Advancements in double-layer target production exploiting innovative physical vapor deposition techniques

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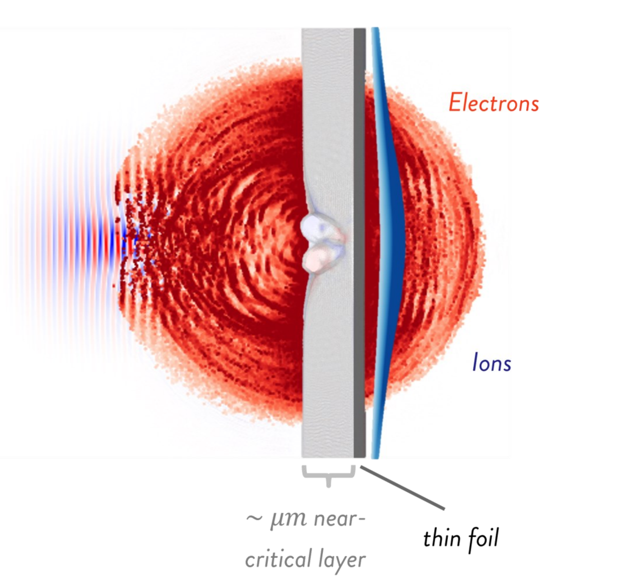
POLITECNICO MILANO 1863 — Target Fabrication Workshop

Near-critical double-layer target (DLT)

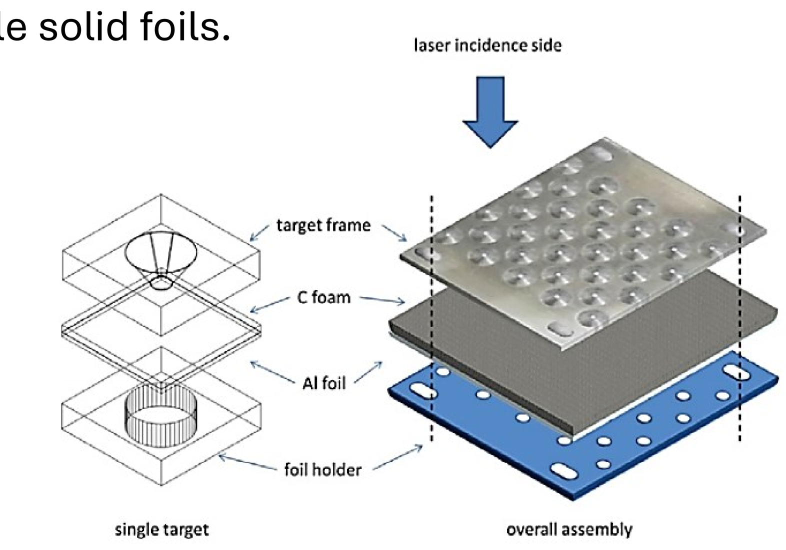


- Solid foil covered by a near-critical density layer.
- Enhanced laser-plasma coupling through the near-critical layer.
- Hotter relativistic electrons.
- More ions at higher energies.

Standard DLT production

- Deposition of near-critical layer on commercially available solid foils.
- Foam-based DLT successfully exploited in laser-driven experiments [1,2,3].
- Limitations: thickness uncertainty, limited thickness and material available, deformation while handling and attaching to the holder.

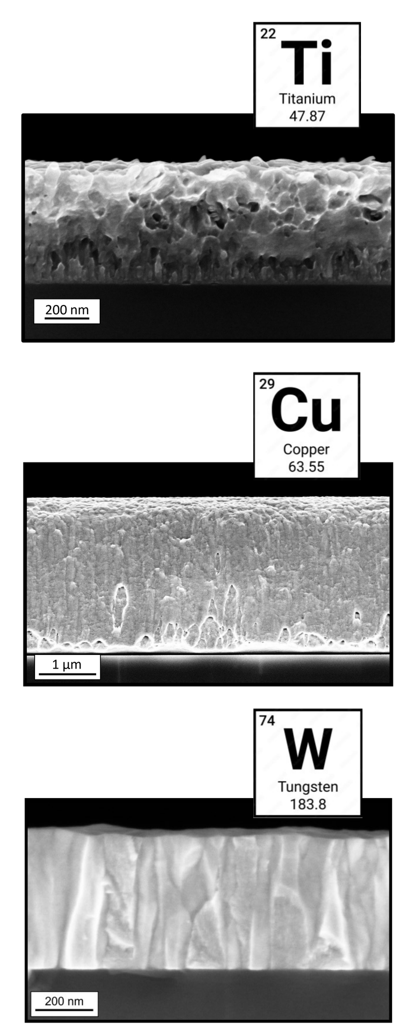
Direct deposition of target on the holder by Physical Vapor Deposition (PVD) techniques!

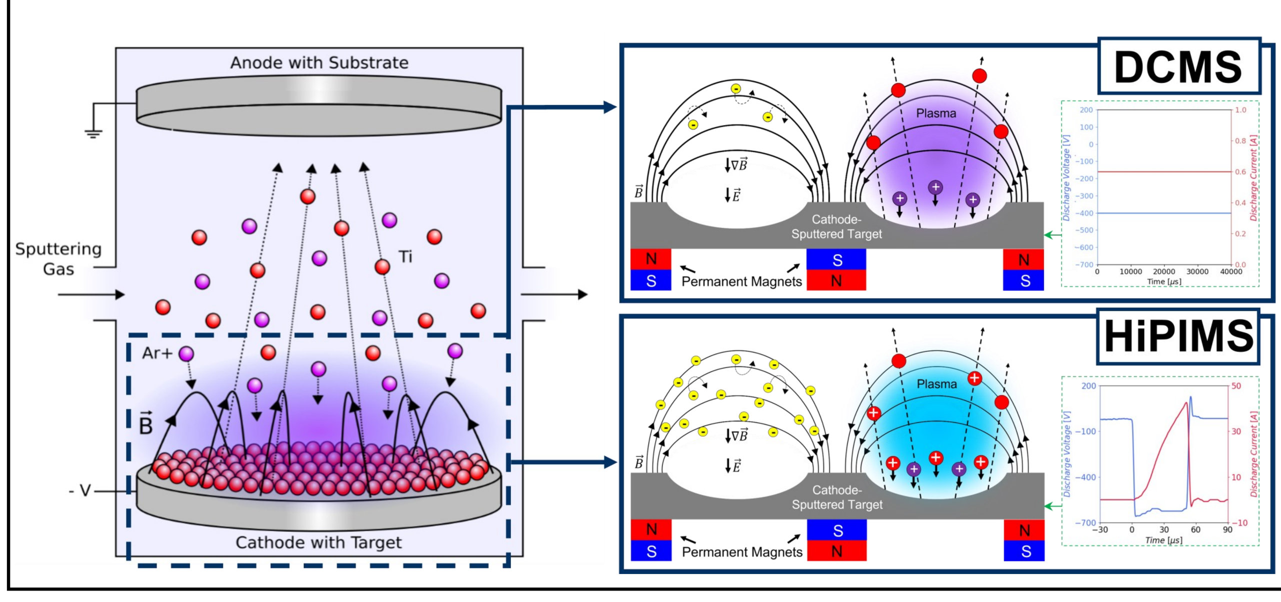


Experimental Methods: PVD techniques

Magnetron Sputtering (MS)

- Ejection of atoms from a target caused by energetic ions of an inert gas. Electrons are trapped by a properly shaped magnetic field.
- Direct Current Magnetron Sputtering (DCMS): a constant voltage is applied to sputter.
- High Power Impulse Magnetron Sputtering (HiPIMS) [4]:
  - pulses with high peak power
  - pulse length 50 – 400 µs
  - low repetition frequency (50 – 5000 Hz)
  - low duty cycle (< 10 %)
- ↑ density plasma, ↑ ionization degree, ↑ sputtered species energy.
  - Improvement of film properties.
  - Deposition on complex substrates.





Pulsed Laser Deposition (PLD)

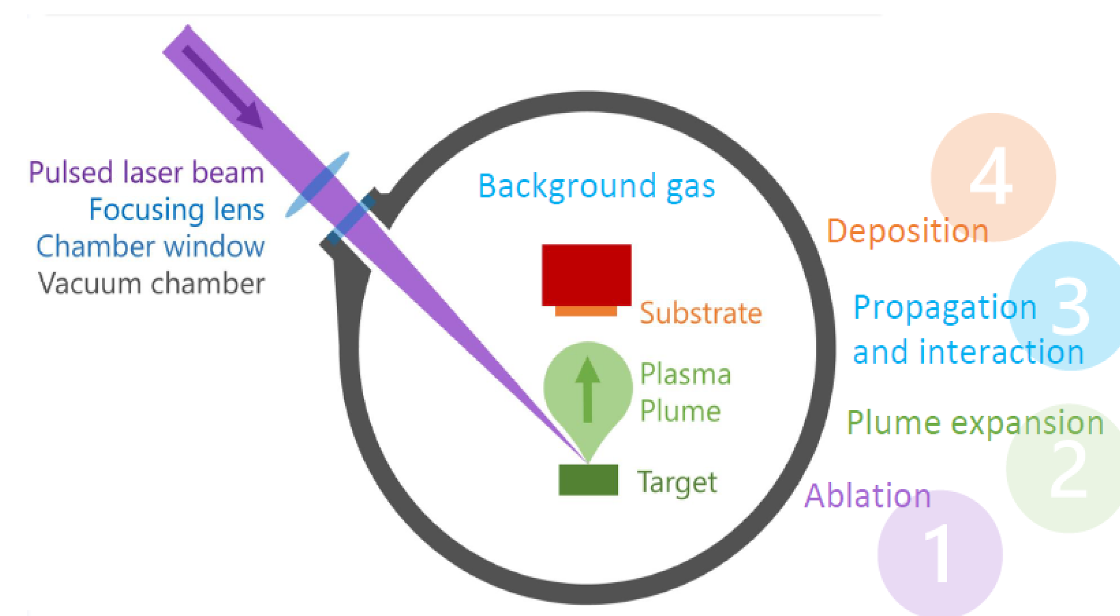
- Ablation of material from a solid target by laser pulses.

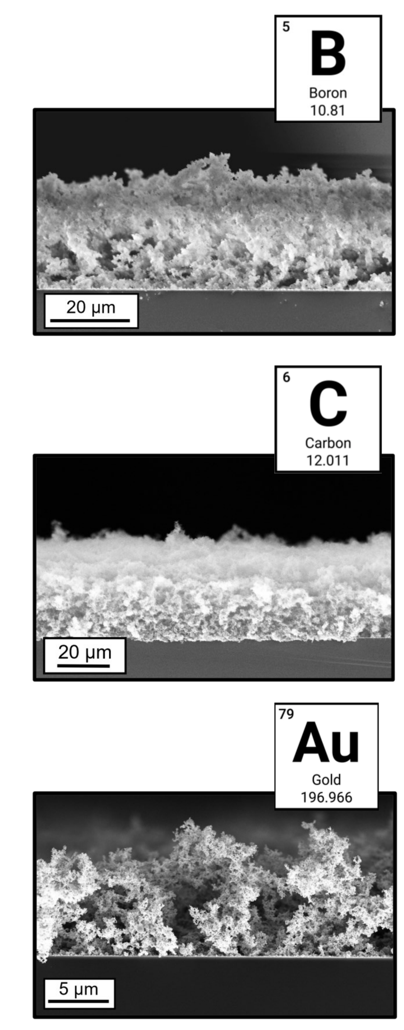
ns-PLD

- well established.
- few ns pulses.
- 100s mJ per pulse.
- Up to 10 Hz.

fs-PLD

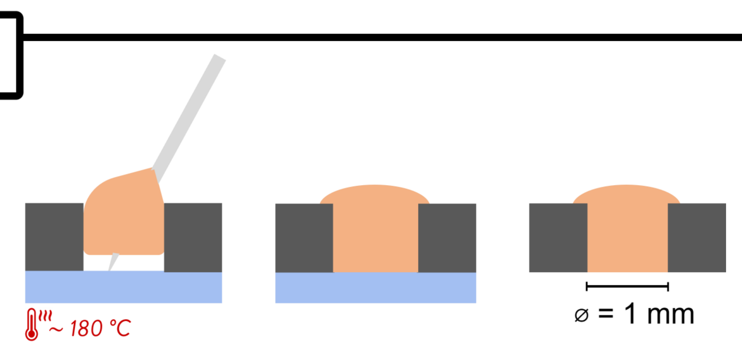
- non-standard technique [5].
- <100 fs pulses.
- few mJ per pulse.
- kHz or higher.
- Nanostructured low-density film of any element.





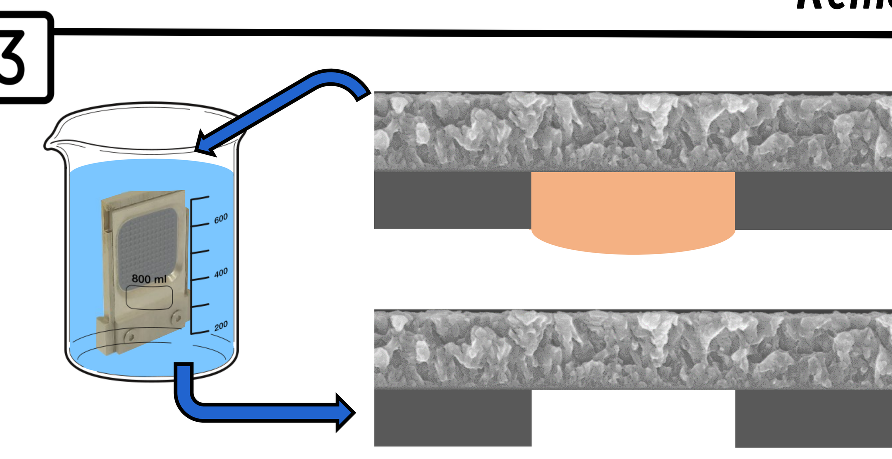
Strategy for Freestanding DLT Production

1 ***Holder preparation***

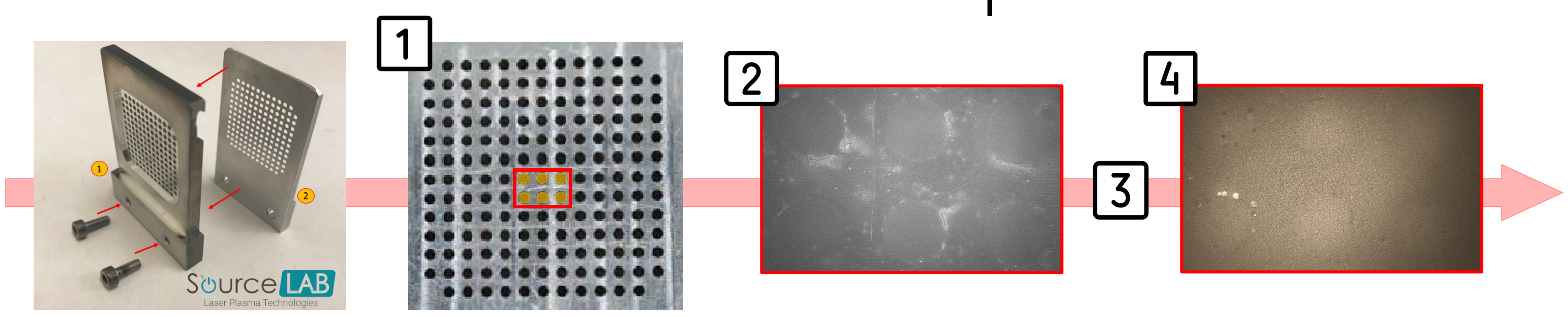


- Holder holes filled with a sacrificial material to be removed after the solid-density layer deposition.
- Caramel: soluble in water, amorphous material, planar uniform surface, compatible with PVD subsequent depositions.

3 ***Removal of the filling material***

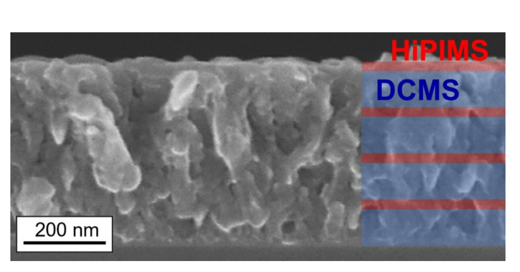


- Caramel dissolution in water (few minutes).
- Titanium freestanding films.



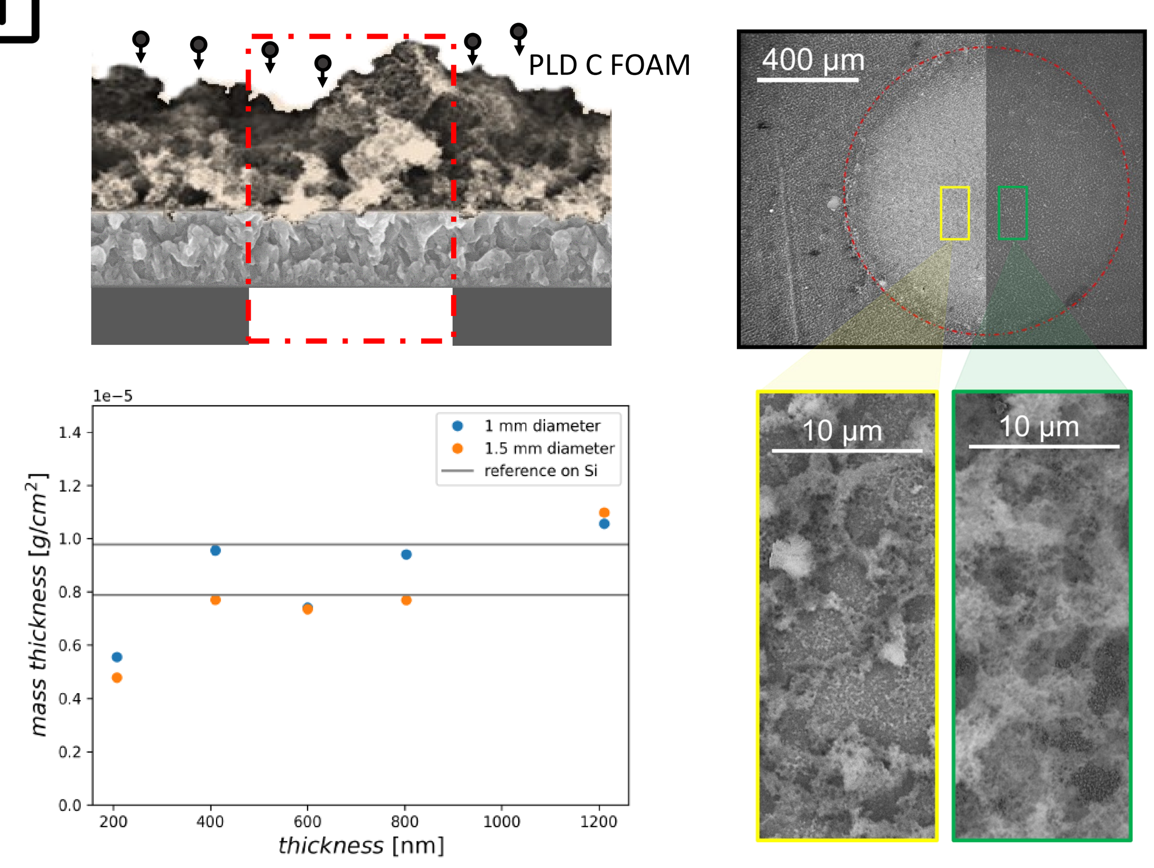
2 ***Titanium film deposition***

- Deposition of hybrid DCMS/HiPIMS titanium films [6]:
  1. 4 hybrid layers (80% DCMS, 20% HiPIMS)
  2. Application of substrate bias voltage.



- 200 nm ÷ 2 µm thickness range.
- Near-bulk film density (80% or greater).
- Low residual stress state.

4 ***Near-critical carbon foam deposition***



- fs –PLD carbon foam deposition [7]:
  1. High Argon pressure (250 Pa)
  2. Void-rich fractal structure.
  3. Thickness ≈ 10s µm .
  4. Density ≈ 6 mg/cm^3.
- Good adhesion on freestanding titanium films with thickness equal or greater than 400 nm.
- Low material deposition on the 200 nm-thick freestanding films.
- Freestanding films vibrations during PLD deposition.

Conclusions & Foreseen Activities

- Effective production of near-critical DLT directly on target holders.
- Compatibility between layers grown by HiPIMS/DCMS and fs-PLD.
- Exploration of different combinations of materials for solid and near-critical layers.
- Experimental test in particle acceleration campaigns.

References

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