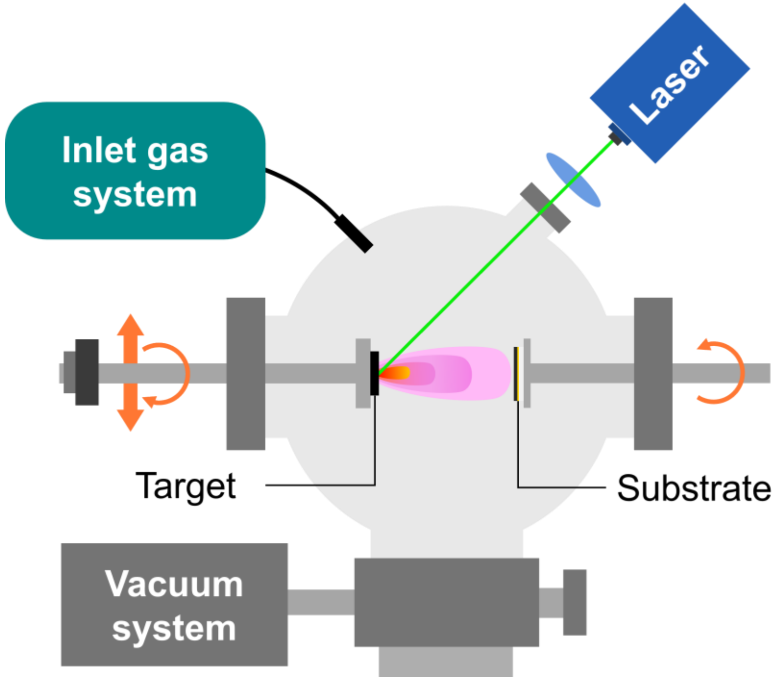
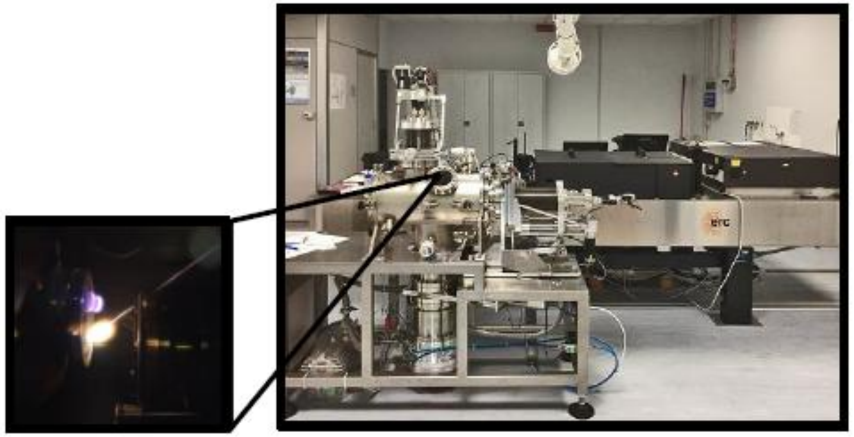
PLD: Working principle

How does it work?

Laser induced **target ablation** → **Plasma plume** → **Film deposition**





D. Orecchia et al., Small Structures, 5, 2300560 (2024)

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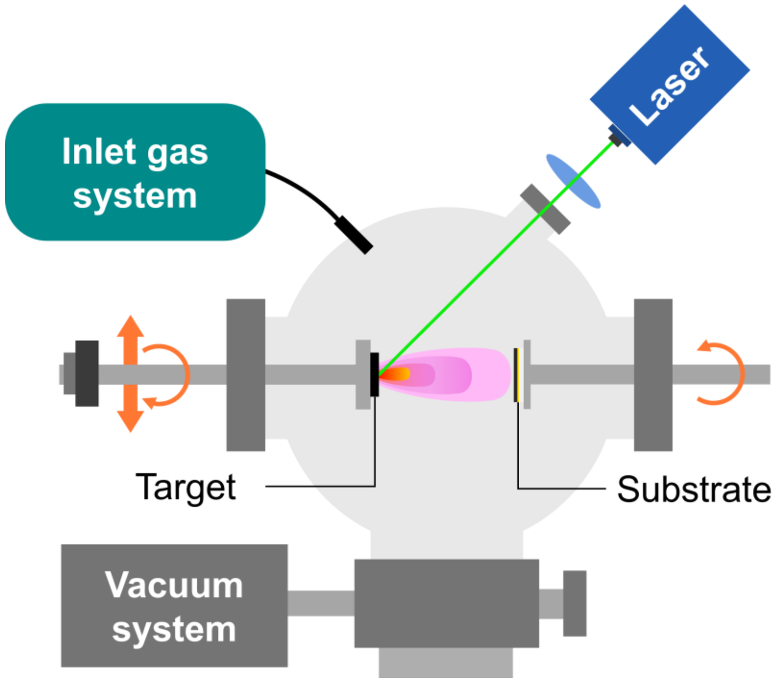
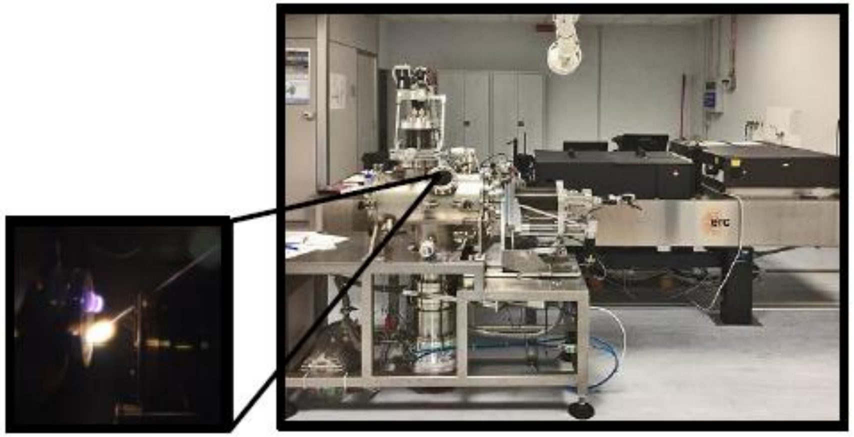
Film properties

- Composition

Operating parameters

- Target Composition





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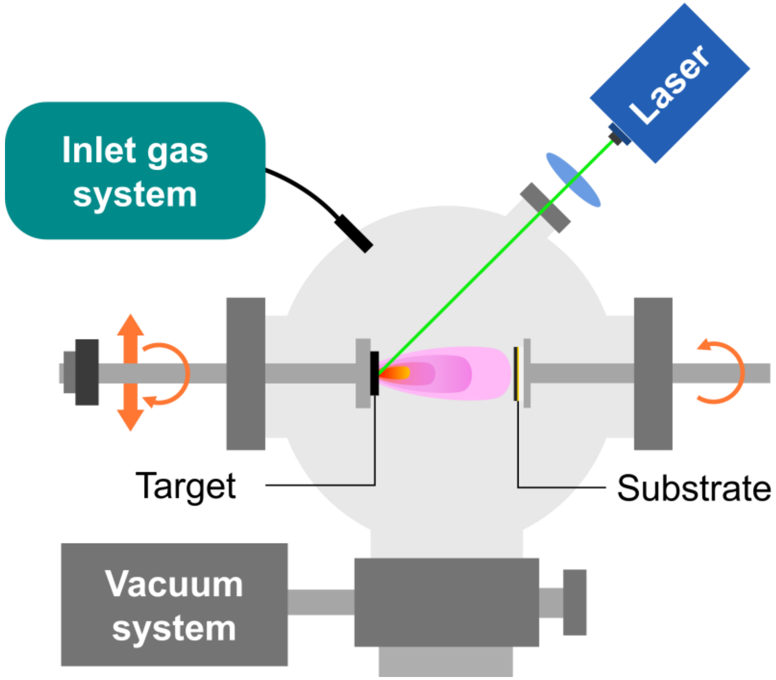
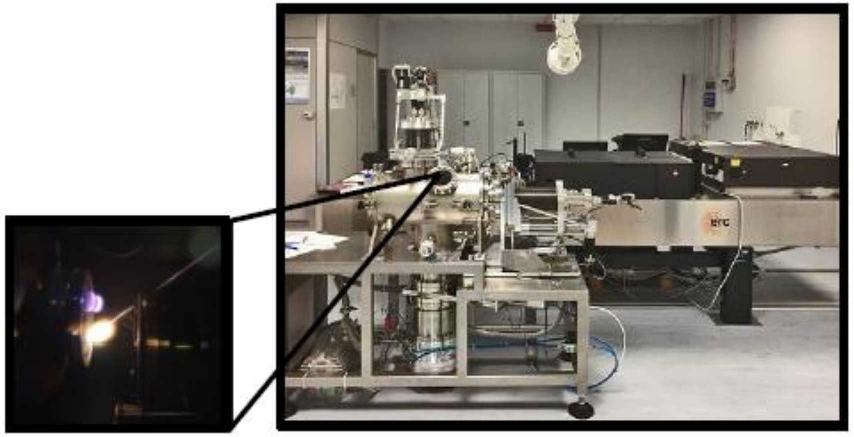
Film properties

- Composition
- Nanostructure

Operating parameters

- Target Composition
- Pulse Duration
- Laser Fluence





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Film properties

- Composition
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- Thickness

Operating parameters

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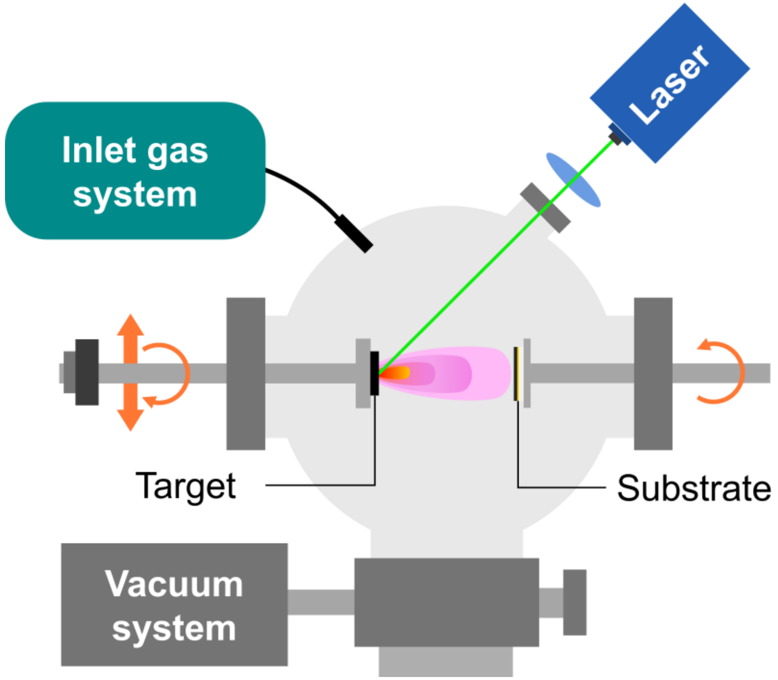
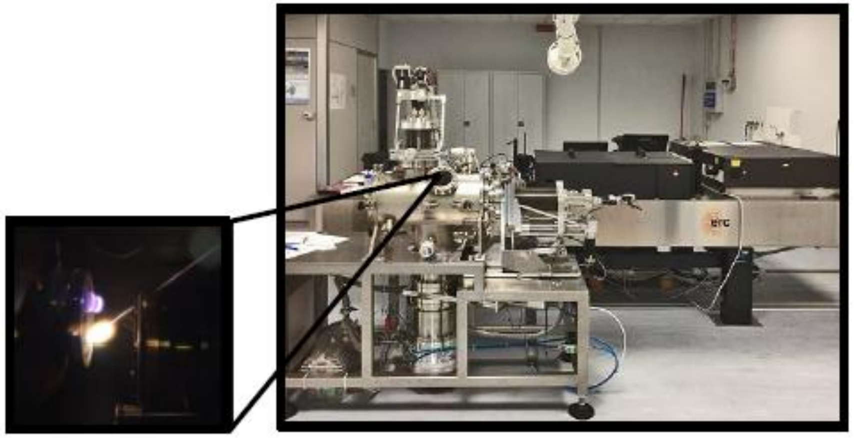
- Deposition Time





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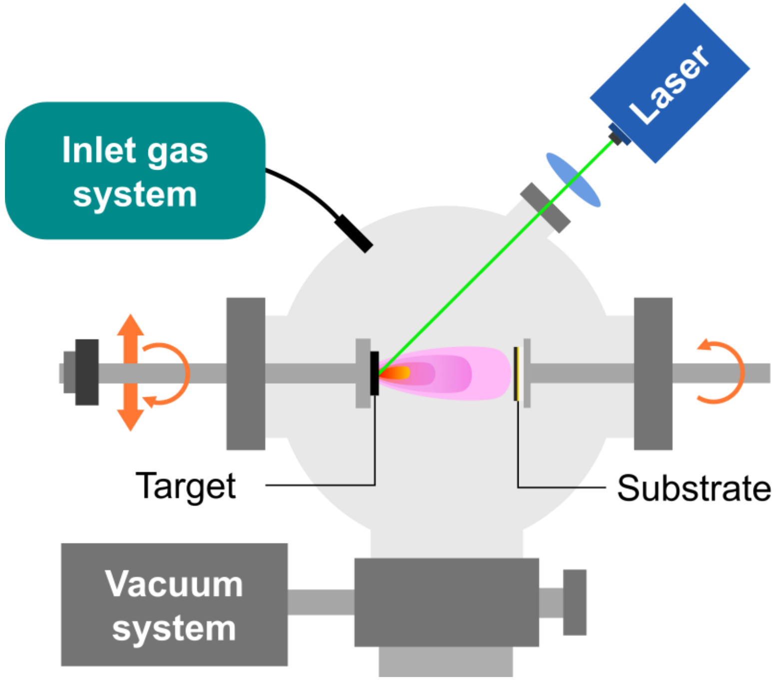
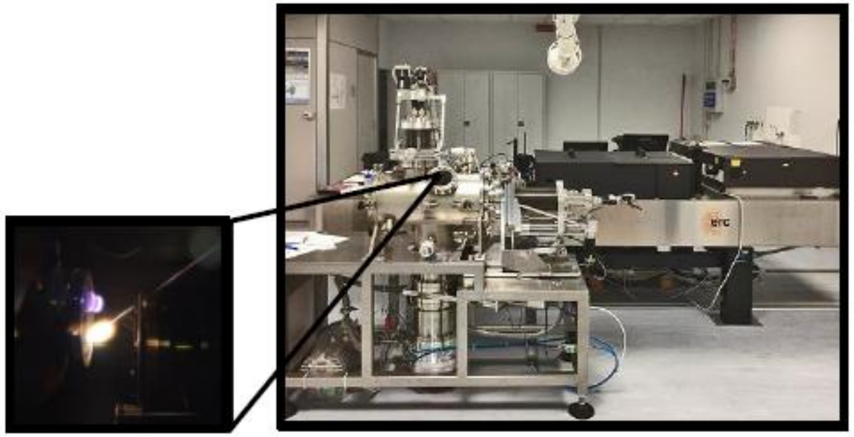
Film properties

- Composition
- Nanostructure
- Thickness
- Density

Operating parameters

- Target Composition
- Pulse Duration
- Laser Fluence
- Deposition Time
- Background Pressure





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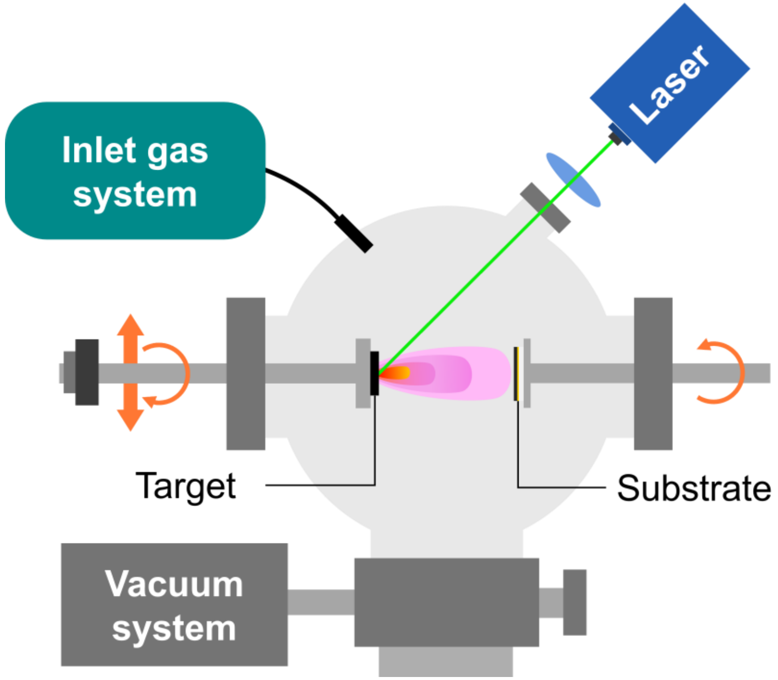
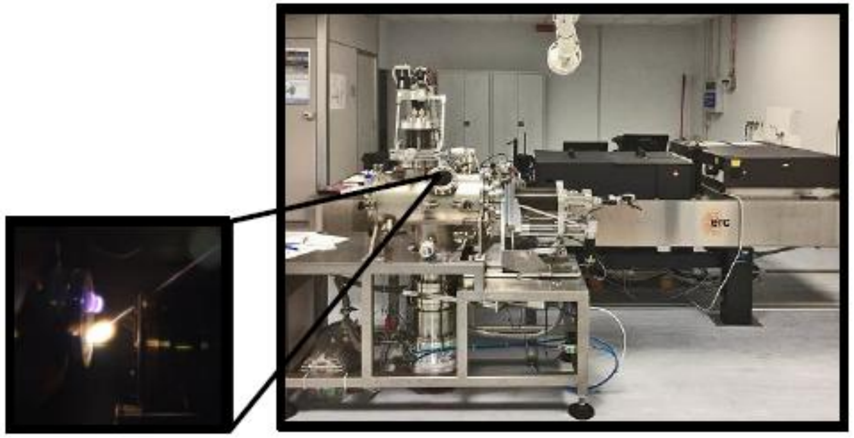
↑ Deposition time → ↑ Thickness

↑ Pressure → Nanoparticle clustering → ↓ Density





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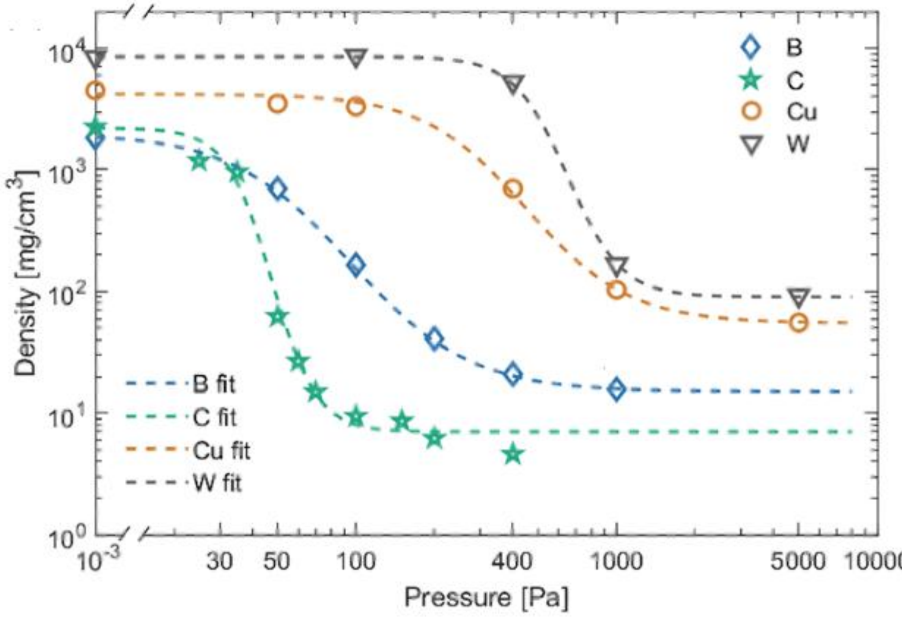
PLD: Background pressure effect

Possibility of **controlling morphology** through **background gas pressure**



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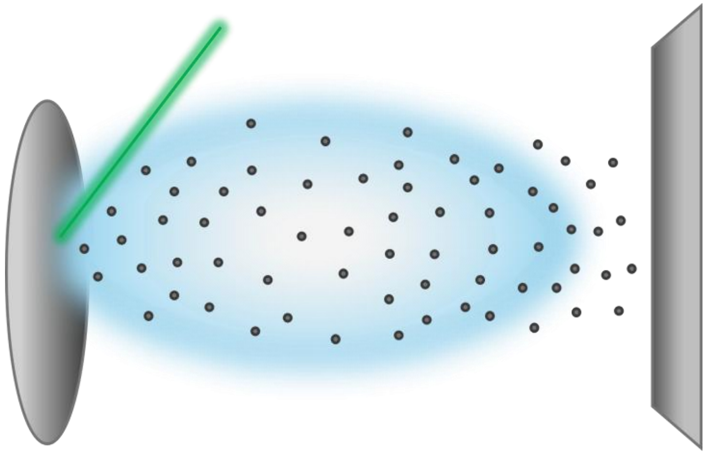

Ballistic regime

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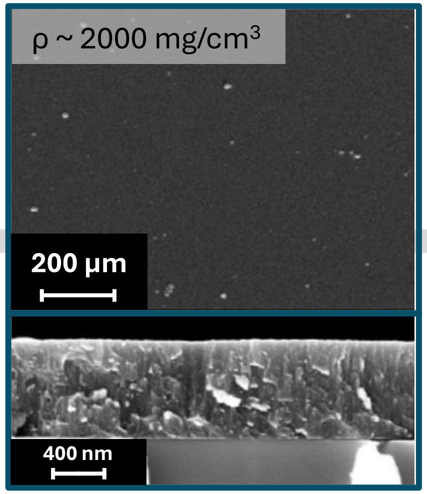
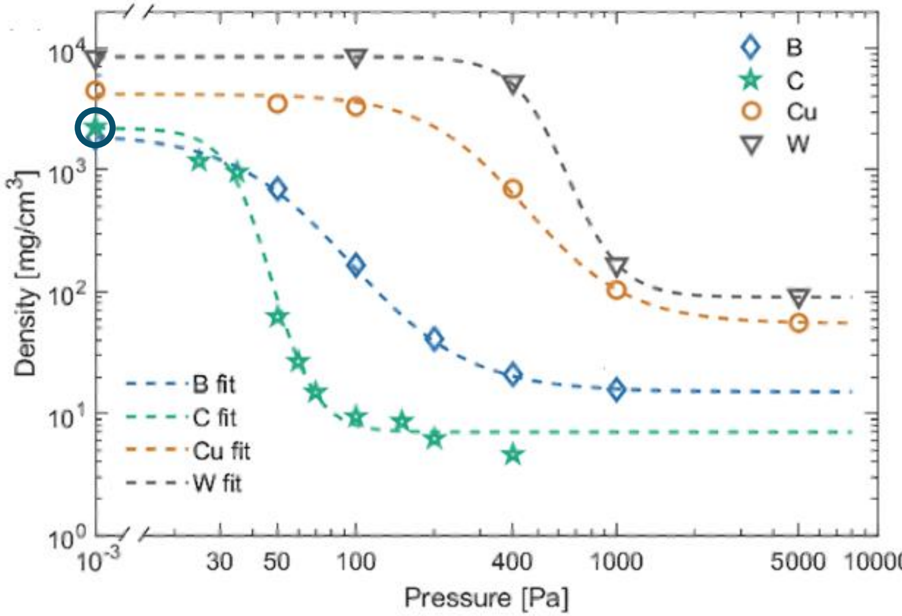


Compact

Pressure increase



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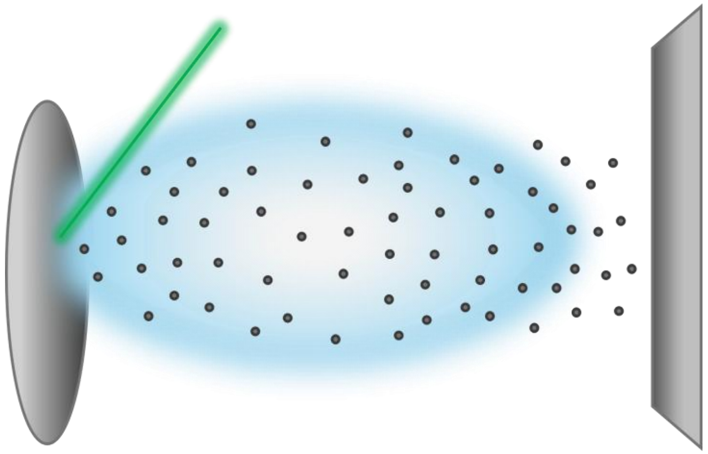
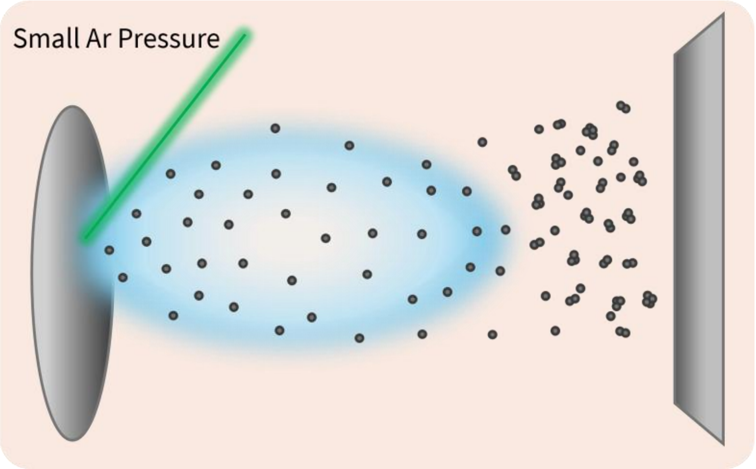
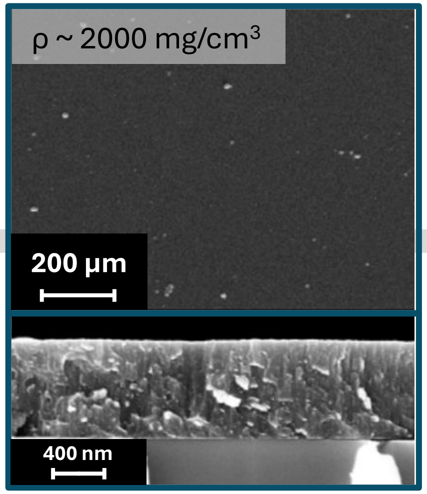




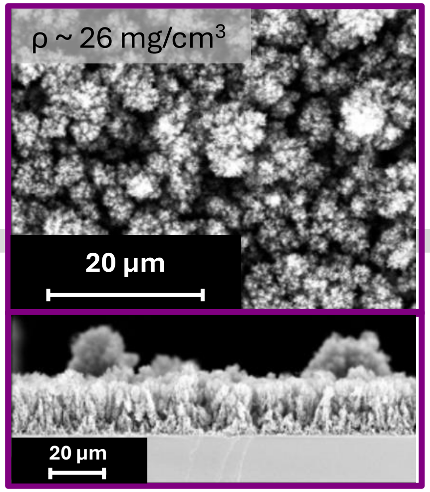
Ballistic regime

Possibility of **controlling morphology** through **background gas pressure**

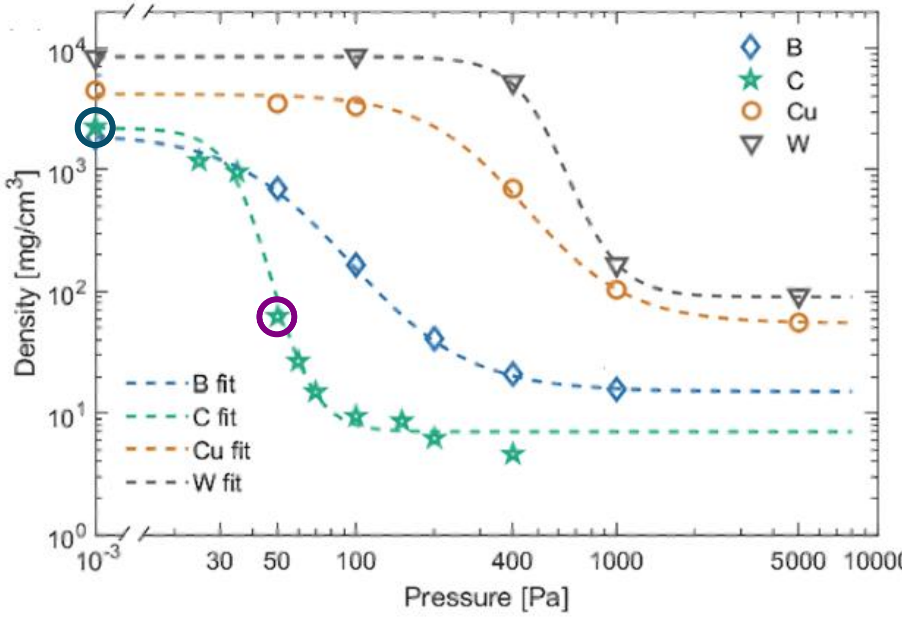
Diffusive regime



Compact



Tree-like



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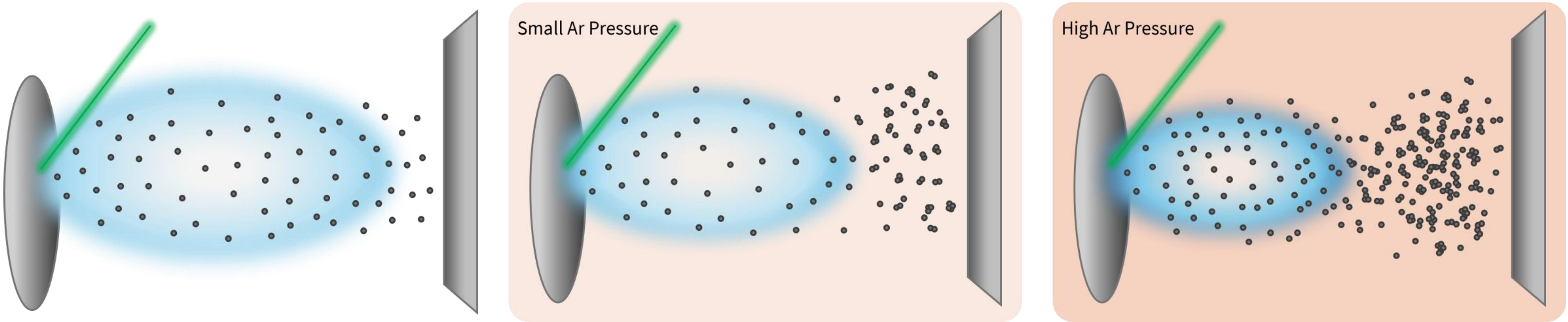

Ballistic regime — Diffusive regime

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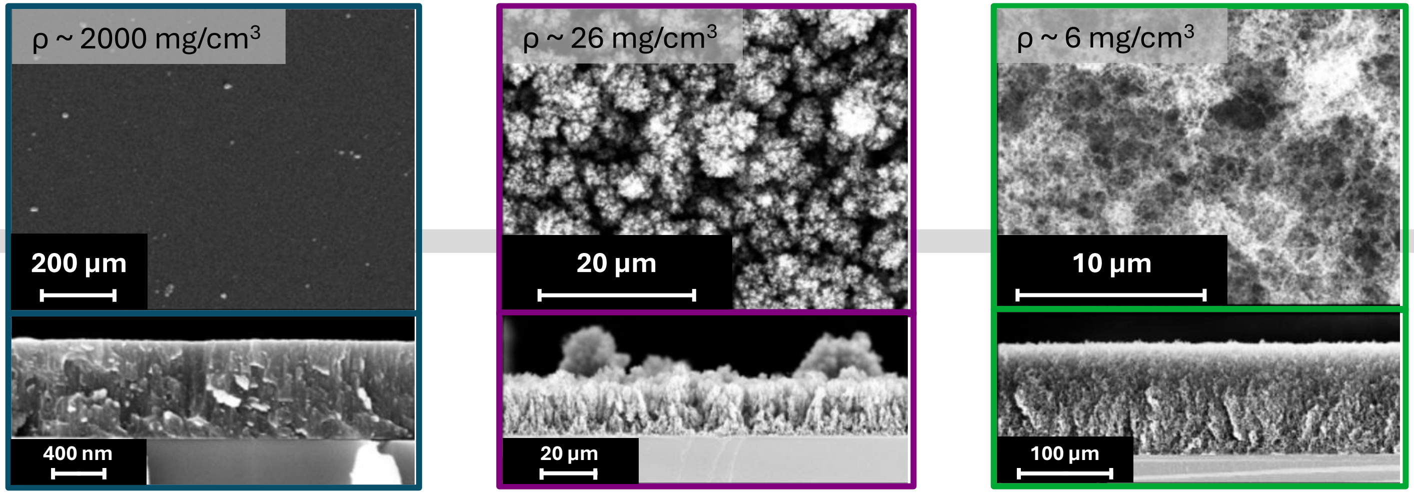
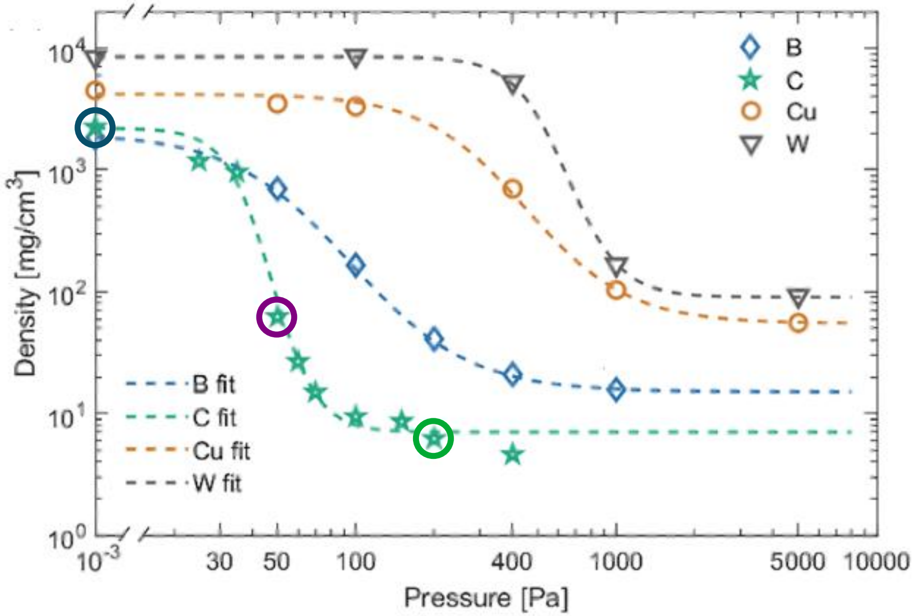
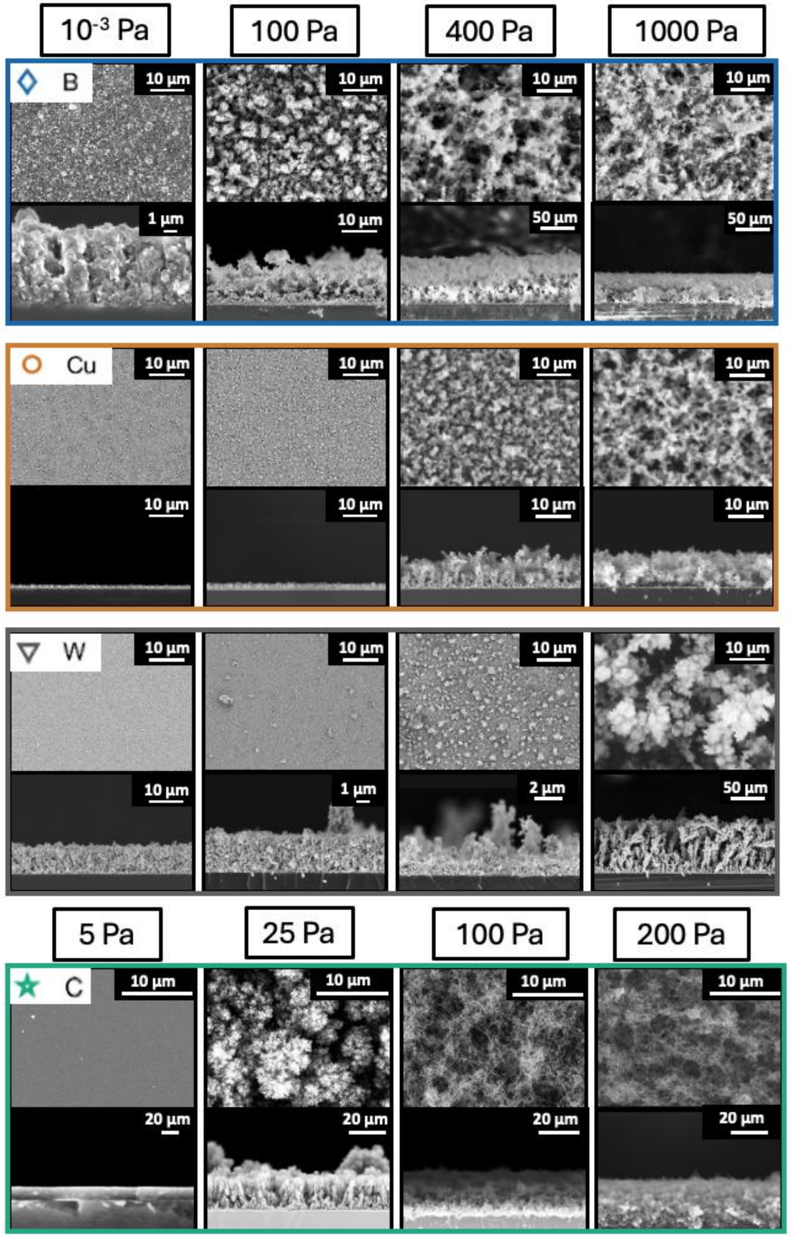


Compact **Tree-like** **Fractal-like**



D. Orecchia et al., Small Structures, 5, 2300560 (2024)

PLD: Lot of material to play with



- ns and fs ablation regimes **guarantee high versatility**

D. Orecchia et al., Small Structures, 5, 2300560 (2024)

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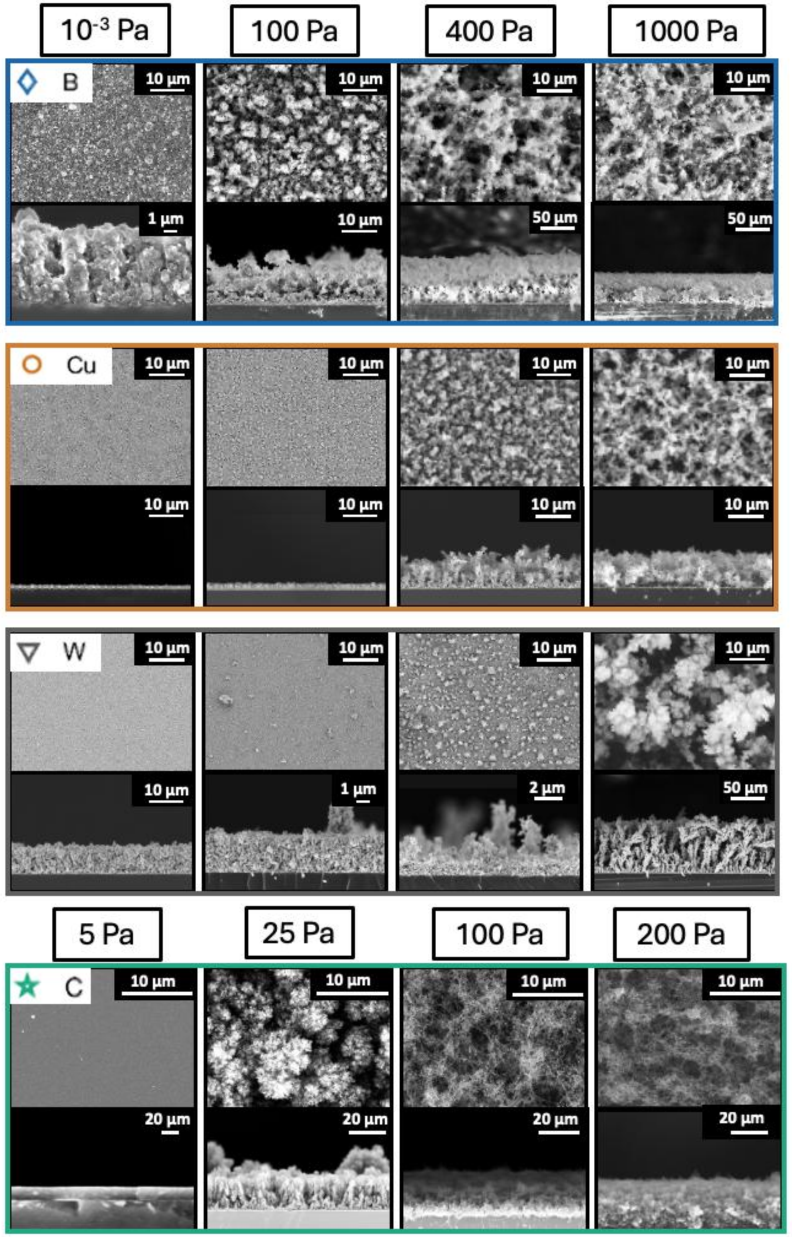
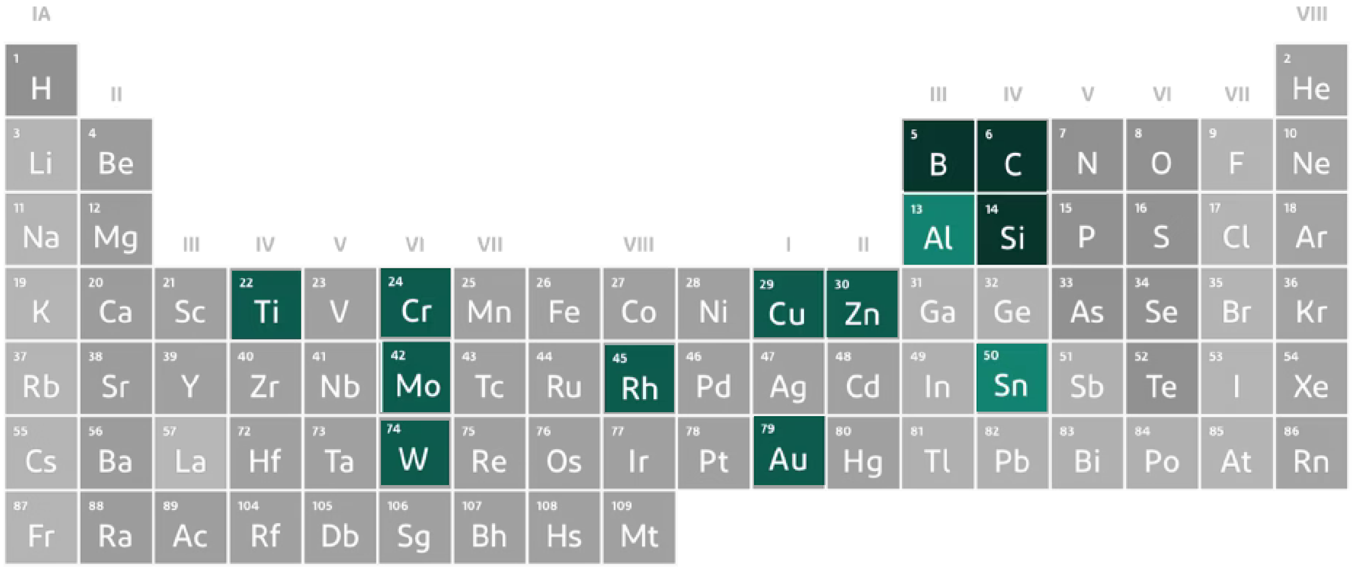
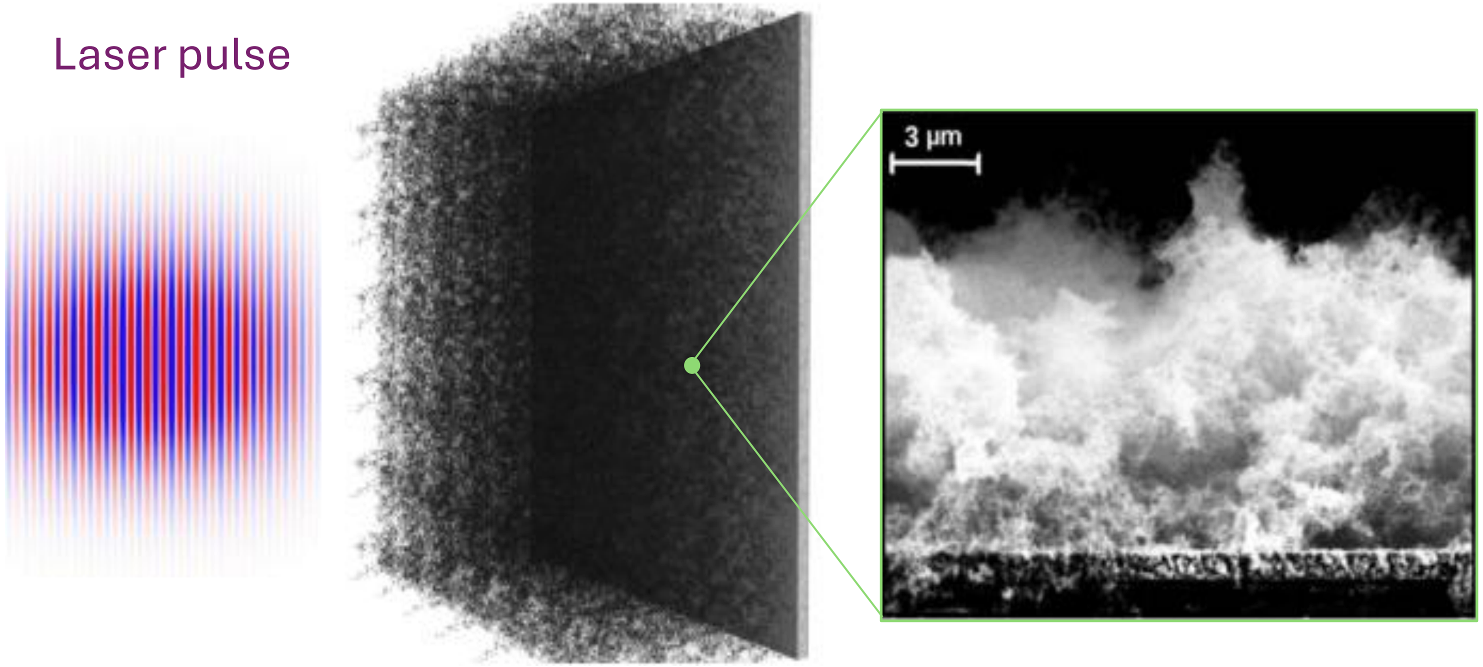


- ns and fs ablation regimes **guarantee high versatility**
- Wide choice of **metallic and non-metallic materials**
- Possibility of **Co-deposition of different materials**
- **Stoichiometric transfer** from target to film



D. Orecchia et al., Small Structures, 5, 2300560 (2024)

Nanofoam-based Double Layer Targets (DLTs)

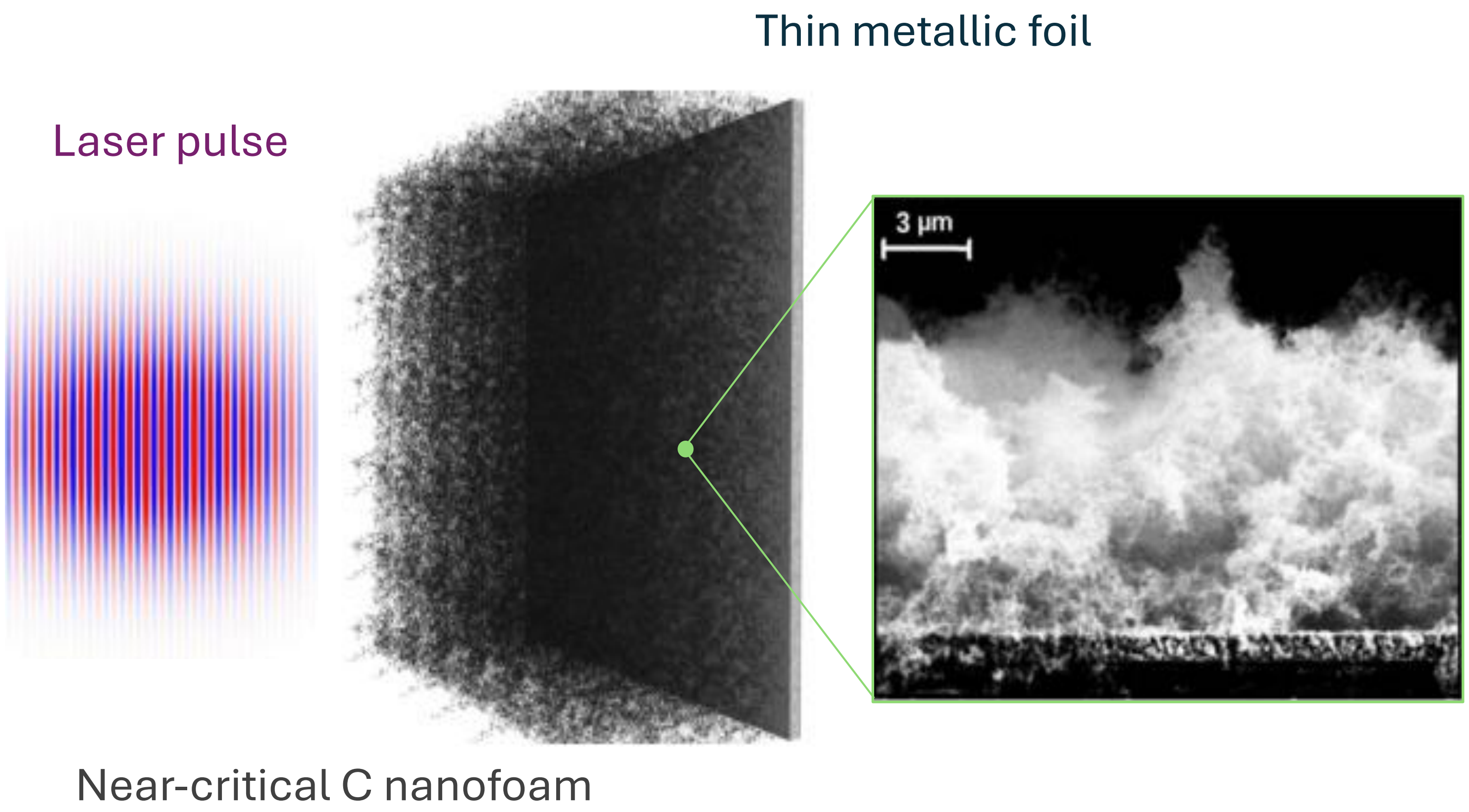


DLTs

- Thin film + Nanofoam
- Enhanced laser-plasma coupling
- Increased hot-electron generation

M. Passoni et al., Plasma Physics and Controlled Fusion 61, 014022 (2019)

Nanofoam-based Double Layer Targets (DLTs)



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Application

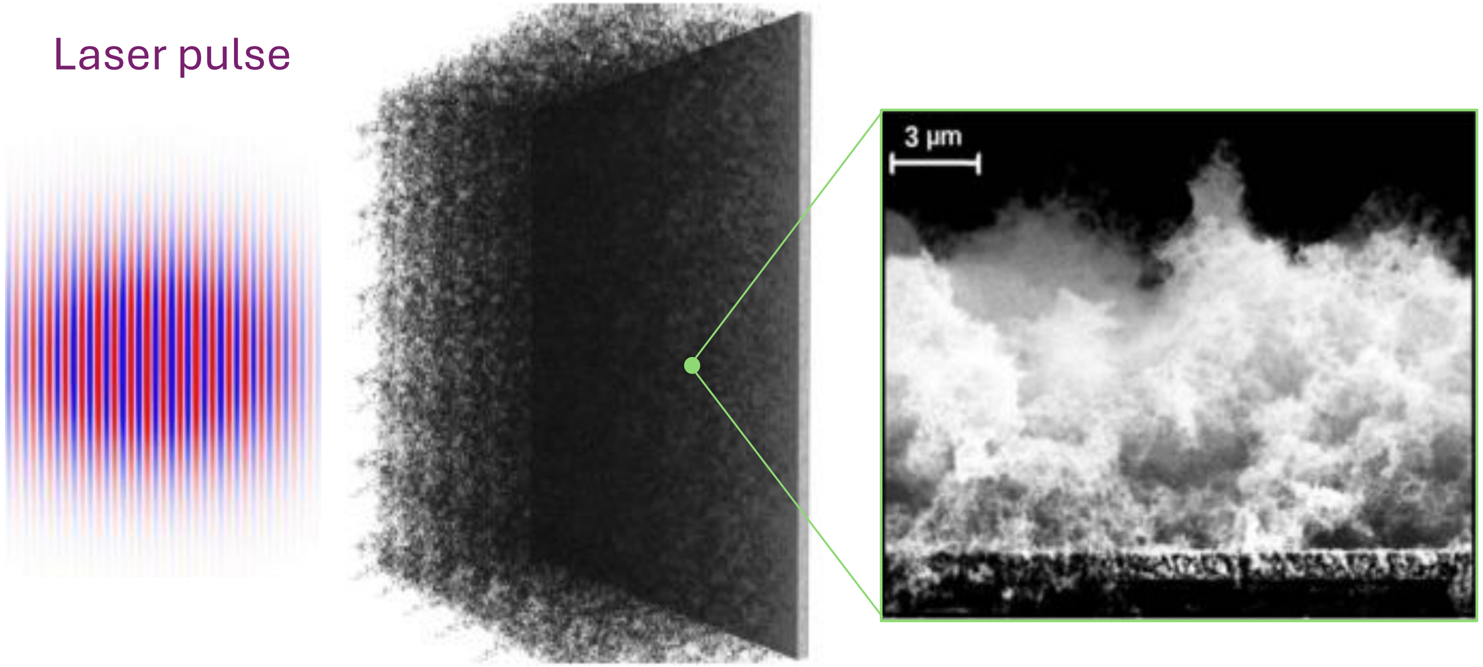
- Laser-driven proton acceleration
- Gamma photon generation
- Advanced fusion studies
- Neutron sources
- High-energy electron generation
- Radioisotope production

M. Passoni et al., Plasma Physics and Controlled Fusion 61, 014022 (2019)

Nanofoam-based Double Layer Targets (DLTs)

Thin metallic foil

Laser pulse



Near-critical C nanofoam

DLTs

- Thin film + Nanofoam
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M. Passoni et al., Plasma Physics and Controlled Fusion 61, 014022 (2019)

Why nanofoam
and
What is it?

1

2

3

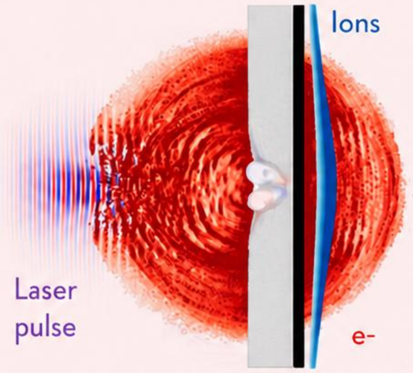
Some
applications

How to produce
nanofoam - PLD

Nanofoam material for laser-plasma
interaction

Nanofoam applications – Particles interaction

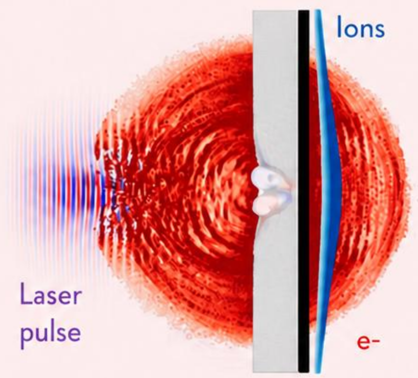
Laser driven proton acceleration

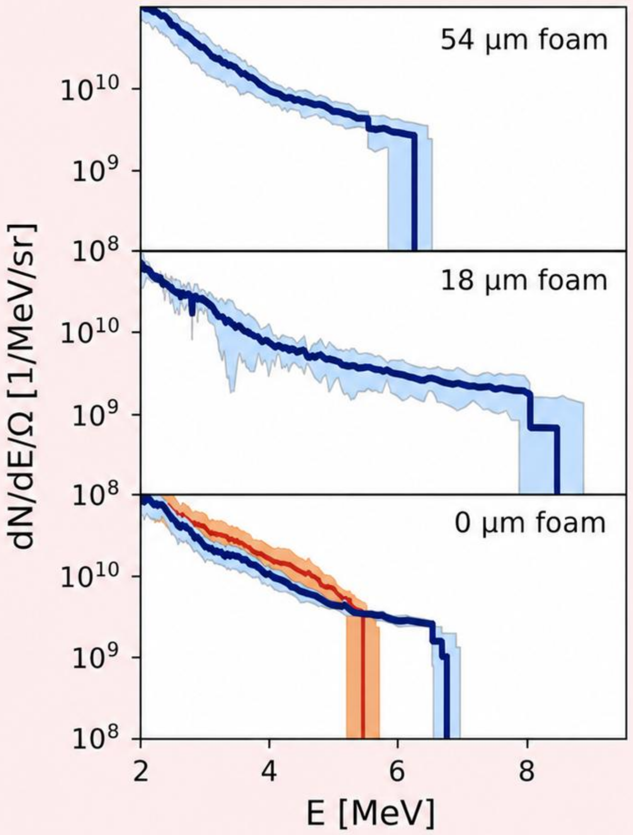


F. Mirani, et al. Physical Review Applied 24.1 (2025)

Nanofoam applications – Particles interaction

Laser driven proton acceleration





Increase in both **proton cutoff energy** and **proton number** in DLTs with respect to both **Commercial Al foils** and **MS deposited Al foils**

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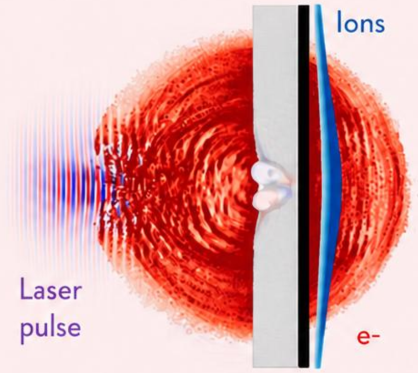
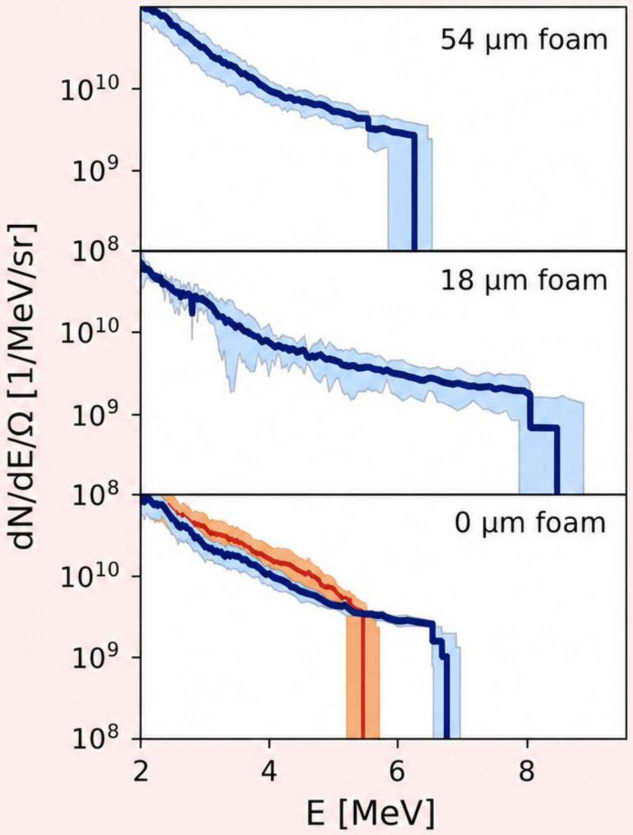
Nanofoam applications – Particles interaction

Laser driven proton acceleration





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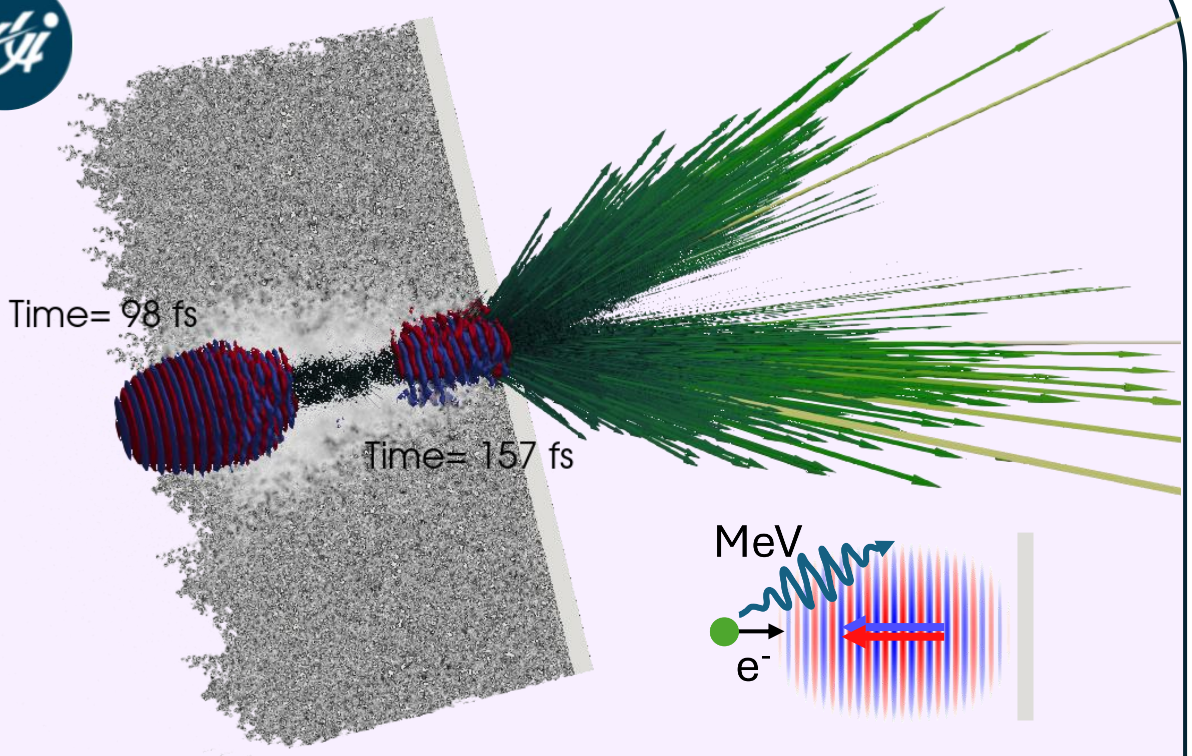

M. Galbiati, et al. Under review at Scientific Reports (2025)

Nanofoam applications – Particles interaction

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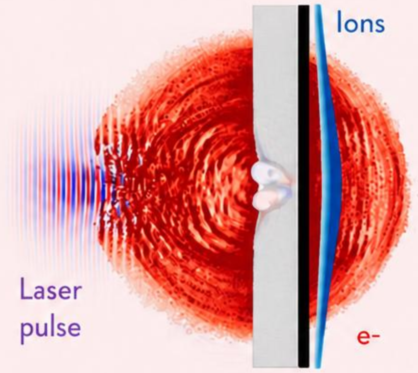

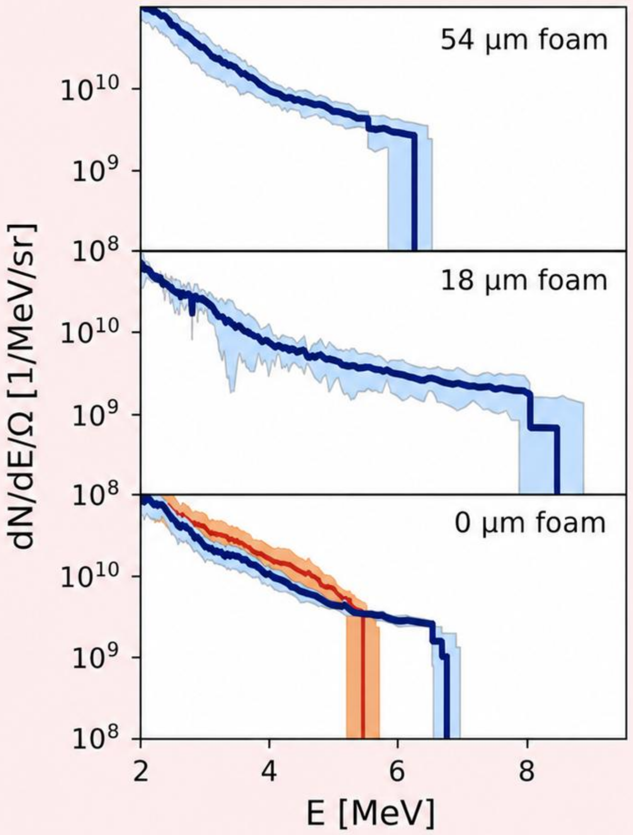

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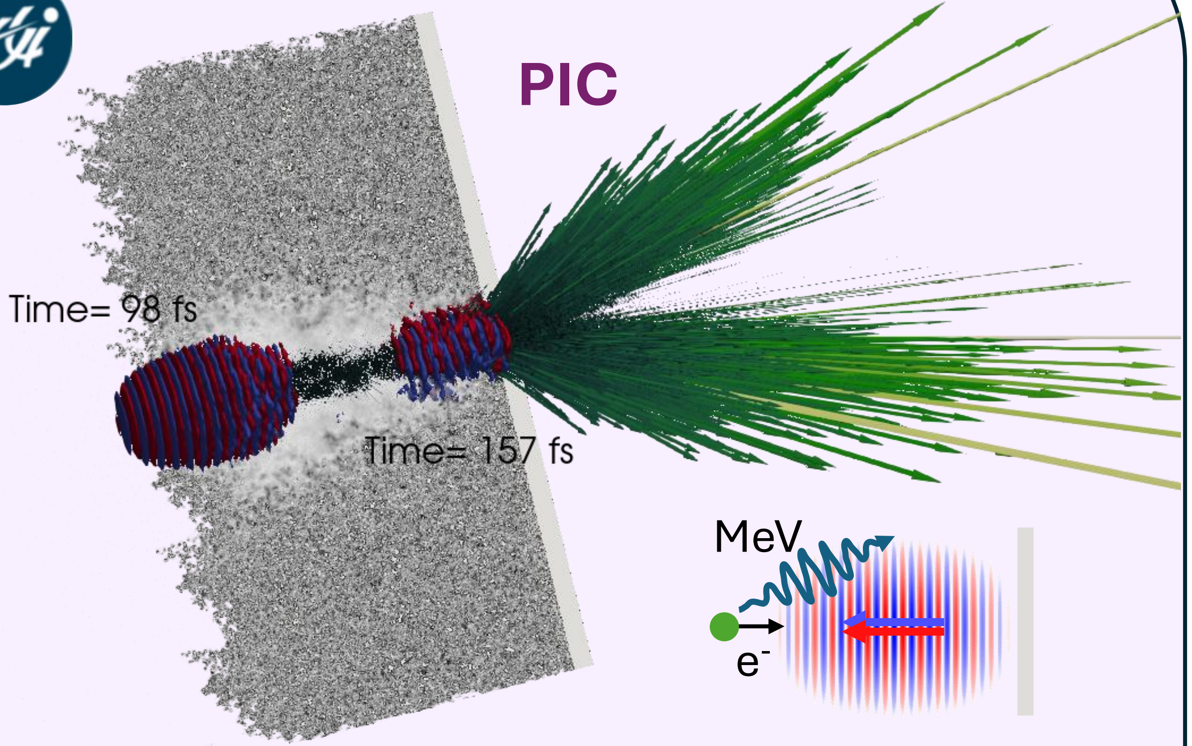


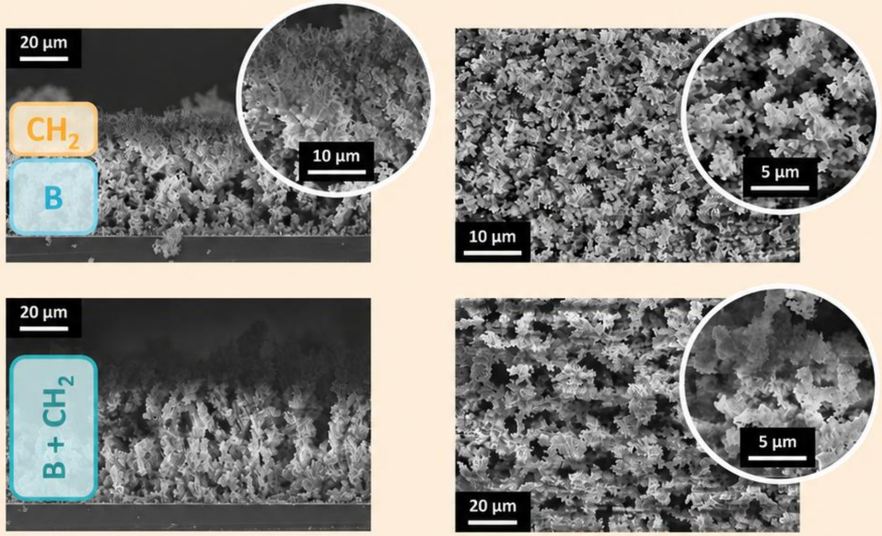
Nanofoam layer **enahnce gamma photon generation** via **non-linear inverse compton scattering**

M. Galbiati, et al. Under review at Scientific Reports (2025)

Nanofoam applications – Fusion schemes

QUEEN'S UNIVERSITY BELFAST

$p^{11}B$ fusion targets



D. P. Molloy, et al. Physical Review Research 7.1 (2025)

Nanofoam applications – Fusion schemes

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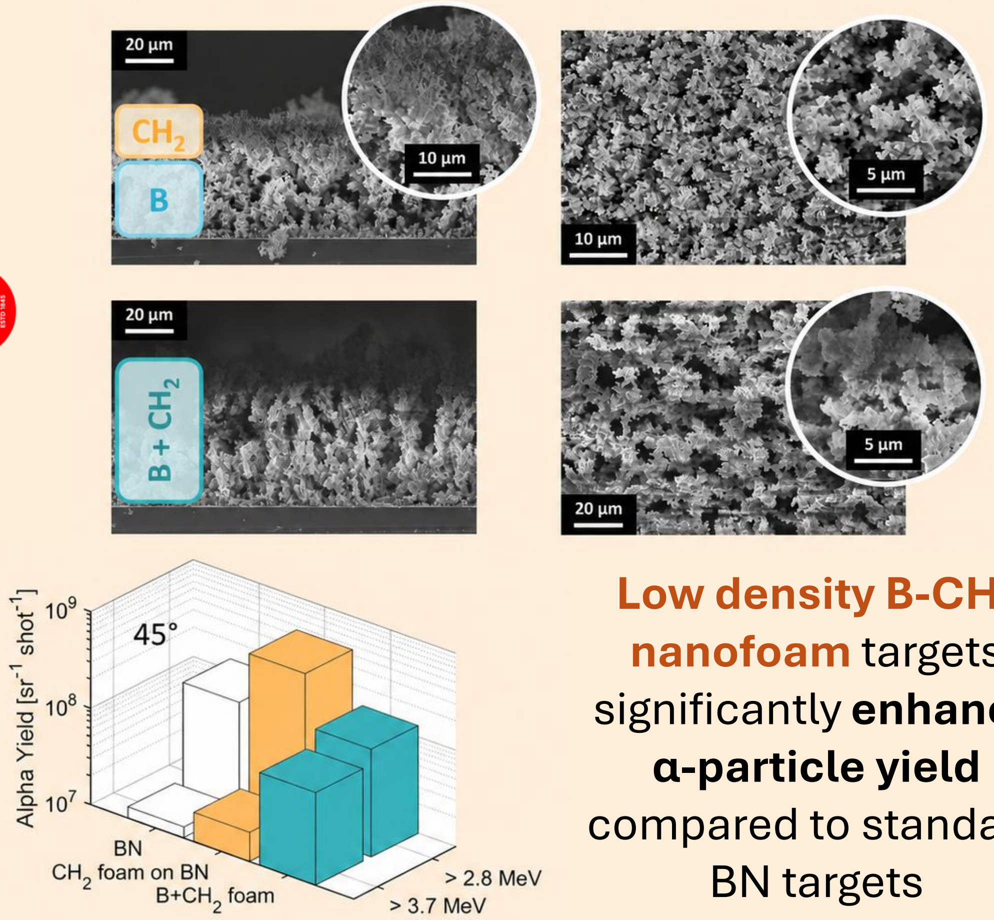

Low density B-CH_2 nanofoam targets significantly **enhance α-particle yield** compared to standard BN targets

D. P. Molloy, et al. Physical Review Research 7.1 (2025)

Nanofoam applications – Fusion schemes

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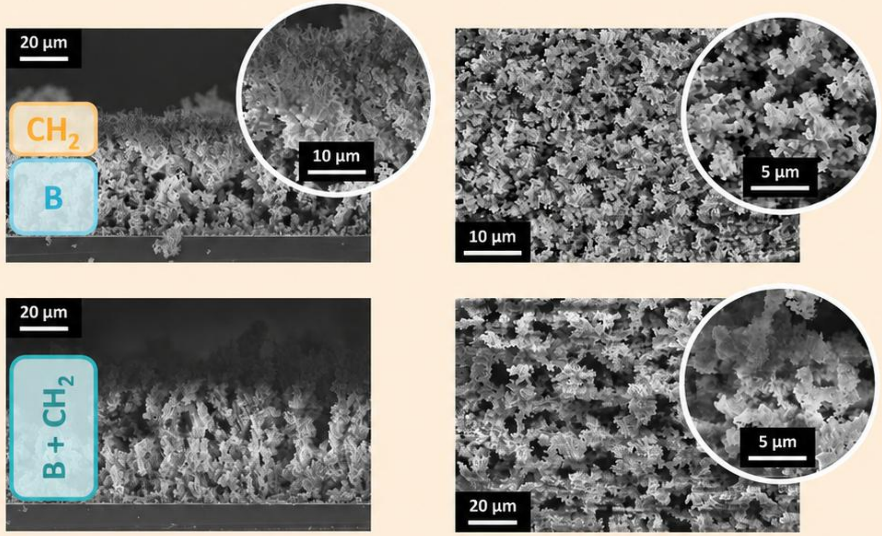

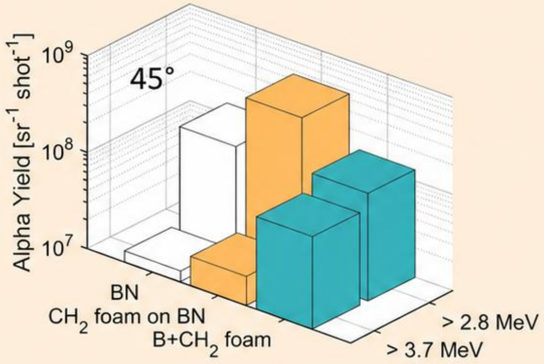

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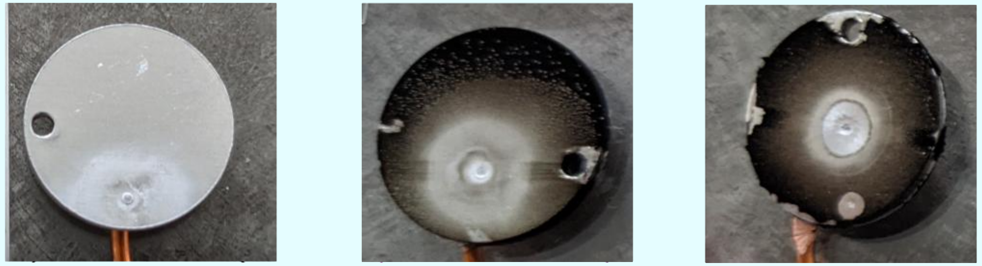
Advanced ablators for ICF

No foam | **Tree-like** | **Fractal-like**

Bare Al disk | 7.8 nc, 156 µg/cm^2 | 1.8 nc, 156 µg/cm^2



M. Cipriani, et al. Matter and Radiation at Extremes 11.4 (2026)

Nanofoam applications – Fusion schemes

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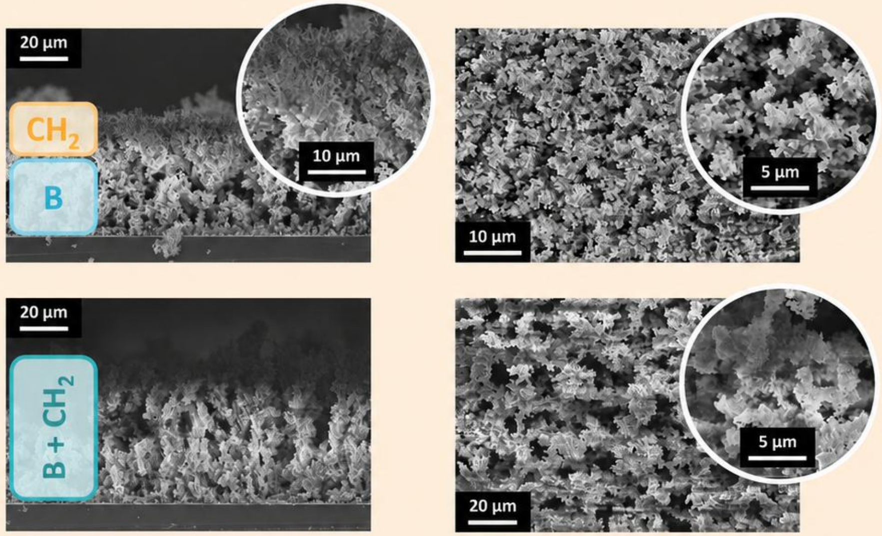

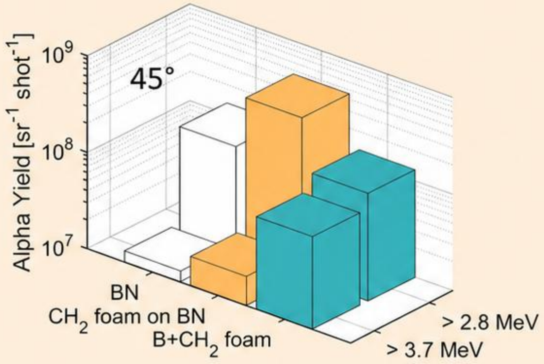

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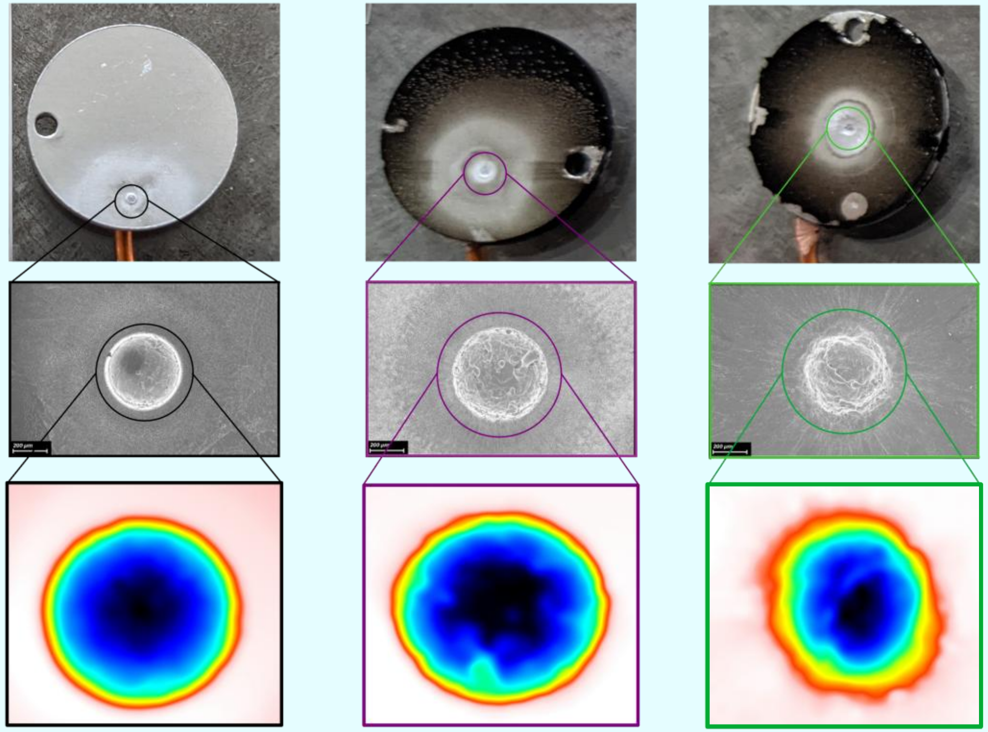

V ~ 3 * 10^7 µm^3	**V ~ 6* 10^7 µm^3**	V ~ 4* 10^7 µm^3

M. Cipriani, et al. Matter and Radiation at Extremes 11.4 (2026)

Conclusions

- ✓ Nanofoam based DLTs have demostrated a **versatile tool for Laser-Plasma interaction** experiment
- ✓ Modelling and experiments indicate that low-density nanofoam in front of a micrometric foil increases electron heating and **shift the proton spectrum toward higher energy and charge**
- ✓ Simulations confirmed the importance of the nanofoam layer to **enahnce gamma photon generation** via non-linear inverse compton scattering
- ✓ Experimens using polymer and boron-polymer nanofoams produced by PLD demonstrate **alpha particle fluxes competitive with the state of the art** at moderate laser energy
- ✓ **Tree-like carbon nanofoams** have been experimentally demonstrated to **provide high ablation loading efficiency**, highlighting their potential as advanced laser-driven fusion targets.

For more information

M. Passoni, et al. Plasma Physics and Controlled Fusion 61.1 (2019)

A. Maffini et al., Applied Surface Science 599, 153859 (2022)

D. Orecchia et al., Small Structures, 5, 2300560 (2024)

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F. Mirani, et al. Physical Review Applied 24.1 (2025)

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A. Maffini, et al. Plasma Physics and Controlled Fusion 68 (2026)

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Thank you for the attention

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