High throughput production of solid targets for laser-driven particles acceleration through MEMS based processing.

Introduction
- PLA Collaboration
- Aim of the project
- Specific objectives
- Laser-proton acceleration

Target Fabrication
- Objectives
- Process of fabrication
- Results

Proton Laser Acceleration
- Where
- Experimental downstream
- Methods
- Results
Partner Institutions

ICTS in numbers

<table>
<thead>
<tr>
<th>2012-2014 annual average</th>
<th>4000 h Electrical characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000</td>
<td>550</td>
</tr>
<tr>
<td>Processed waters</td>
<td>Runs</td>
</tr>
<tr>
<td>190 equipment</td>
<td>40 People ICTS Staff</td>
</tr>
<tr>
<td>500 packaging tasks</td>
<td>2300 m² surface</td>
</tr>
<tr>
<td>40 Open access equipment</td>
<td>People with licenses</td>
</tr>
</tbody>
</table>

Principal Processes
- Thermal Processes and CVD
- Ion Implantation
- Photolithography
- Dry Etching
- Microsystems and wet etching
- Nanolithography

Back end Processes
- Electrical characterization
- Packaging
- System integration

Other Laboratories
- Sensor/Biosensor
- Chemical Transducers
- Radiation detectors
- 3D prototyping
- Reverse Engineering
- Power Device
- Thermal systems
Aim of the Project

“Investigation, development and validation of a system to produce radiopharmaceuticals through laser acceleration by means of primary and secondary targets”

PET/SPECT
Diagnosis & Disease monitoring

immunoPET
Drug discovery & therapy development

RadioImmunoTherapy
Solid cancer & lymphoma treatment

Nuclear reactor/ Accelerator

Medical Isotopes Processor

Radiopharmac. Manufacturers

Hospital

Clinician
Laser-driven particle acceleration

**Introduction**

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PARTICLE ACCELERATION

- ELECTRON TRANSPORT
- ISOCHEMIC HEATING
- SHOCK-COMPRESSION PHYSICS
- LABORATORY ASTROPHYSICS
- WARM DENSE MATTER
- STRONG MAGNETIC FIELDS

Target Normal Sheath Acceleration (TNSA)

- CPA laser pulse
- Thin metallic foil
- Relativistic electrons
- Proton Beam
- Rear surface electrostatic sheath
- Hydrogen contaminants

$I > 10^{18} \text{W/cm}^2$

Big Infrastructures

- CERN
- ALBA
- APRI-GIST
- CLPU

Compact Buildings
**Objective 1**

To develop technologies for the optimal laser focusing and positioning on the acceleration target.

**Objective 2**

To develop primary targets optimized to produce protons of $10-15$ MeV for multi-shot usage.

**Objective 3**

To develop secondary target for the production of radioisotopes $^{11}$C and $^{15}$O with high specific activity.

**Objective 4**

Integration of all previous results to obtain a proof of concept technology.
Objectives of fabrication

Development of wafer-scale processes for the production of primary targets optimized for sequential laser-plasma interactions

I. Membranes of different materials and thicknesses in a silicon frame (4”).

II. Grow, deposit, integrate micro-nano structures on membranes surface
Fabrication process

1. Grow/deposit insulating layer
2. Deposit Metallic layer (back)
3. Selectively remove material to create features
4. Create the pattern (front)
5. Create the pattern (back)
6. 1cm
7. 1mm²
8. 0.5mm²
9. 19 July 2017 XXXVI Biennial Meeting of RSFE

Target Fabrication

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Flat **Al** and **Au** membranes with variable thicknesses, both **self-standing** and supported by **SiO₂**; Variable **SiO₂**

**Results: Global Yields**

100 nm **SiO₂**  
1 µm **Al**

300 nm **SiO₂**  
1 µm **Al**

400 nm **SiO₂**  
100 nm **Au***

200 nm **SiO₂**  
1 µm **Al**

**Al membranes:** 0.25 µm, 0.65 µm and 1 µm

* **Au:** 70 nm (10 nm Ti; 20 nm Ni)

Membranes for sequential shots

500 membranes/wafer; 10 days; ≈ 1€/membrane
Results: Membrane stress

Compressive

Tensile
Results: Surface roughness

- 1μm Al; 100nm SiO$_2$: $R \approx 5$ nm
- 1μm Al; 200nm SiO$_2$: $R \approx 8$ nm
- 1μm Al; 300nm SiO$_2$: $R \approx 20$ nm
- 100nm Au; 100nm SiO$_2$: $R \approx 2$ nm

Increasing surface roughness with thicker SiO$_2$
Where we are
Laser System @PLA

Table-top Ti: Sapphire laser

Diode Pumping (Nd:YAG) for high rate (10-100 Hz)

Multi-pass amplification stages

2 saturable absorbers for enhanced contrast
Laser Parameters

**Power**
- 3 TW

**Peak Energy**
- 165 mJ

**Pulse duration**
- 55 fs

**Before Energy**
- 265 mJ

**Compression**
- $10^{8}$ ASE

Proton acceleration proven with thin foil target*

*P. Bellido et al. JINST, 12, 2007

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Experiments

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Experimental downstream
Interaction chamber

Light Source

L1

M1

Glass

Obj 10x

Target

Off-axis parabolic mirror

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Experiments
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Detection system

CR-39 plates, 1 cm² (Radosys, Budapest)*:

- Relation $E_p$ - track diameter calibrated on 3 MV tandem accelerator (CNA, Seville)
- Up to 1 MeV, unique relation
- For higher energies, thin Al absorbers
- Etching in 6.25N NaOH, 90°C, 4 hours
- Automatic readout (Radosys PT10 microscope)
- Self-developed track recognition software for image analysis

Time-of-flight detector:

- Based on fast plastic scintillator
- Dynamic range adjustable with optical filters
- Calibrated with pulsed proton beam as function of beam current (CNA)

* Bellido et al. JINST, 12, 2017
Focus determination is carried out for each target array by means of the speckle.

Then for following membranes ($i>1$) we considered variation within ±150 µm relative to the initial zero.

Typical Spectra obtained from TOF
For all membranes we observe a “bell” shape around the maximum.

An off focus greater of $\pm 50 \, \mu m$ affects the maximum proton energy less of 10%.

Data tendency with membranes thicknesses should be studied more deeply.

*Margarone et al. PRL, 109, 234801 (2012); ** Li et al. Angewandte Chemie, 45(16) 2537 (2006)*
For Aluminium based targets we observed slightly higher energies when Membranes are supported by SiO$_2$.

SiO$_2$ etching is the last fabrication step and also one of the more critical (rapid dip HF).
Membranes are **easier** to manipulate inside interaction chamber than standard thin foils and they are also **more efficient** for proton acceleration.
Discussion

Experiments

M. Seimetz et al. Proceedings of ELIMED
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Laser Energy Upgrade

Micro-nano structuring target surface

Proof of concept will be run @L2A2

- Energy: 1 J
- On target
- Proton Energy: 10 MeV
- Rep rate: 100 Hz
- Target: $^{11}\text{C}$, $^{11}\text{B}$
Acknowledgements

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