UNIVERSITY OF WARSAW

Targets for nuclear physics studies


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Heavy Ion Laboratory

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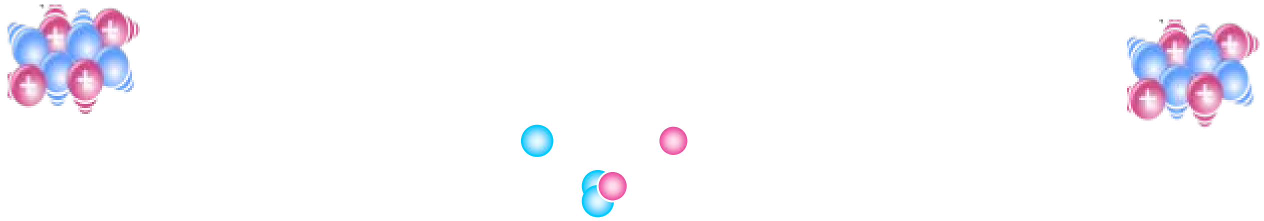
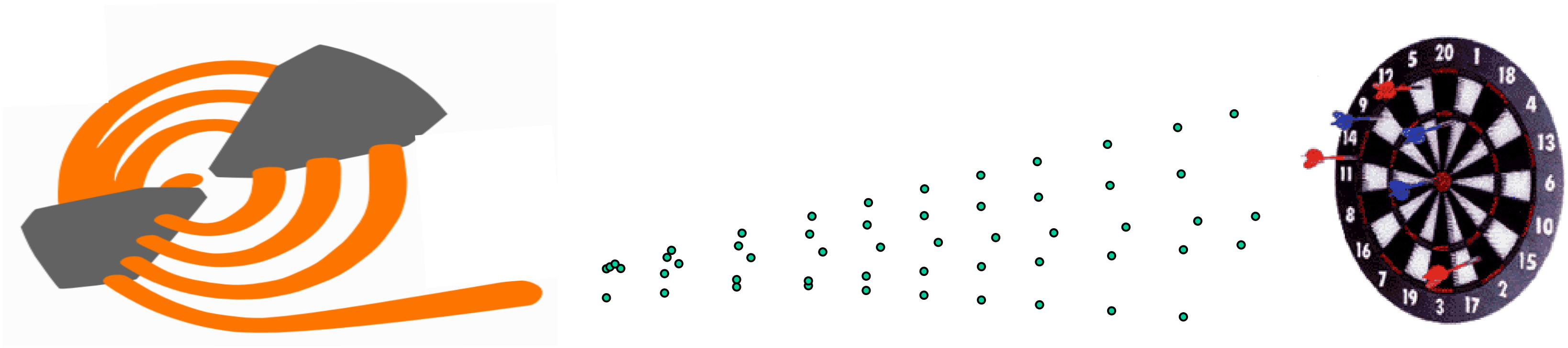
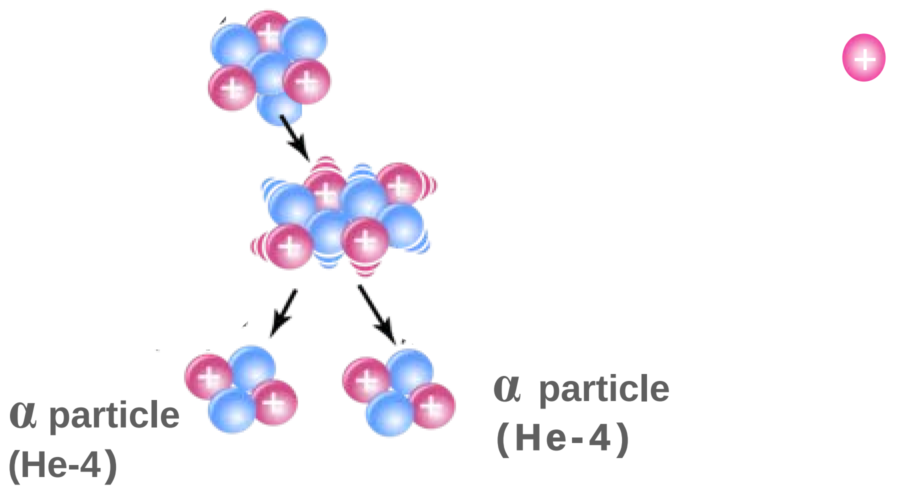
Nuclear reaction is a process in which two, three nuclei or nuclei and particle such as neutron, proton ... collide producing the product other than the initial ‘items’.







The first artificial nuclear reaction was performed by John Cockcroft and Ernest Walton in 1932. They bombarded the ^{7}Li with ‘artificially’ accelerated protons. In result the two helium nuclei (α particles) were created.

What is the target?

Gasous or liquid

- gas or liquid flow (the melted metals as well)

- material closed in the chamber kept in the low temperature

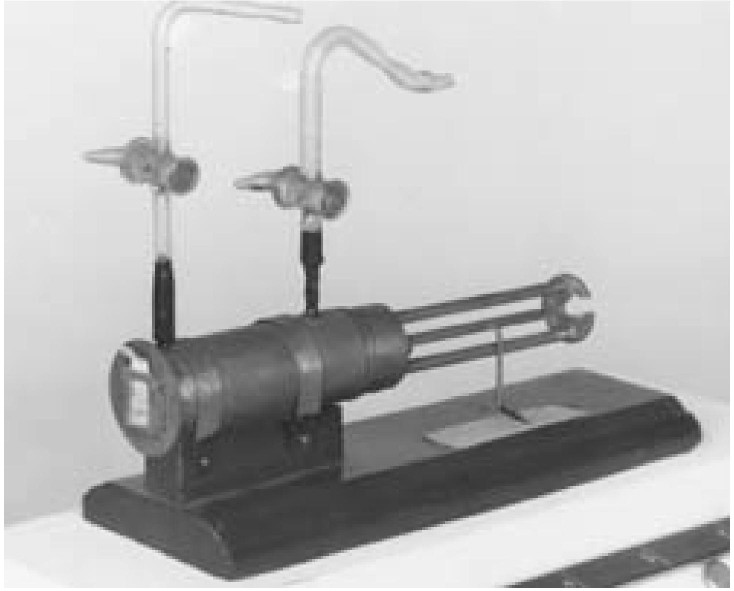
- in case of gaseous target:
  implantation into the solid backing/carrier

Rutherford transmutation

„An anomalous effect in nitrogen,”

the alpha particle (from Polonium) which passed through the container with nitrogen gas and nitrogen nucleus stuck together, with a proton flying loose.

$$^{14}N + \alpha \rightarrow {}^{17}O + p$$



The aparatus used by Rutherford in 1919 for transmutation of nitrogen into oxygen

What is the target?

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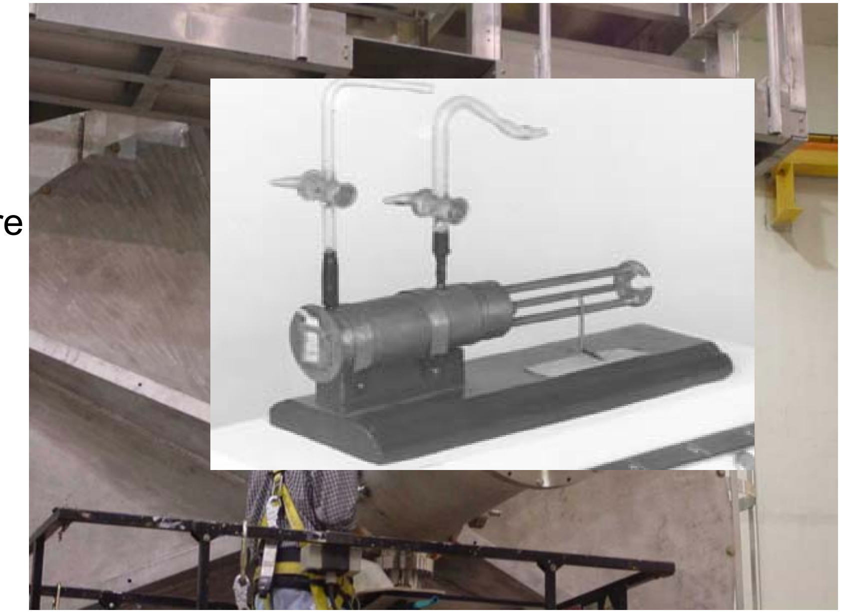
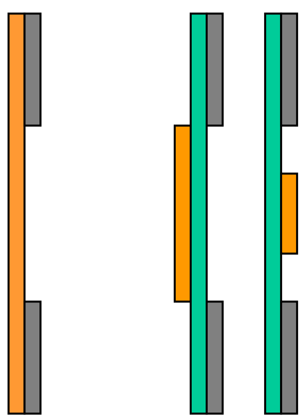
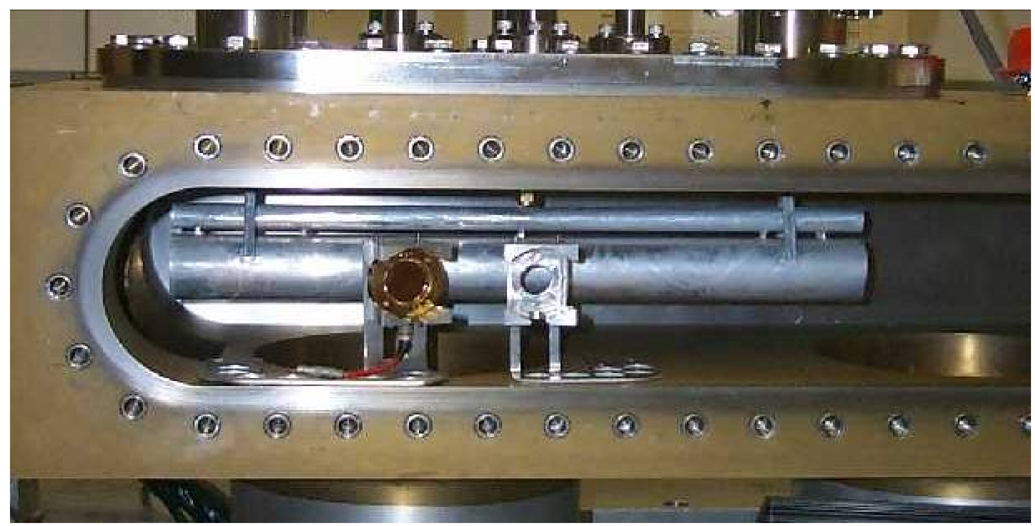


Solid targets

- self supporting
- on the backing





How to make the target?

The choice of the method depends on many aspects:

- target form (phase) and characteristics/parameters:
  element/isotope, thickness, size
- availability of the tools/method in the target lab
- avoiding unnecessary costs
- avoiding contamination of the material

Target properties/characteristic

Target material: element-isotope
and its phase: solid, liquid, gaseous

Thickness and its homogeneity

Chemical form required and available

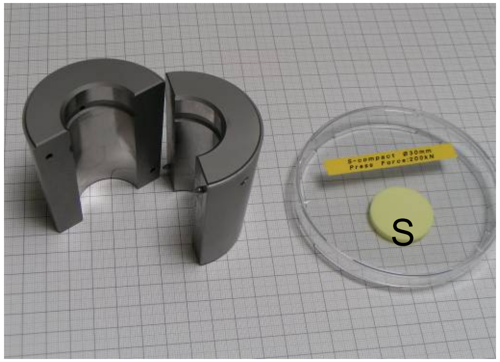
Self-supporting or on the backing

How ???

mechanical shaping:

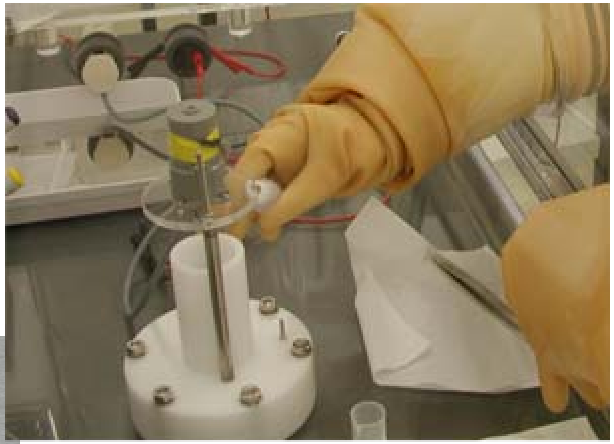
rolling

tablet pressing



chemically: electro-deposition from hydrous or organic medium

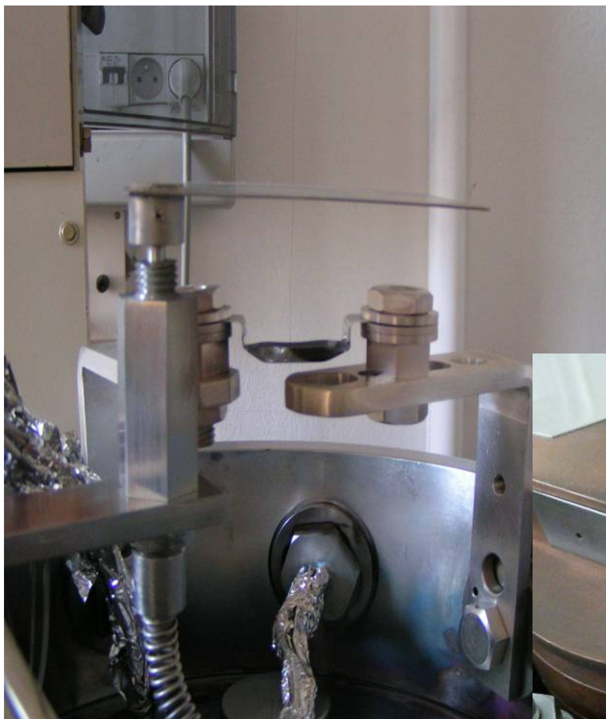
(always on the backing)

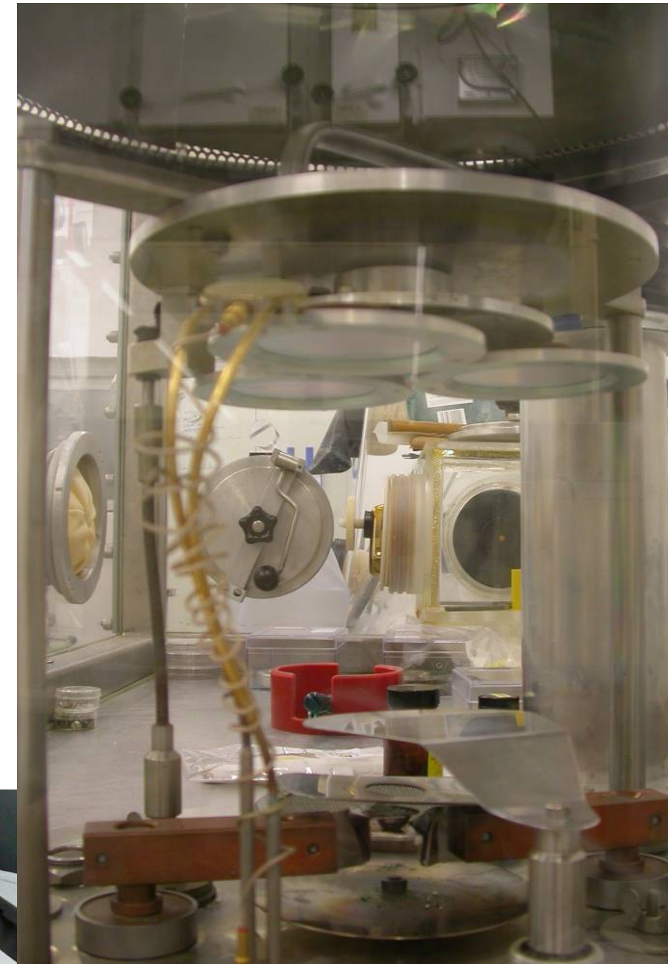


How ???

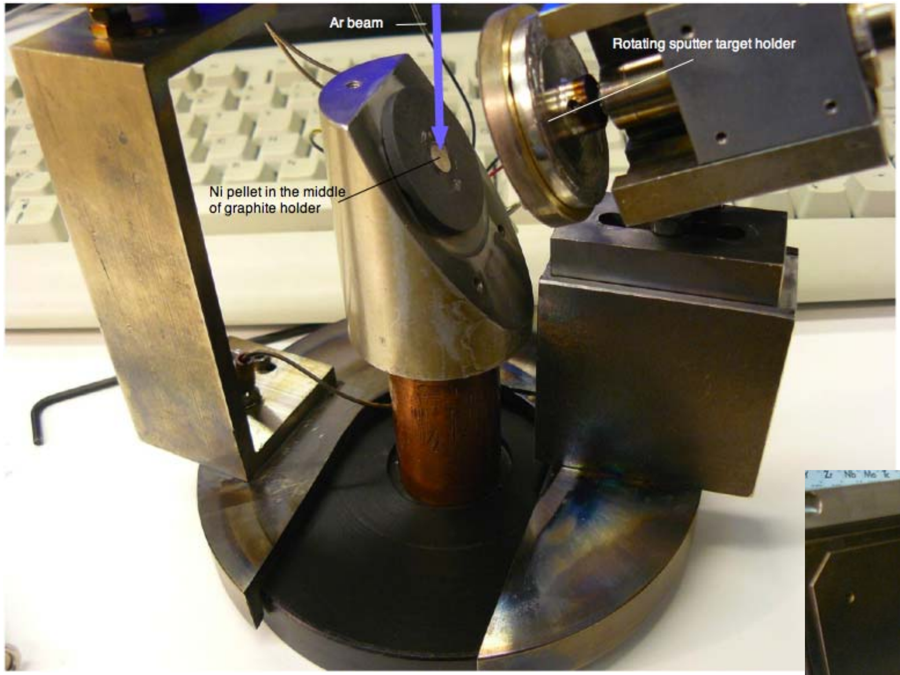
vapour deposition in the high vacuum
(self-supporting or on the backing)

- -resistance heating
- -e-gun
- -sputtering

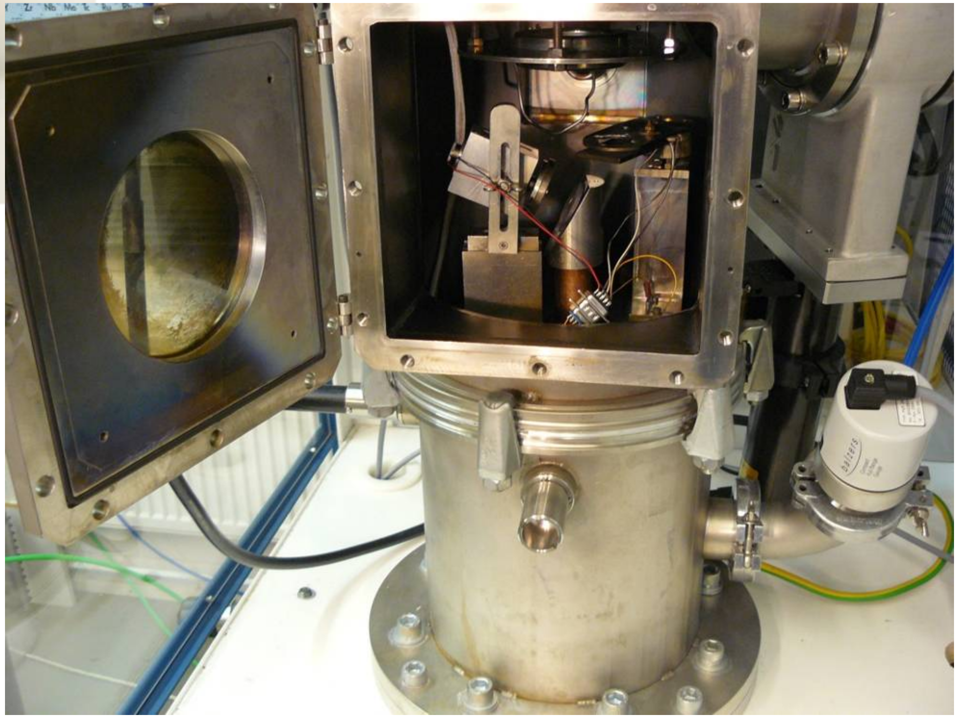




How ???



sputtering i.e. target material ejection by accelerated ions of the nobel gas



How??

carbon arc
laser ablation
e-gun

How ???

Resistance heating

- The method is very simple, robust

but

- limited to the materials of the low melting point (not higher then 1800 °C)
- and not alloying with the boat material.

E-gun

- The method is more complex, but extremely versatile.
- Can achieve temperatures in excess of 3000°C.
- Use evaporation cones or crucibles in a water cooled copper hearth.
- Typical emission voltage is 8-10 kV.

but

- Exposes substrates to secondary electron radiation.
- X-rays can also be generated by high voltage electron beam

Sputtering

- The method can be applied to the most of the materials except those which can degrade due to ionic bombardment
- This technology allows to released the deposited material at much lower temperature than evaporation.
- gives easy film thickness control via time, allows alloy deposition, no x-ray damage

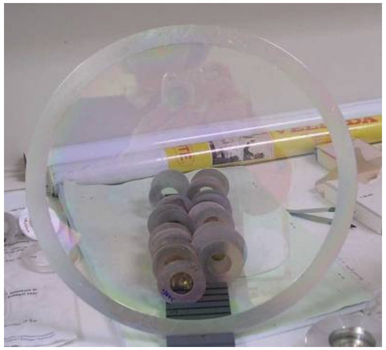
but

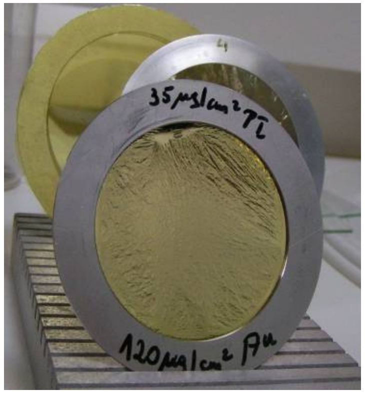
- requires rather big surface of the sputtered material to avoid bombarding of the cathode material.
- There is as well big chance for the impurities incorporation due to low vacuum.

Backings?

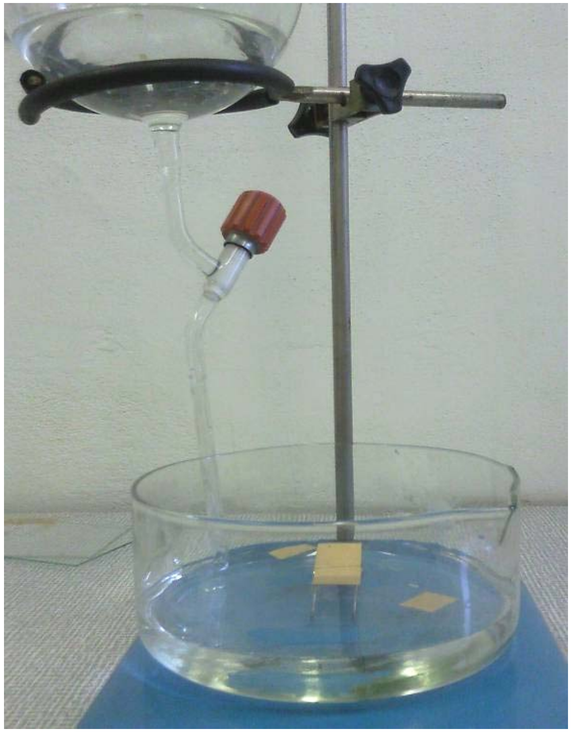
on the backing or self-supporting

- backings
  - thin metal foils
  - carbon foil
  - plastic: Mylar, Kapton, Formvar

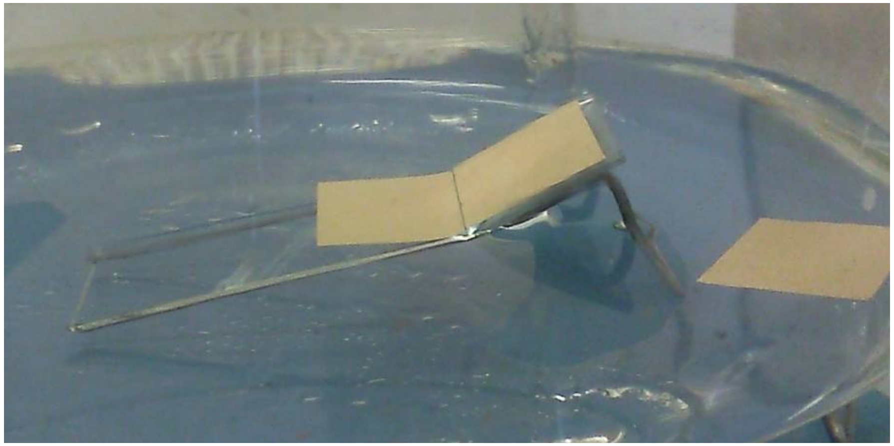


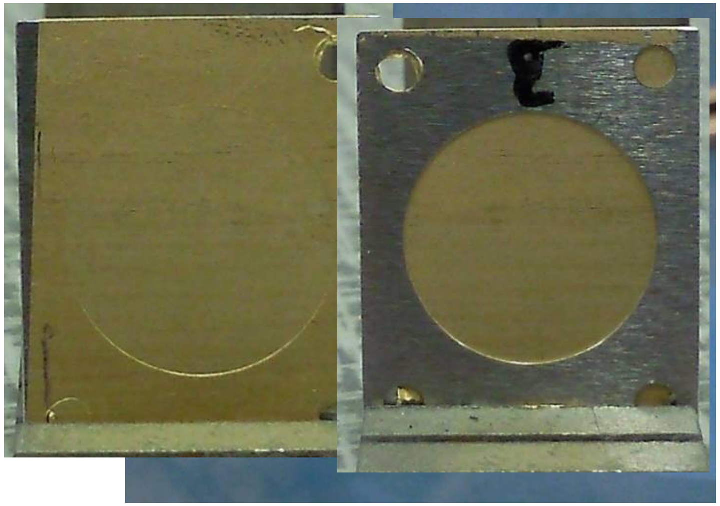


How???



by vapour deposition
on substrate





Target characterisation

Thickness:

(mass/area i.e. g-mg-µg/cm^2)

$1\ b\ (\sigma) = 10^{-24}\ cm^2$

it's approx. the sectional area of the U nucleus

Thickness estimation: mass/area i.e. g-mg-μg/cm²)

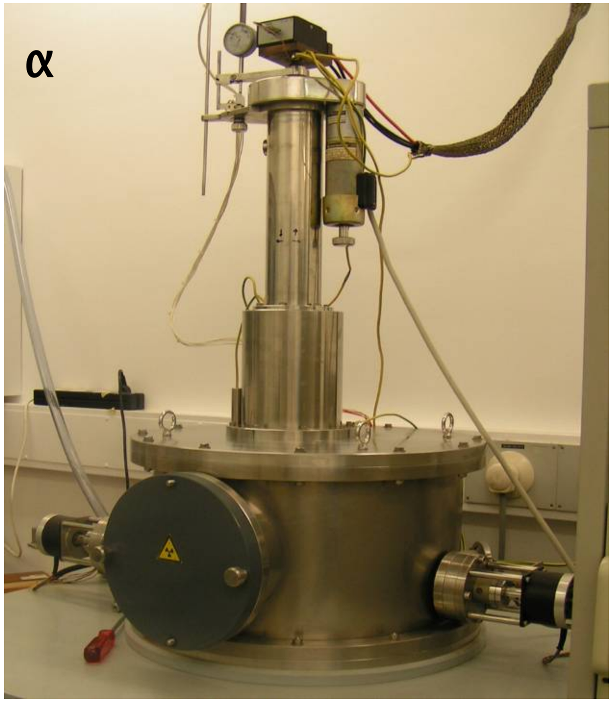
* mechanically or electrically i.e. using caliper, micrometer screw??) or thickness induction gauge
* weighing the defined area
* in-situ during the vapour deposition process using the quartz microbalance
* spectrophotometrically
* measurement of the α particles or X-ray ener
* profilometers working in a contact or non-contact modes

Thickness estimation of the radioactive targets:

if made by evaporation: during preparation with quartz microbalance

ready target: measurements of the radioactivity

thickness homogeneity by radioactivity scan across the target area



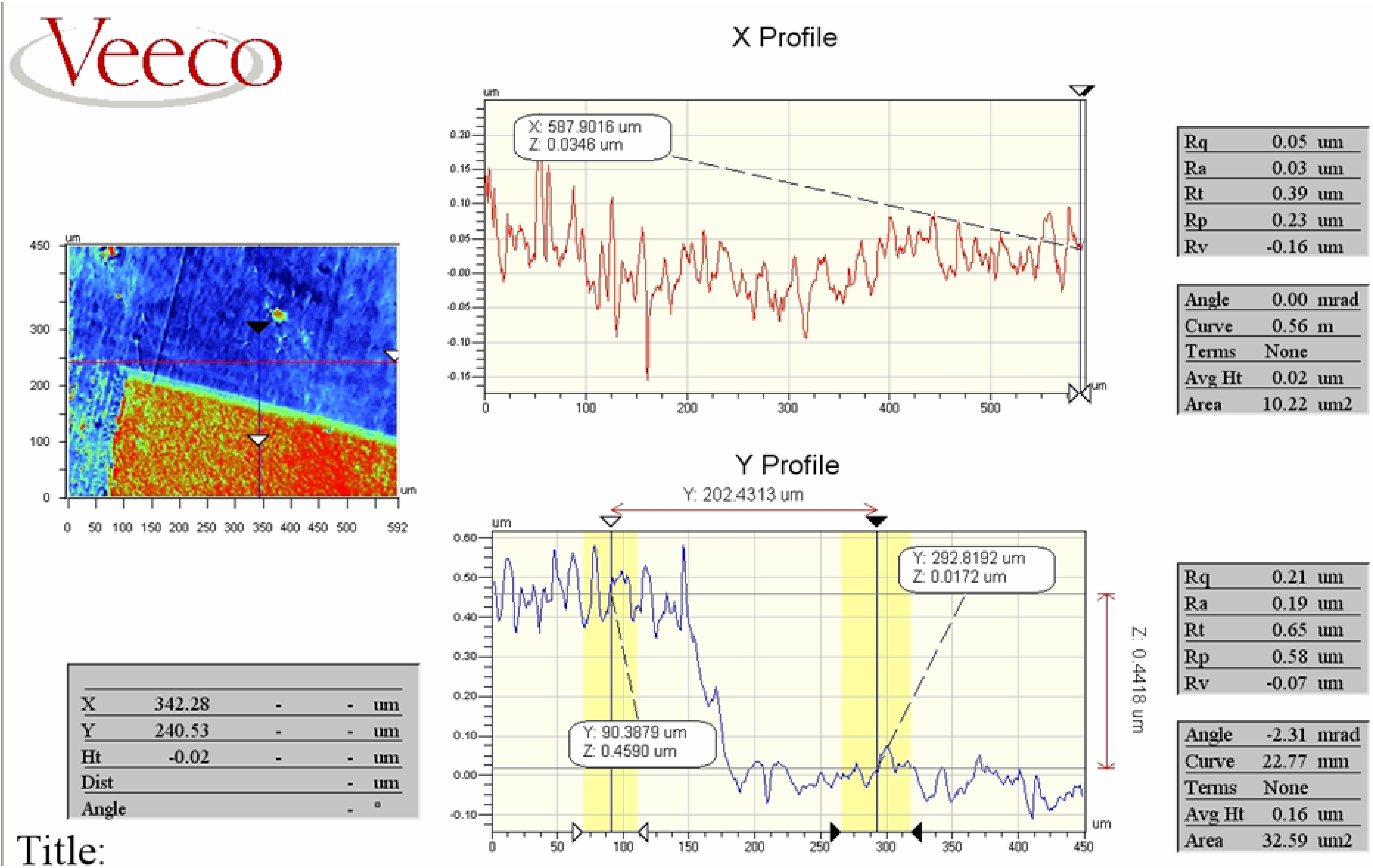
Target characterisation

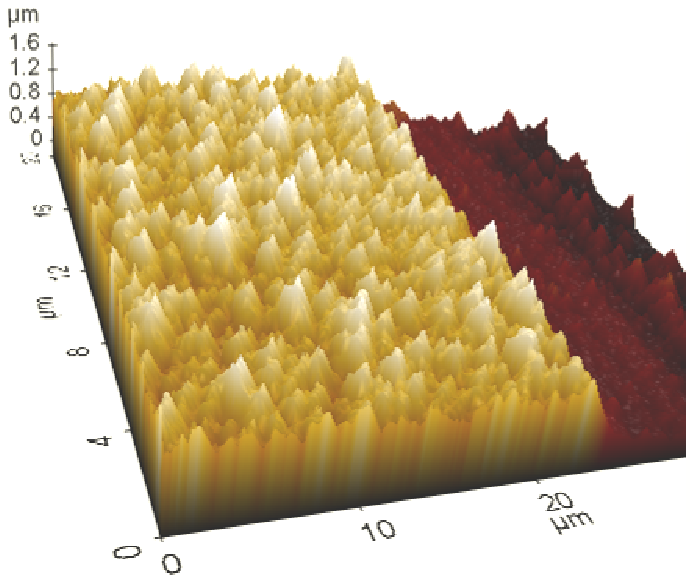
Thickness: (mass/area i.e. g-mg-μg/cm^2)

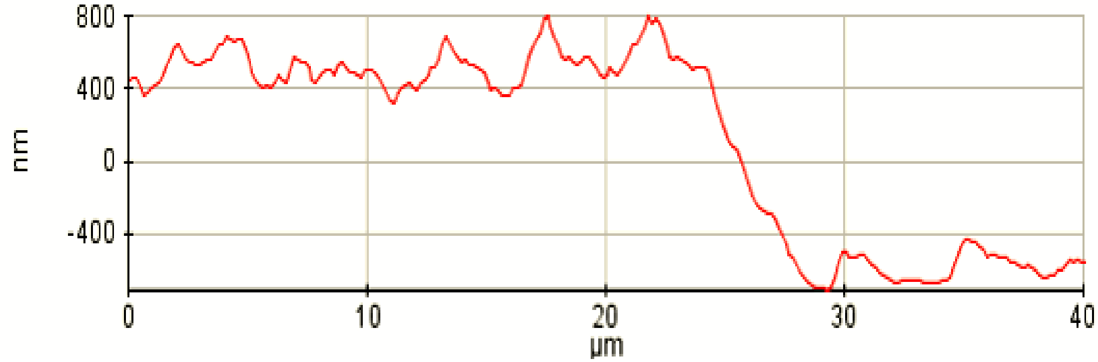
Thickness homogeneity:

?

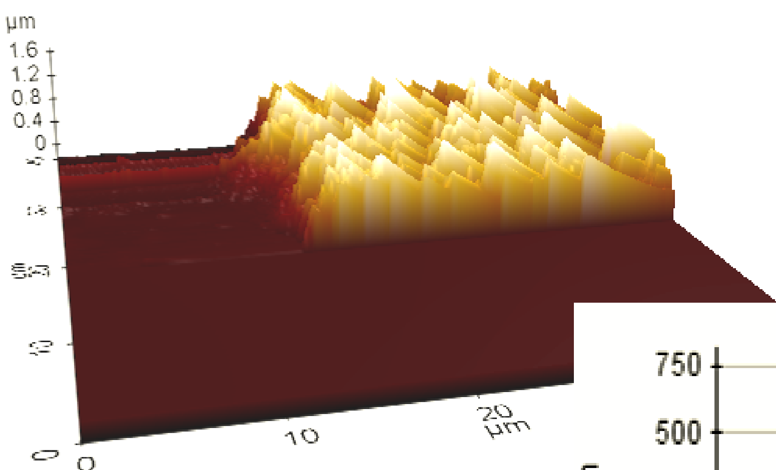
Surface characterisation

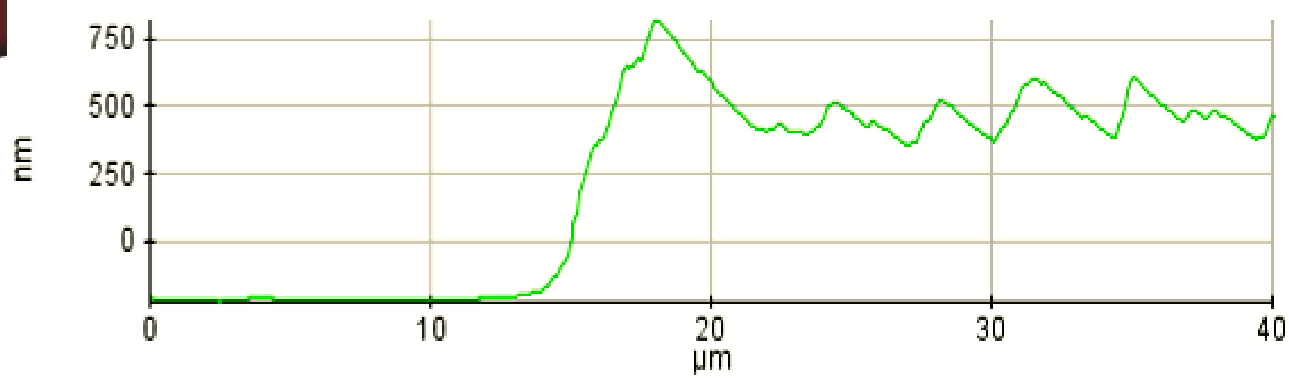






AFM images of tristearin layer





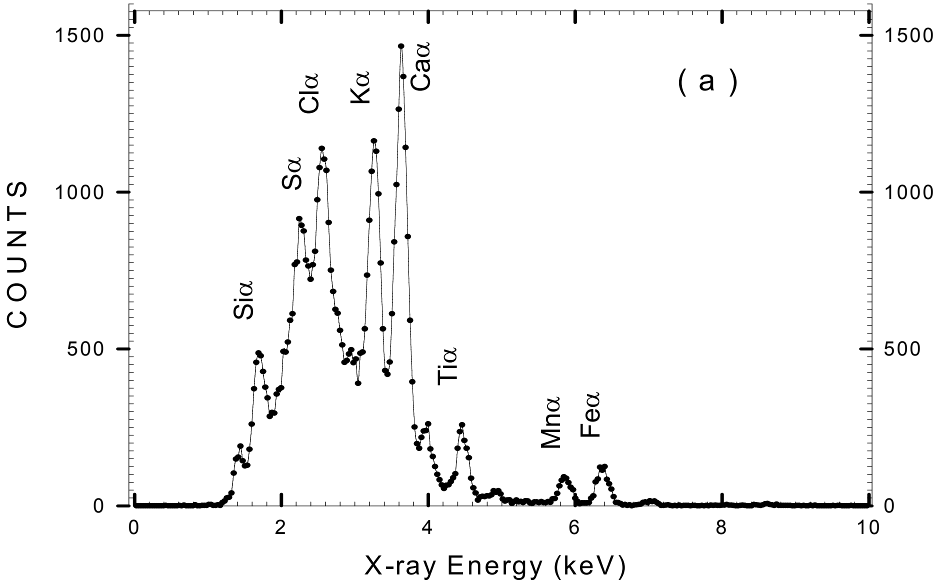
Target characterisation

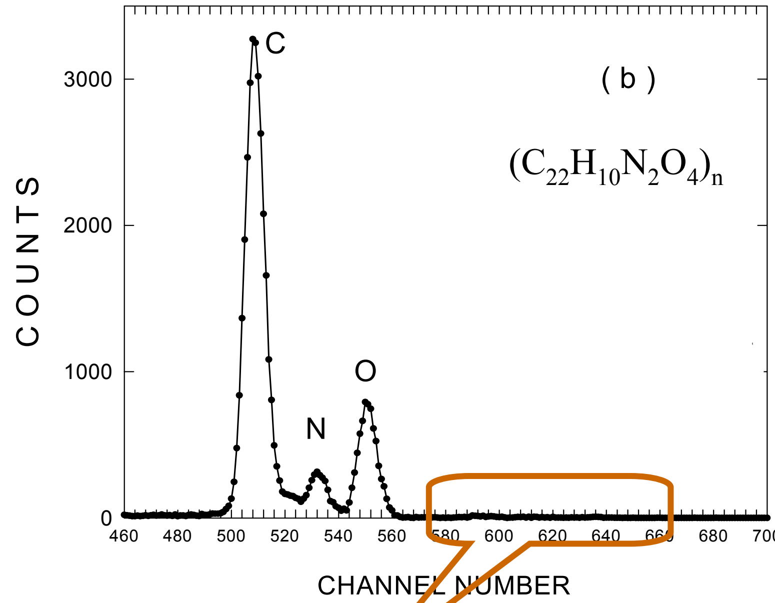
Thickness: (mass/area i.e. g-mg-µg/cm^2)

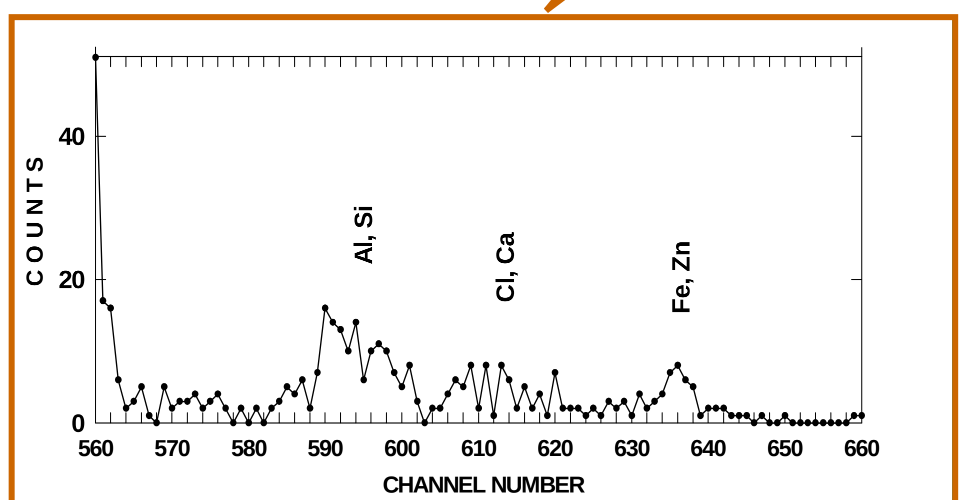
Thickness homogeneity (including surface topography)

Purity/composition

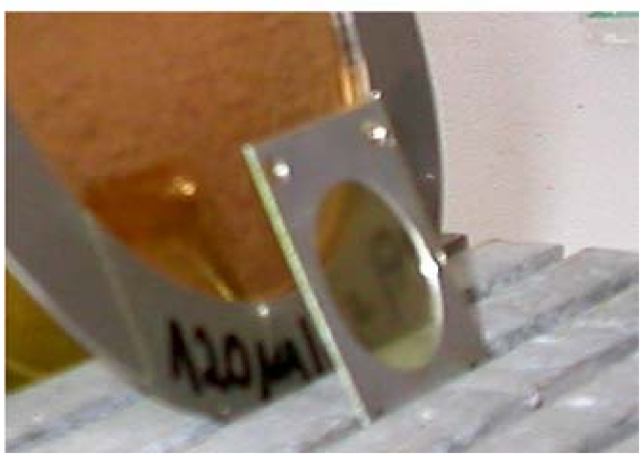
Purity/composition







PIXE spectrum of polyimide foil



Closing advices

When ordering a target define the characteristic needed/significant for planned studies but avoid exaggeration i.e. do not order a target with much better characteristic than really needed. This may cause additional costs and/or ... delay.

element/isotope
thickness, dimensions
supported or not, if yes what can be considered as support
purity

Do not overestimate the importance of the chemical form of the target material.

not always have to be a pure elemental form, the compounds may suite your needs as well but often it is much easier (cheaper) to make the target from compound

Discuss with target maker your planned target. Target preparation people can do sometimes more for you than you believe; it is often a question of communication and of raising the relevant problems/aspects.

target bibliography index by *International Nuclear Target Development Society*

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