Production and characterization of ultra-low density foams for laser driven ion acceleration in near-critical regime

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Motivation & aims

Near-critical regime

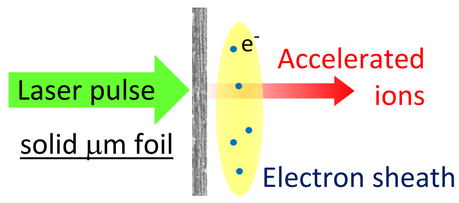
$$n_c = \gamma \frac{m_e \omega^2}{4\pi e} \approx 6\ \mathrm{mg/cm^3}$$
(@ γ = 1, λ=800 nm)

n ~ ***n*$_c$** ⇒ **Enhanced** laser-plasma **coupling**

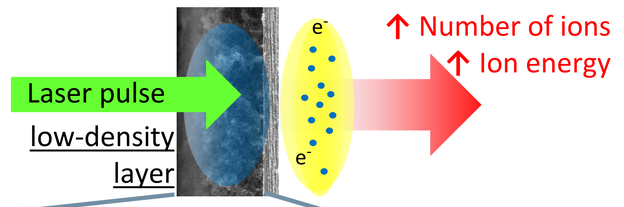
Ultra-low density material required

Foam concept!
(Up to 99.5 % of void!)

Conventional Target



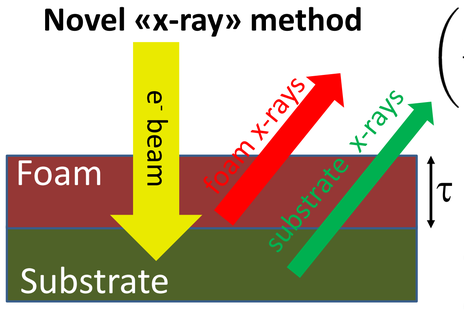
Foam-attached Target



Foam characterization

Density measurement

Novel «x-ray» method



$$\left(\frac{I_{foam}}{I_{sub}}\right) = f(\rho \times \tau)$$ SEM

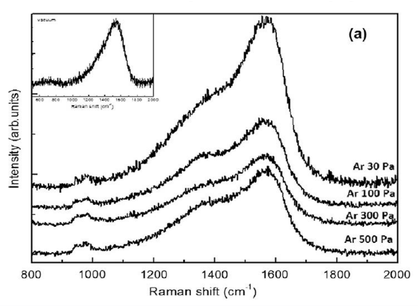
Modelling and/or MC simulations

+ (preliminary) **IBA confirms** X-rays results!

I. Prencipe *et al.*, Sci. Technol. Adv. Mater., 16, 025007 (2015)

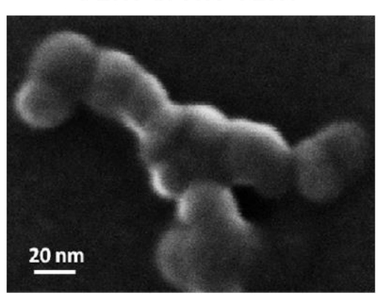
Structural & morphological characterization:

Raman Spectroscopy



sp^2 network of topologically disordered domains (~ 2 nm)

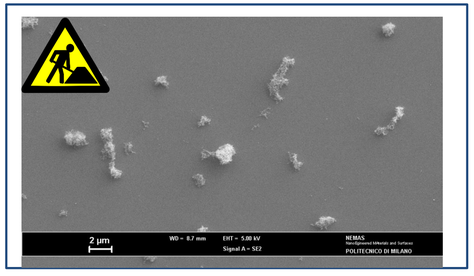
SEM & HR-TEM



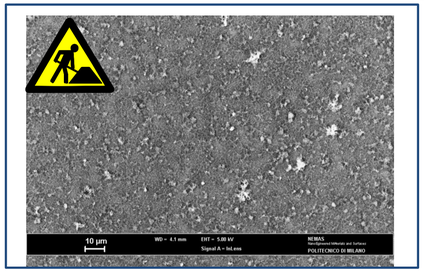
Building blocks: 10 nm nanoparticles

Zani, A., et al. Carbon 56 (2013) 358-365.

Foam growth dynamics



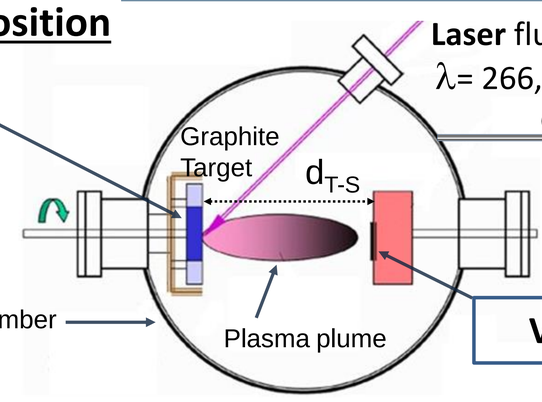
Uniformity vs Thickness



Production of carbon foams

Pulsed Laser Deposition

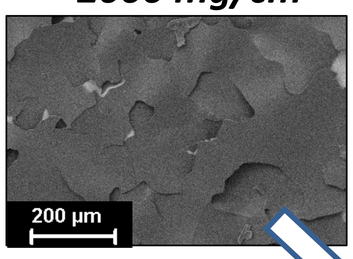
Not limited to C: Plastics, metals, oxides…



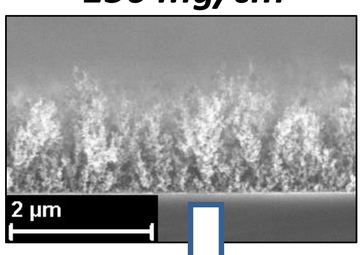
Composition Can be controlled with reactive gases

Virtually any kind of substrate!!

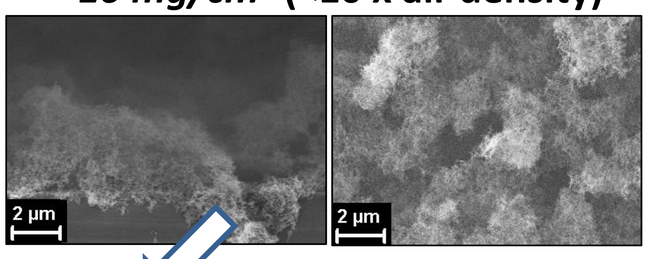
~ 2000 mg/cm³



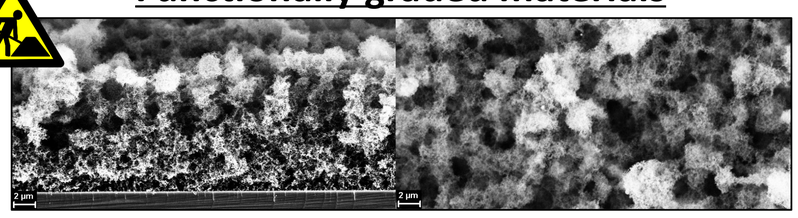
~ 150 mg/cm³



~ 10 mg/cm³ **(<10 x air density)**



Functionally graded materials



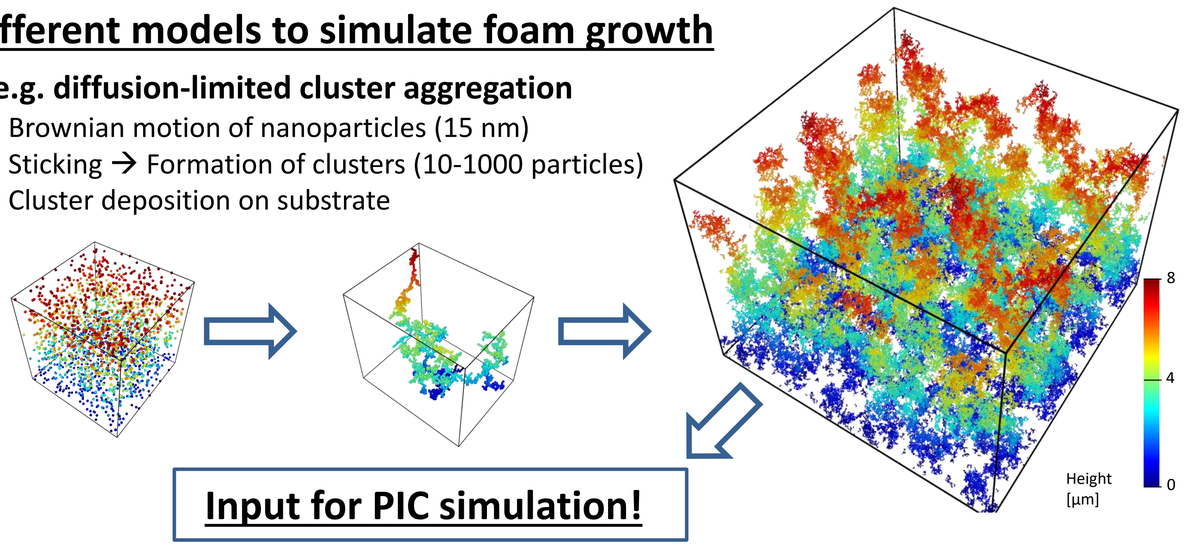
Potentially from 10 to 2000 mg/cm³ in a few tens of μm!

Numerical simulation of foams

Different models to simulate foam growth

e.g. diffusion-limited cluster aggregation

1. Brownian motion of nanoparticles (15 nm)
2. Sticking → Formation of clusters (10-1000 particles)
3. Cluster deposition on substrate



Input for PIC simulation!

See L. Fedeli talk on Friday!

Laser-driven ion acceleration

Foam attached targets tested @ different laser facilities:

UHI100 @ SLIC
2J, 25 fs, 10^{19} W/cm^2

PULSER @ GIST
8J, 30 fs, 5×10^{20} W/cm^2

DRACO @ HZDR
3J, 30 fs, 10^{21} W/cm^2

+ 20%-200% proton E_{max}

Higher e$^-$ temperature: more hard x-rays?

Related targetry issues: (e.g. foam robustness)

Foam optimization is required!!!

M. Passoni et al., Plasma Phys. Control. Fus. 56 (2014): 045001

M. Passoni, et al., Phys. Rev. Acc. Beams 19 (2016): 061301
I. Prencipe, et al., Plasma Phys. Control. Fus. 58 (2016): 034019

See D. Dellasega talk on Friday!

Conclusion and perspectives

We are able to:

- Produce C foams with **tunable density** (10-150 mg/cm^3)
- Design **foam-attached targets** using (almost) any kind of substrate
- **Measure ultra-low densities** with a novel «x-ray» method
- **Simulate** the foam **aggregation**

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Our next steps :

- Gain **more insight** in the foam **growth dynamics**
- Produce and characterize **foam-based FGMs**
- **Optimize** foam parameters for **laser-driven ion acceleration**
- Address related **targetry issues** (e.g. robustness, prepulse effect)
- Explore **new production techniques** (fs-PLD, HiPIMS,..)
- Explore **different foam composition** (CH, high Z metals,..)