Pulsed Laser Deposition of carbon nanostructured foams for Inertial Confinement Fusion

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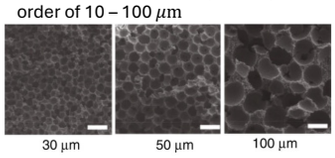
1 BACKGROUND

- **Foam:** porous material characterized by alternation of voids and solid parts
- **Applications:** laser-driven radiation sources, equation of state studies, Inertial Confinement Fusion (ICF)
- **Foams in ICF:** Made of plastic (low-Z material), voids and solids dimension in the order of 10 – 100 μm



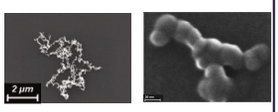
- ✓ Interesting as ablation layer
- ✓ Improve laser energy absorption
- ✓ Smooth laser inhomogeneities
- ✓ Enhance ablation loading [1]

- **Mid-Z materials in ICF:** mitigation of laser-plasma instabilities and increase in implosion efficiency [2]

2 MOTIVATIONS & GOALS

Carbon nanofoams produced via PLD as ablation layers

- Pure carbon foams → Combine benefits from both porous and mid-Z materials [3]
- Nanostructured → Multiscale structure
  - Fractal – like aggregates
  - Nanoparticles constituents
  → Possibility of finely tuning morphology and density



- Successfully employed for laser-driven proton acceleration (ultra-short, ultra intense laser pulses)
- Numerical simulations hints positive results in ICF relevant conditions (short, intense laser pulses)

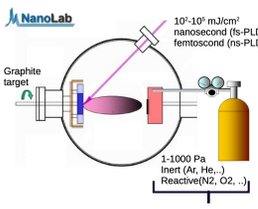
→ Foams with mass thickness up to1600 mg/m^2

3 PULSED LASER DEPOSITION OF CARBON NANOFOAMS

Synthesis of nanostructured films via Pulsed Laser Deposition (PLD)

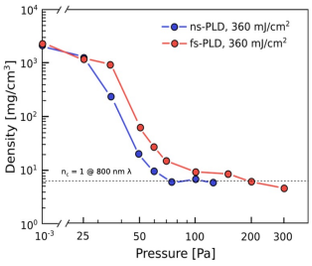
Tuning of process parameters
- **Working gas pressure**
- target-to-substrate distance
- laser fluence
- laser pulse duration

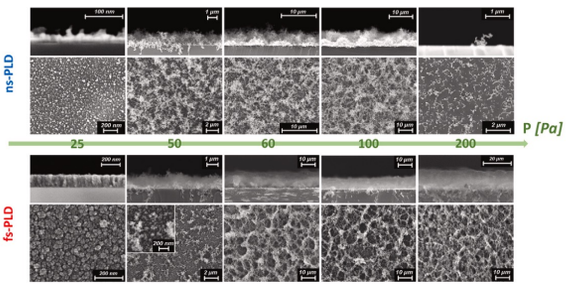
Control of film properties
- Nano/micro-scale morphology
- Uniformity
- Thickness



Different ablation mechanisms

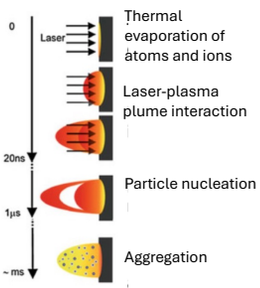
Effect on density & morphology [4]

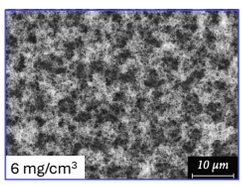




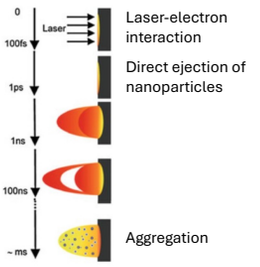
Morphology & nanostructure

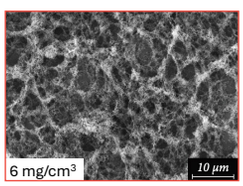
ns-PLD





fs-PLD

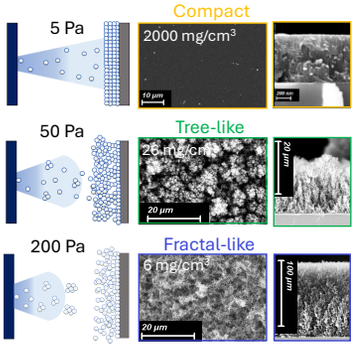




Adapted from Harilal et al. 2014

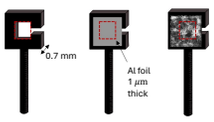
4 TARGETS PRODUCTION FOR EXPERIMENTS

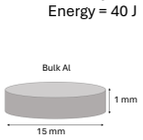
For further details see talk by M. Cipriani



PLD parameters
Laser fluence = 636 mJ/cm^2
Laser pulse duration = 7 ns
Frequency = 10 Hz
Wavelength = 532 nm

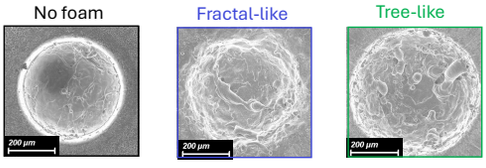
- Production of three different types of foams, tailored to ABC laser parameters
- Suitable substrates





ABC parameters
Wavelength = 1054 nm
Temporal FWHM = 3 ns
Intensity = 10^{14} W/cm^2
Energy = 40 J

- Post–mortem characterization of targets



5 CONCLUSIONS

- Targets successfully employed in ICF experimental campaign @ ABC
- PLD deposited carbon foams potential as ICF ablators confirmed
- Future work: understand the role of nanofoam morphology
- Future work: optimization of nanofoam properties to improve ICF performance

References

[1] M. Cipriani et al., High Pow. Laser Sci. Eng., 9 (2021) e40
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[3] A. Maffini, et al., Laser and particle beams 2023 (2023) 1214430
[4] A. Maffini, et al., App. Surf. Sci. 599 (2022) 153859