Post-mortem characterization of C nanofoam-based double layer targets for laser-driven ion acceleration

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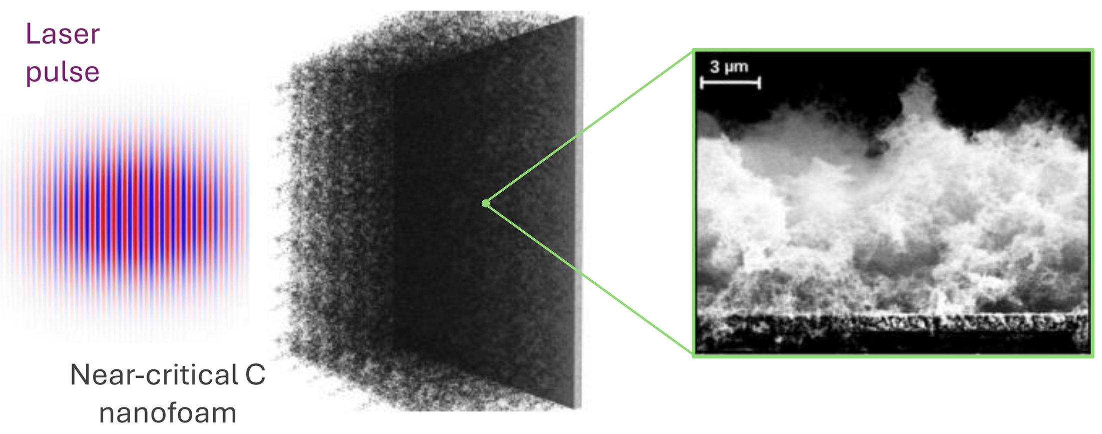
1. Introduction [1], [2], [3], [4], [5]



↑ Laser-plasma coupling ⇒ ↑ Cut-off energy, ↑ Ion number

Double Layer Target (DLT)

- Solid foil + **Nanostructured layer**
  - Nanospheres
  - Nanowires
  - Nanofoams

Nanofoam

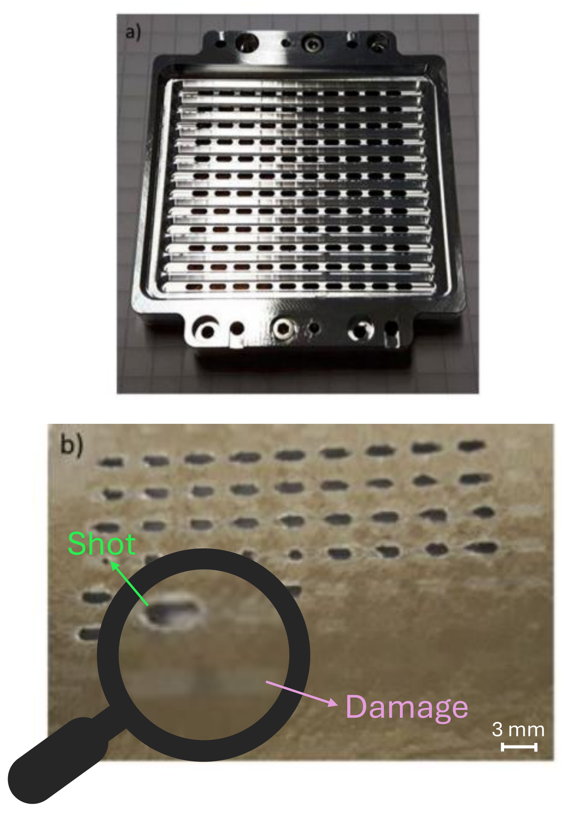
- **Highly porous, nanostructured** material
- **Ultra-low density** (*few mg/cm³*)

Production

- **Carbon** made nanofoam @ NanoLab
- **Physical Vapour Deposition (PVD)**
  - ✓ Tunable density
  - ✓ Tunable thickness

Application

- Observed **improvement** in **Target Normal Sheath Acceleration (TNSA) efficiency**



Open issues

- ❑ Structural homogeneity and **reproducibility**
- ❑ **Nanofoam behavior** under stress and irradiation
  - Nanofoam damaging → ↓ Acceleration efficiency

Damaging of the neighbors of the shot is **problematic for high-repetition-rate** operations

Objective

Investigate how nanofoam **density, thickness** and **laser conditions** influence the **damage resistance**

2. Experimental setup & methods [6], [7]

eli experimental campaign

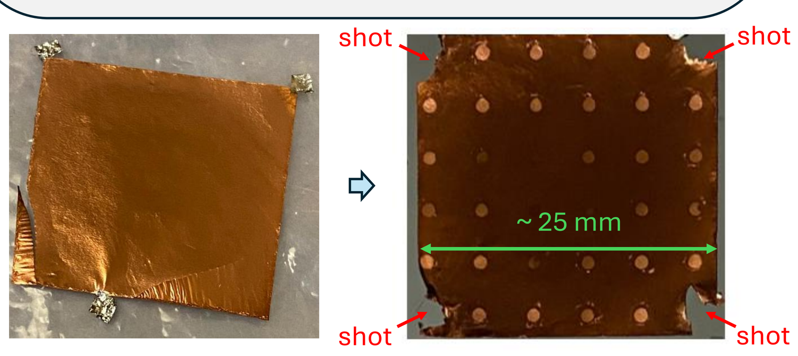
Laser
- ELIMAIA, ELI Beamlines
- λ = 800 nm
- τ ~ 30 fs
- E_p = 2.27 J & 10 J
- Ø = 1.3 µm × 1.7 µm

Targets
- 2 µm Cu substrate
- C nanofoam
- 6 types of DLTs

I ~ 10^{21}-10^{22} W/cm²

Objective

Post-mortem analysis of DLTs for TNSA: study of proton spectra and damage in non-irradiated regions



NanoLab experiment

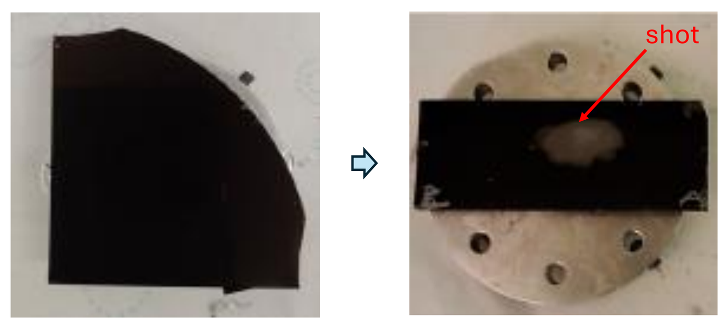
Laser
- λ = 1064 nm
- τ ~ 5 ns
- E_p = 450 mJ
- Ø = 1 cm × 0.6 cm

Targets
- Si substrate
- C nanofoam
- 4 types of nanofoams

I ~ 10^8 W/cm²

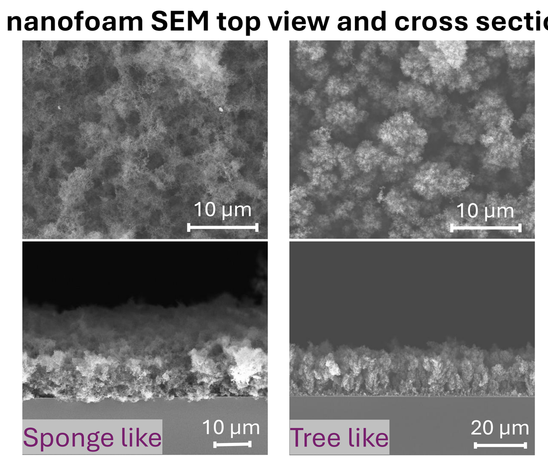
Objective

Study of **nanofoam** behavior under **direct irradiation**



Scanning Electron Microscopy (SEM)

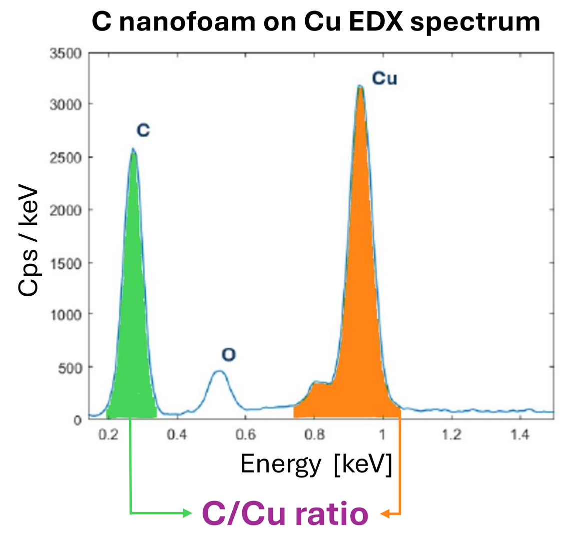
C nanofoam SEM top view and cross section



⇩ **Morphological analysis**

Energy Dispersive X-ray Spectroscopy (EDXS)

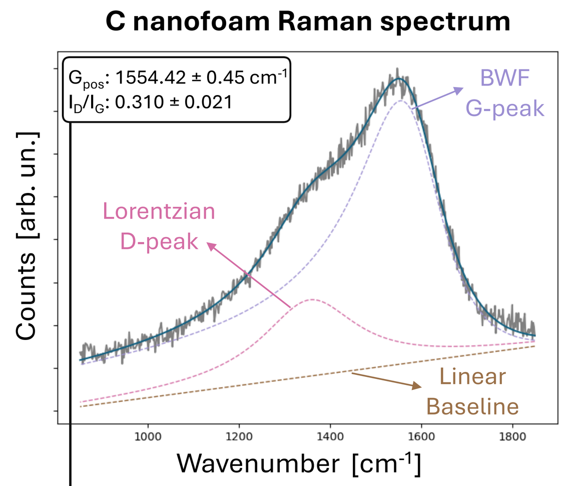
C nanofoam on Cu EDX spectrum



C/Cu ratio ⇩ **Foam mass thickness** $(\rho \cdot th)$

Raman Spectroscopy

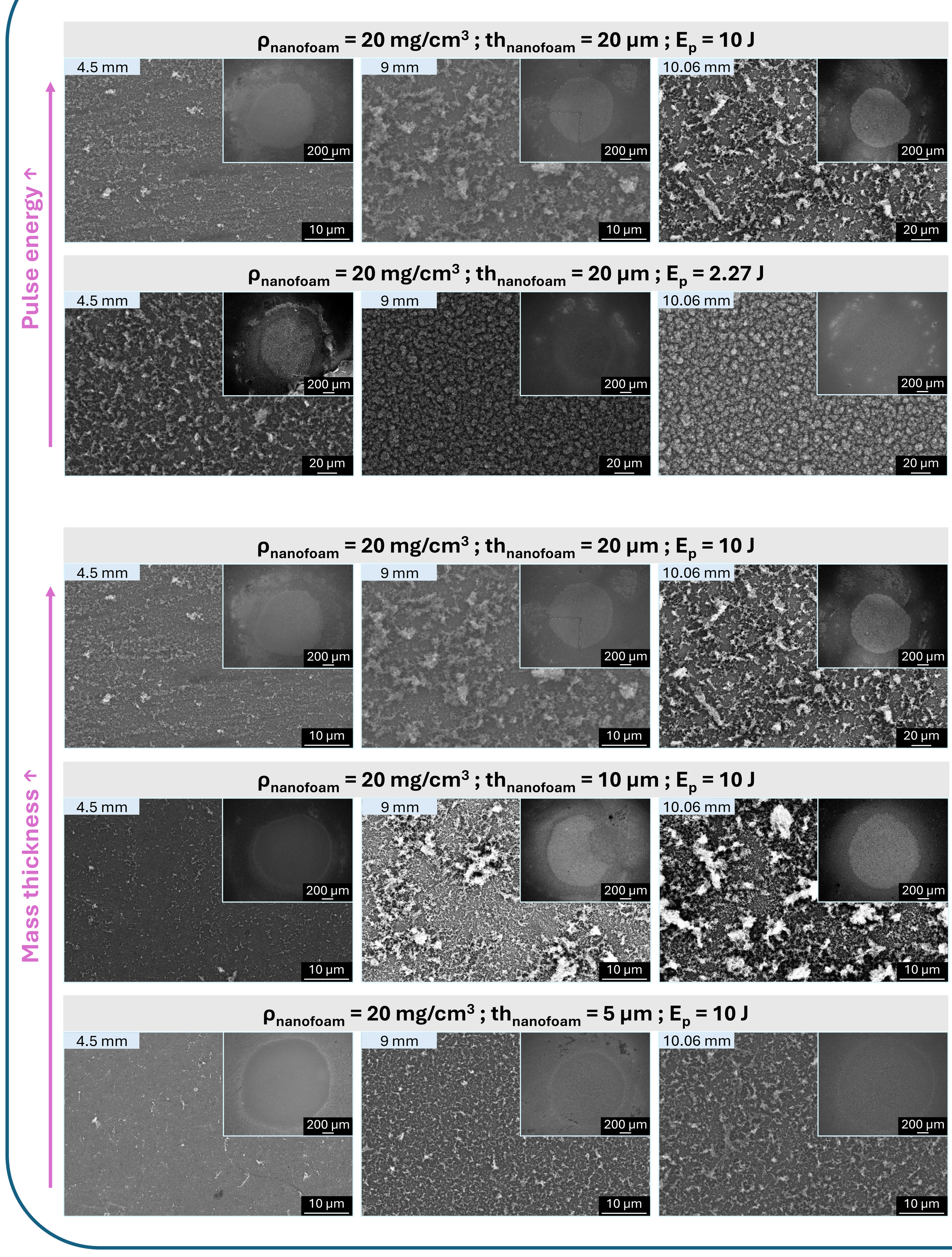
C nanofoam Raman spectrum

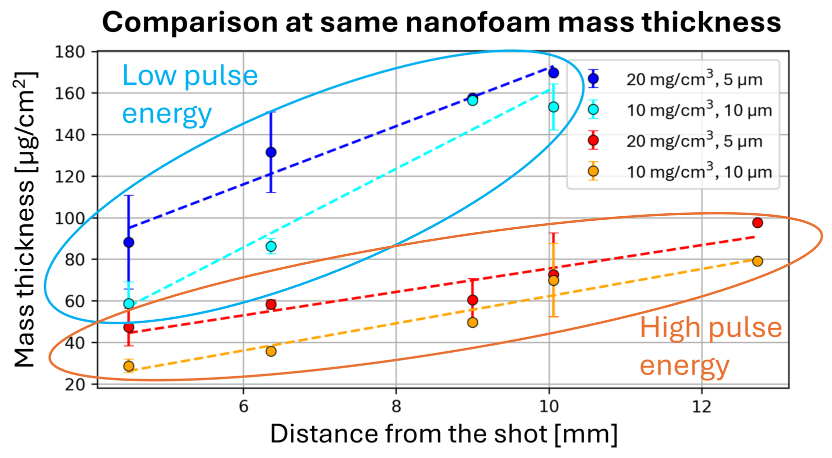


Graphitization { G_{pos} ↑, D/G ↑ } ⇩ **C structural properties**

3. Results

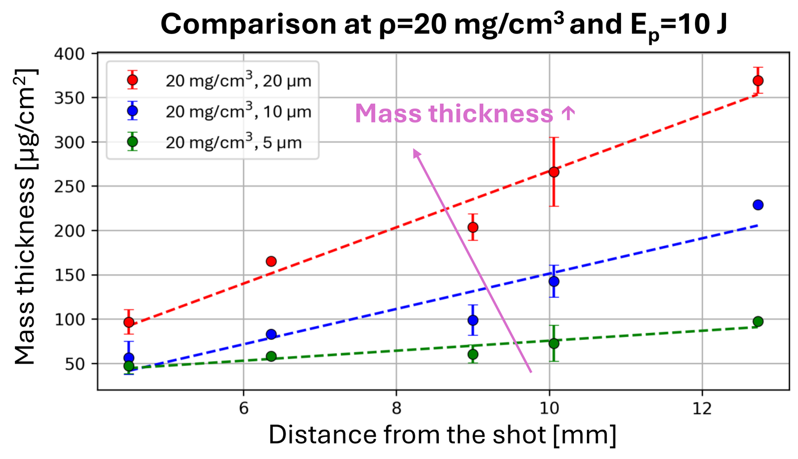
ELI Beamlines : SEM & EDXS analysis

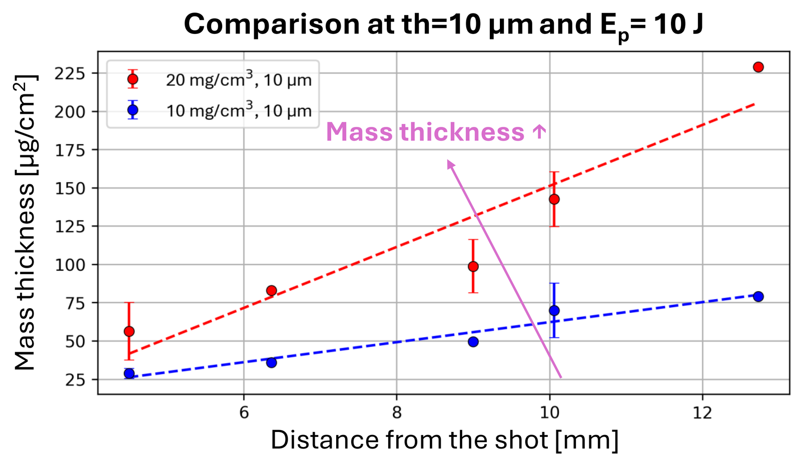




↓ Pulse energy → ↓ Damage extent

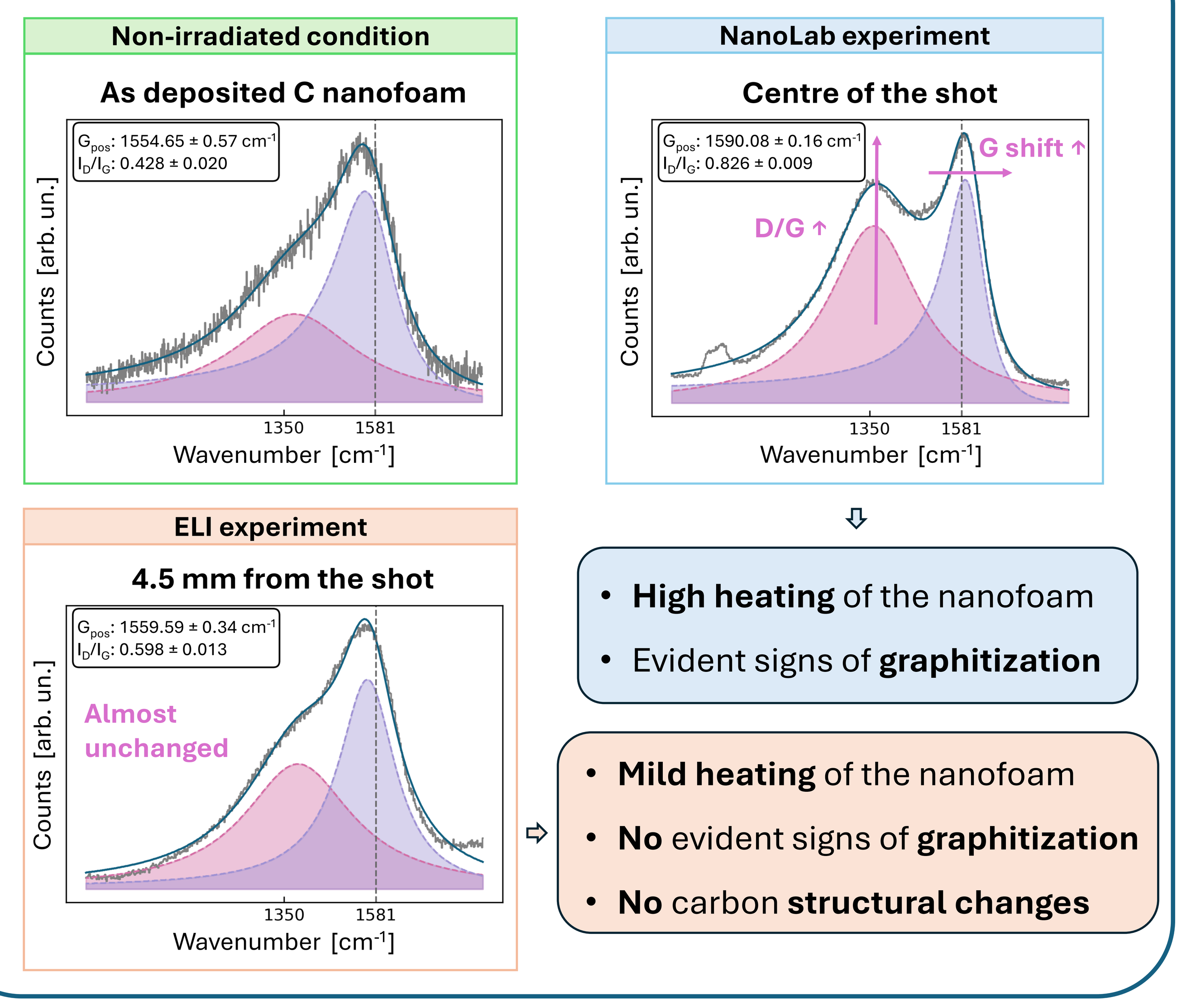
↓ Pulse energy → ↑ Surviving nanofoam





↑ Mass thickness → ↑ Surviving nanofoam

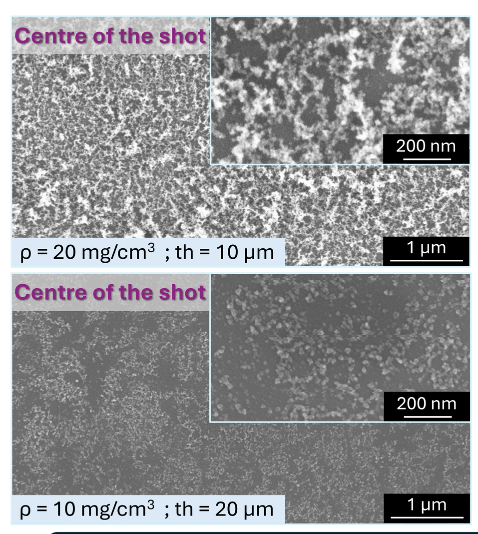
Raman analysis

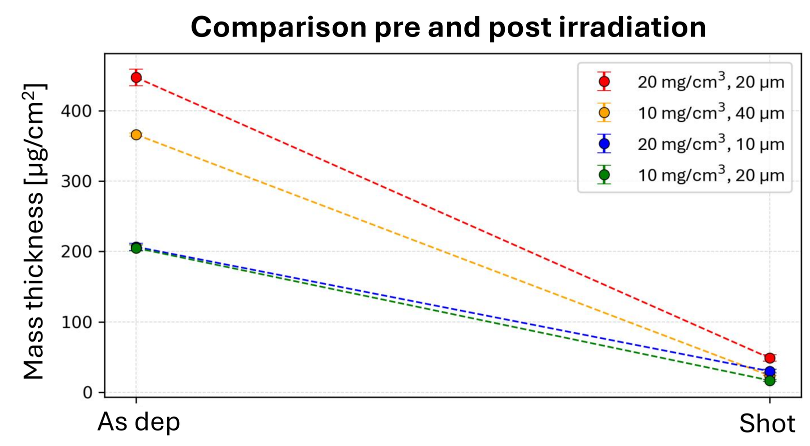


- **High heating** of the nanofoam
- Evident signs of **graphitization**

- **Mild heating** of the nanofoam
- **No** evident signs of **graphitization**
- **No carbon structural changes**

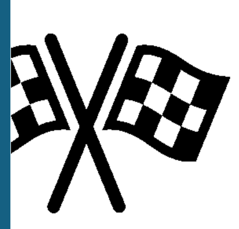
NanoLab : SEM & EDX analysis



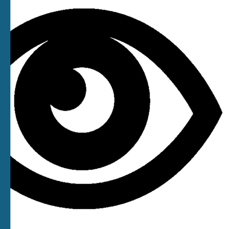


Higher density results in the **preservation of the nanofoam network**

4. Conclusions and future developements



- It has been demonstrated how the **parameters** of carbon nanofoams **influence their damage resistance**
- Raman analysis of ELI samples revealed **no substantial transformation of the carbon structure**
- NanoLab experiment gave **insights on the behavior** of the nanofoams **under direct irradiation**
- Almost **complete removal** of nanofoam occurred in directly irradiated targets, with a **lower impact on the denser ones**



- **Other experiments** can be performed with a **broader set of nanofoam and laser parameters**
- Investigate how **different nanofoam materials** can influence the resistance to the damage
- Data insights could be the starting point for a **redesigning of target holders**

5. References

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