UNIVERSITY OF WARSAW

Targets for gamma spectroscopy studies and not only

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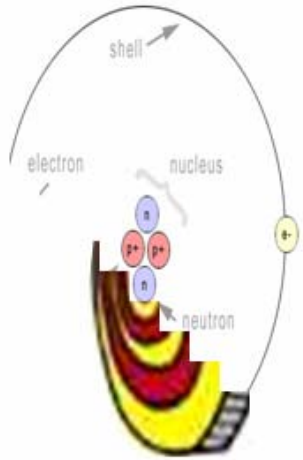
Heavy Ion Laboratory
EAGLE collab


shell
electron
nucleus
n
p+
p+
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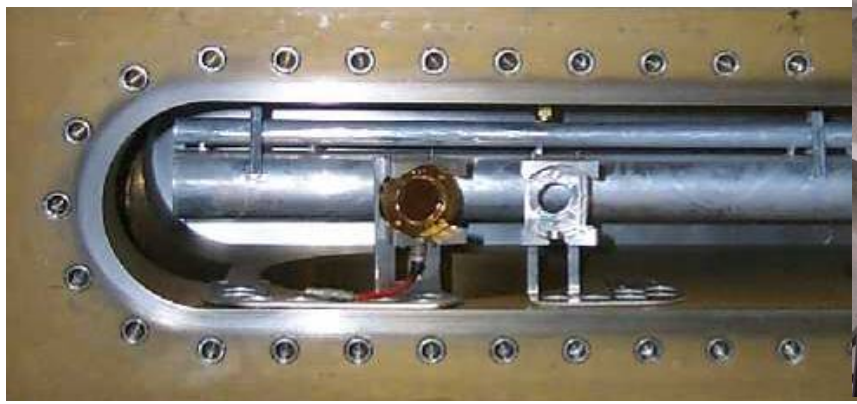
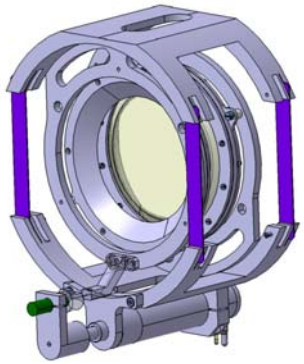
neutron

effective





robust under the beam i.e.

- resisting damage by the beam (pealling, sputtering, thermal)
- mechanically sustaining the stretching in case of plunger targets

but as well

efficient = low costs

How to make the (solid) target?

The choice of the method depends on many aspects:

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

How ???

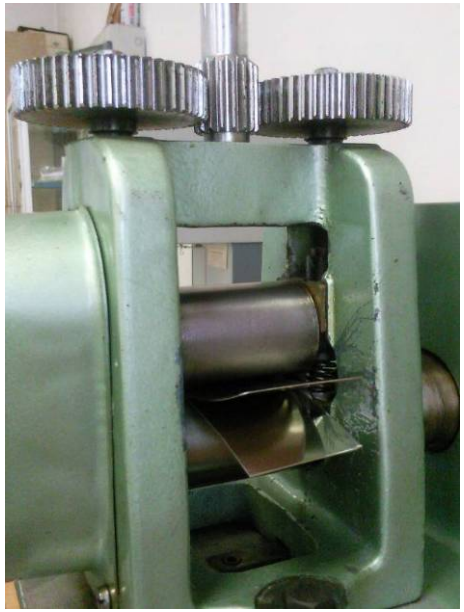
The methods which should be considered as preferable for production of targets with thickness of 1 mg/cm^2 up to tens of mg/cm^2, most frequently used at studies discussed at this workshop:

How ???

mechanical shaping:

rolling – malleable materials

tablet pressing



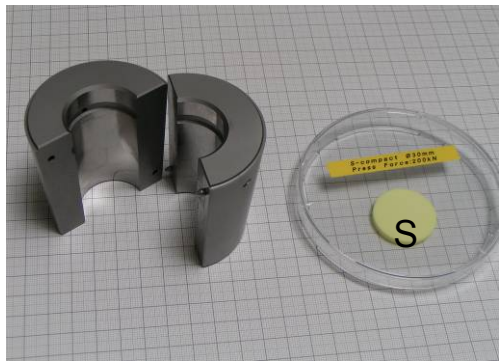
0.5 - ∞ mg/cm^2

low limit for hard but ductile material such as Ni

soft metals >1.5 mg/cm^2

~20 - ∞ mg/cm^2

excluded - very hard materials unless the addition of the binder is accepted

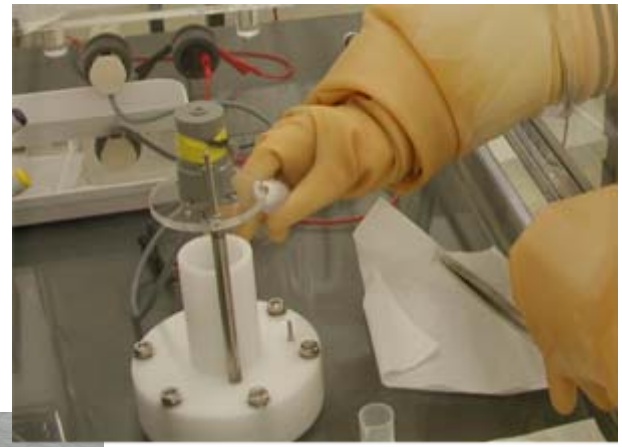


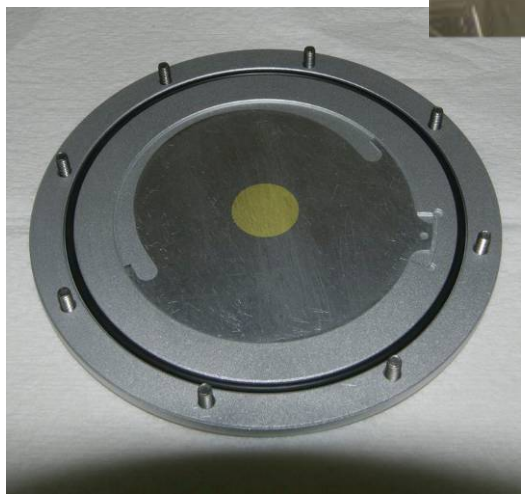
How ???

chemically: electro-deposition from hydrous or organic medium

µg/cm² – mg/cm²

always on the backing





How ???

The methods which should be considered as preferable

method	thickness limitation mg/cm^2	conditions	efficiency
rolling	0.5 - ∞ hard but ductile like Ni soft metals >1.5 mg/cm^2	material has to be malleable	90 – 95 %
pellet	~20 - ∞	excluded - very hard materials unless the addition of the binder is accepted	>95 - 98 %
electrodepo	µg/cm^2 – mg/cm^2	always on the backing	80 - 90%

How ???

other methods

HIVIPP

rolling together

sedimentation with binder such as epoxy resins glue

but as well

vapour deposition in the high vacuum

(because of the material outgo recommended rather for the thin target preparation but could be applied for thicker target production as well)

How ???

other methods

HIVIPP

HIgh energy VIbrational Powder Plating

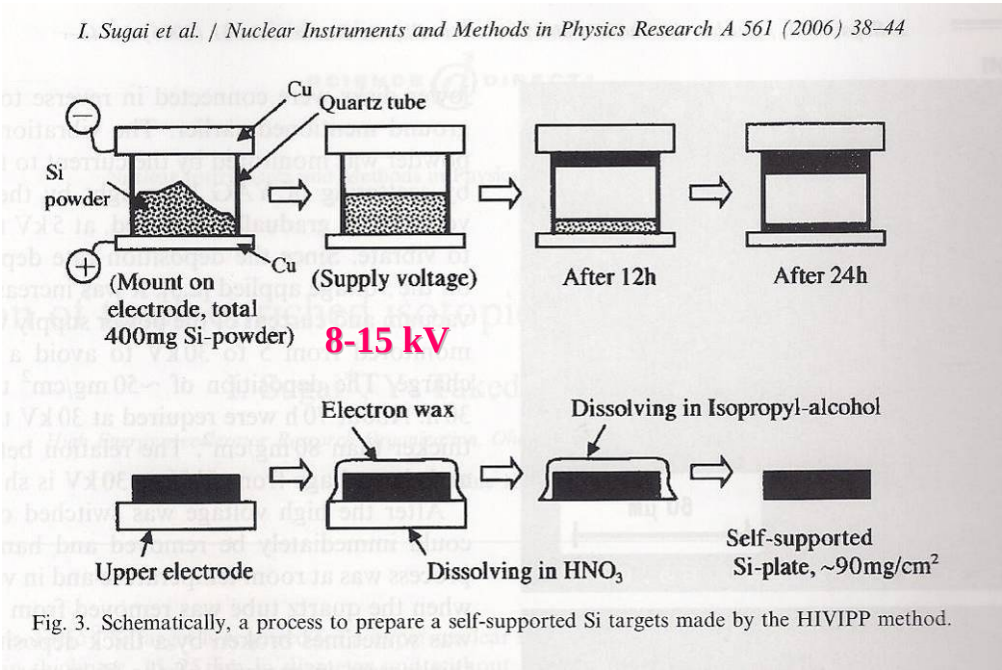


Fig. 3. Schematically, a process to prepare a self-supported Si targets made by the HIVIPP method.

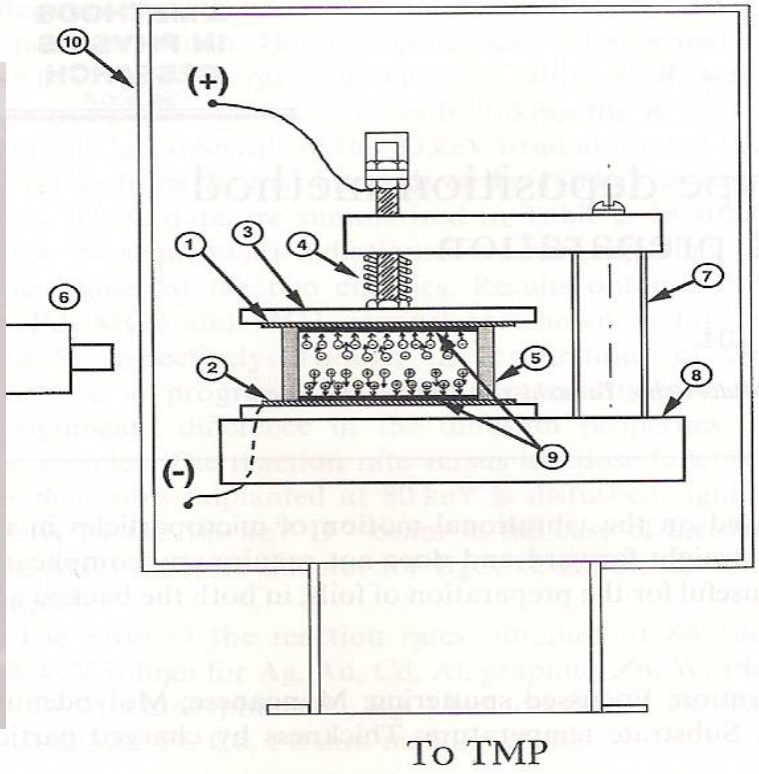
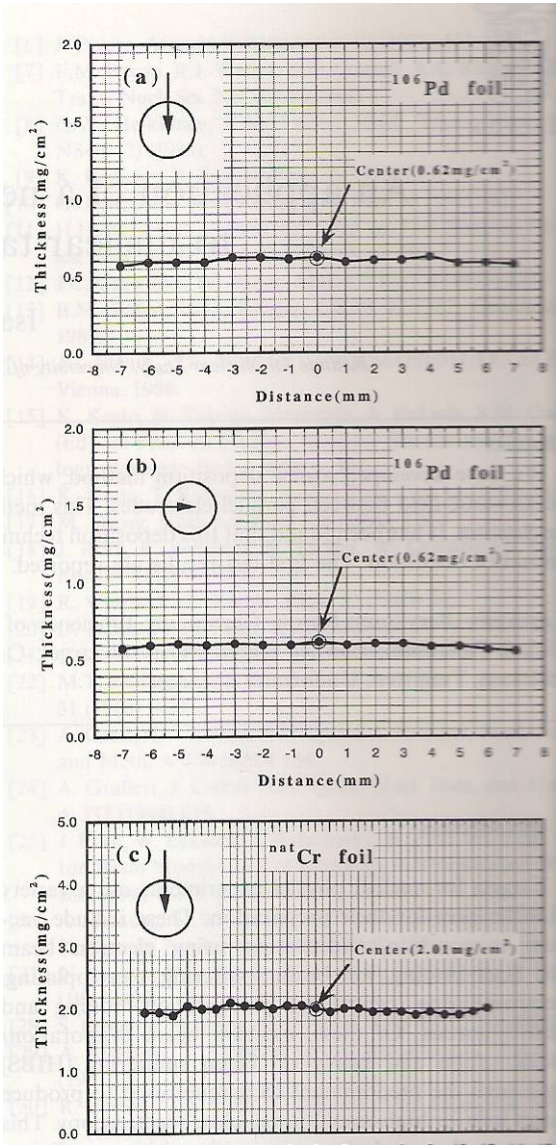


Fig. 1. Schematic drawing of experimental set up; 1: backing foil (upper electrode: anode), 2: backing foil (lower electrode: cathode), 3: press plate, 4: spring for the press plate, 5: glass pipe, 6: He–Ne laser, 7: strut, 8: Teflon holder, 9: deposited layer, 10: glass vacuum chamber.

How ???

other methods HIVIPP



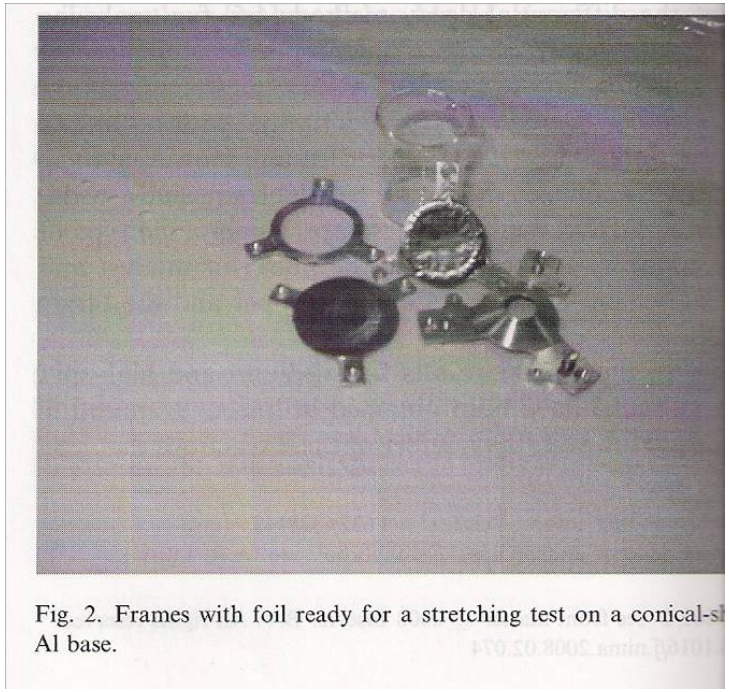


Fig. 2. Frames with foil ready for a stretching test on a conical-s
Al base.

applied to produce the ^{11}B on ^{93}Nb

A.R. Lipski, G. Rainovski, N. Pietralla and A. Dewald
Nucl. Instr. and Meth. A590 (2008) 69

How ???

other methods

Pb and Sn rolled together

The only place where Pb sticks out of the common area of sandwich

Sn side

Pb side

start: 105 μm Pb + 8.5 μm Sn

end: 12.97 μm + 1.05 μm Sn

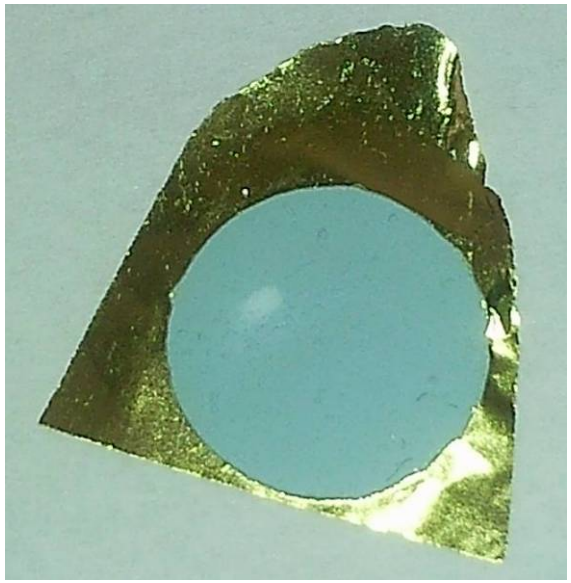
How ???

other methods

sedimentation

few - ∞ mg/cm^2

additional material-binder



3 mg/cm^2 of Nd (as Nd_2O_3) on Au backing
sedimented from expoxy glue solution

How ???

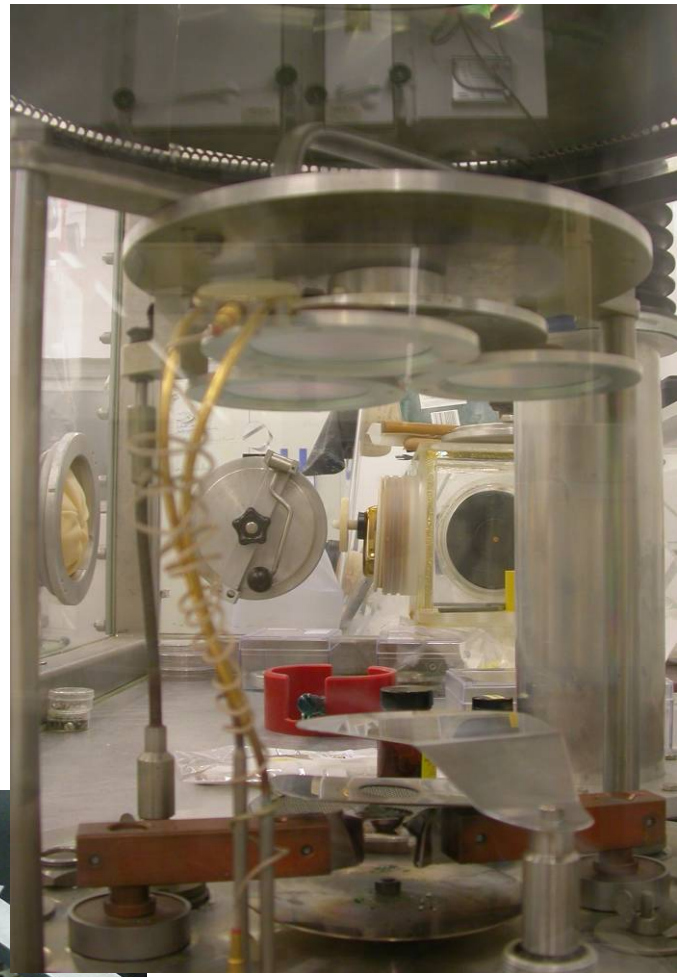
vapour deposition in the high vacuum
(**mostly applied for thin targets - below 1 mg/cm^2**)

-resistance heating
-e-gun
-sputtering

range: μg/cm^2 – mg/cm^2

self-supporting and on the backing

assuring high thickness homogeneity (when deposited at high distance of the vapour source and substrate



for radioactive - devoted evaporators

How: high vacuum evaporation

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 may degrade due to ionic bombardment
- 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.

How ???

The methods which should be considered as preferable

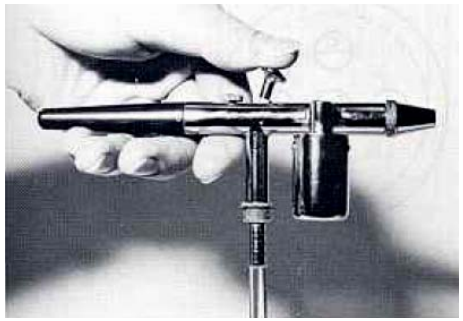
method	thickness limitation	conditions	efficiency
rolling	0.5 - ∞ mg/cm^2 hard but ductile like Ni soft metals >1.5 mg/cm^2	material has to be malleable	~ 90 %
pellet	~20 - ∞ mg/cm^2	excluded - very hard materials unless the addition of the binder is accepted	>95%
sedimentation	few - ∞ mg/cm^2	additional material-binder	95 -98%
electrodepo	µg/cm^2 – mg/cm^2	always on the backing	80-90%
HIVIPP	µg/cm^2 – mg/cm^2	on the backing or without	95-98 %
high vac evap	µg/cm^2 – mg/cm^2	See previous slide self-supporting or on the backing	2-10 % (could be much higher if deposition performed at close distance of substrate and vapour source)

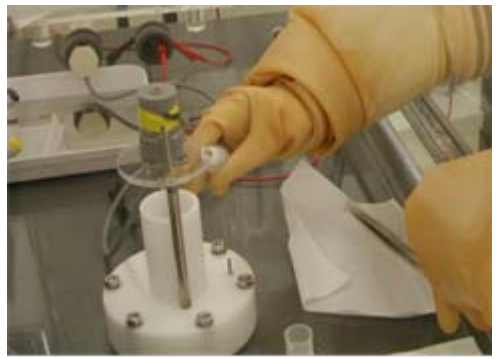
How ???

All this methods can be applied to produce the radioactive targets as well

but use of the vaccum evaporation technique is very much limited by demand of devotion of the evaporation set-up to the particular isotope ≡ high costs. Not many institutions can afford such solution.

Much better e.g. is electrodepo or painting





<u>electrospraying:</u> solution of the active material or suspension (e.g. oxides) forced by high voltage (3-20 keV) to pass through narrow capillary are deposited on conductive substrate (carbon or metalic/metalised foil)

The new lab preparing the radioactive targets become operational (nearly)
CACAO = Chimie des Actinides at Cible radioActives à Orsay

Heat ???

dissipation of the heat ($W=\Delta E \times I$) deposited in the target:
conduction + radiation + convection

heat dissipation by *conductive heat transfer* can be estimated from:

$$q = k\, A\, dT / s$$

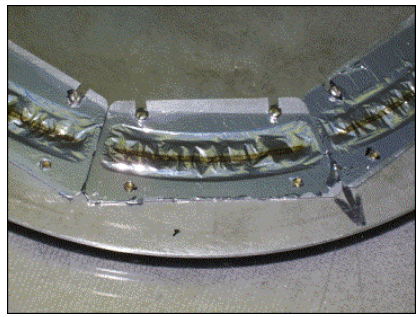
where
- A = heat transfer area (m^2)
- k = thermal conductivity of the material (W/(m K)
- dT = temperature difference across the material (K)
- s = material thickness (m)

heat dissipation by *radiation* can be estimated using expression

$$q = \varepsilon\, \sigma\, T^4\, A$$

where
- ε - emissivity of the object (one for a black body)
- σ - Stefan-Boltzman constant [$W\, m^{-2} K^{-4}$]
- A - area of the object [m^2]
- T - temp of the object [K]

To decrease the thermal impact of the beam:
- target wheel
- beam wobbling

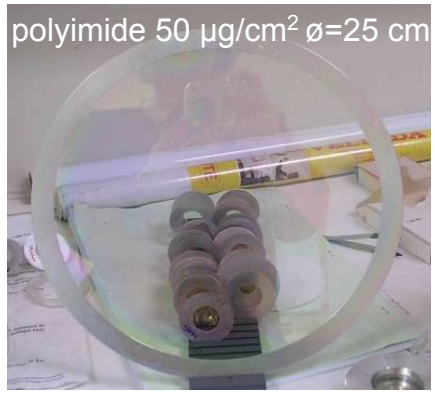


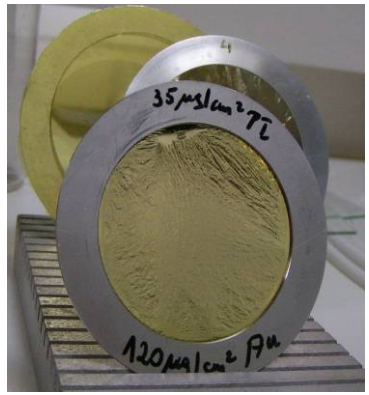
SHE target wheel,
Argonne lab

backings

choice of backings

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





backings ?

examples of target backings

	Mylar $(C_{10}H_8O_4)_n$	Polyimide $(C_{22}H_{10}N_2O_4)_n$	Aluminium Al
Density	1.39 g/cm^3	1.41 g/cm^3	2.7 g/cm^3
Temp. resist.	250 ºC	450- 500 ºC	660 ºC
Thickn. com-ly used	1.5 µm (200 µg/cm^2)	0.21 µm (30 µg/cm^2)	e.g. 2 µm (540 µg/cm^2)
Min thickn. available	as above	0.07 µm (10 µg/cm^2)	depends on technique (rolling or evapo)
thermal conductivity W/mK	0.12-0.14	0.37	237

backings ?

Life-time in ……

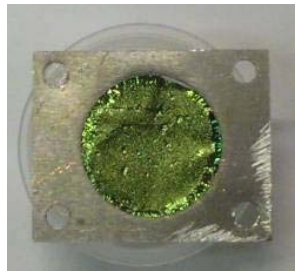
Polyimide foils of 45 - 47 μg/cm^2

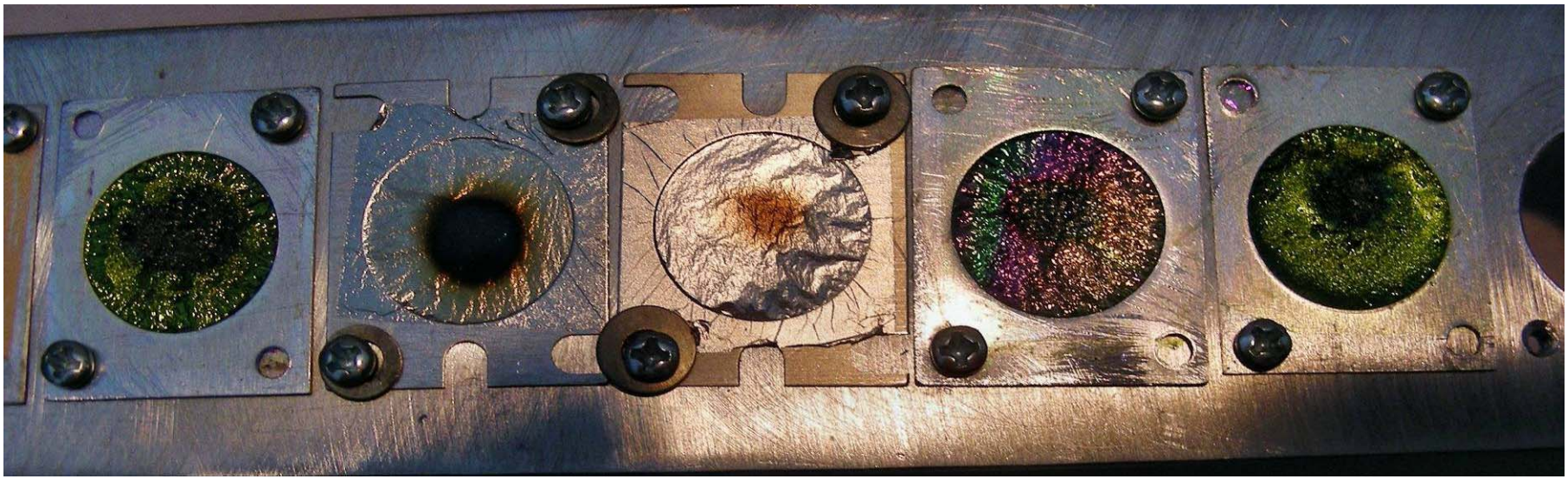
Beam	2.0 MeV ^{4}He – ions			1.5 MeV protons				
beam intensity I (nA)	50	100	160	150	300	500	1000	5000
Beam power $\Delta E \times I$ (W)	4.05×10^{-3}	8.1×10^{-3}	1.3×10^{-2}	1.5×10^{-3}	3.0×10^{-3}	6.0×10^{-3}	1.2×10^{-2}	6.0×10^{-2}
Foil status	foil had long life		foil ruptured after 5×10^{-4} C	foil had long life				foil ruptured after ~10^{-2} C

from M.Jaskóła, A. Korman, A Stolarz , NIM A, 2008

polyimide backing

$^{20}Ne^{+9}$ ions beam of ~50 MeV with intensity of 300 nA
on ~100 μg/cm^2 of Ni deposited on 35 μg/cm^2 polyimide.





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

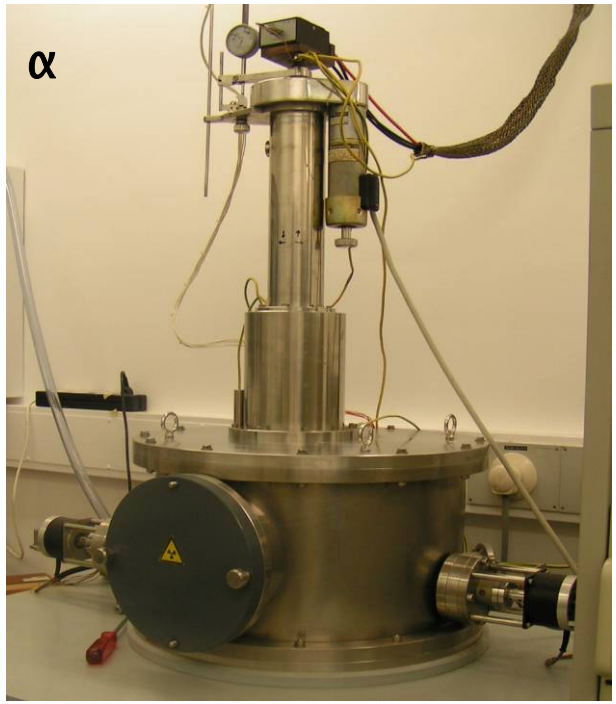
* Mechanically or electrically i.e.
  caliper, micrometer (screw??) or induction thickness gauge
* weighing the defined area
* in-situ during the vapour deposition process
  using the quartz microbalance
* spectrophotometrically
* measurement of the α particles or X-ray energy loss
* profilometers
 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

Thickness estimation of the radioactive targets:

if made by evaporation: during preparation with quartz microbalance

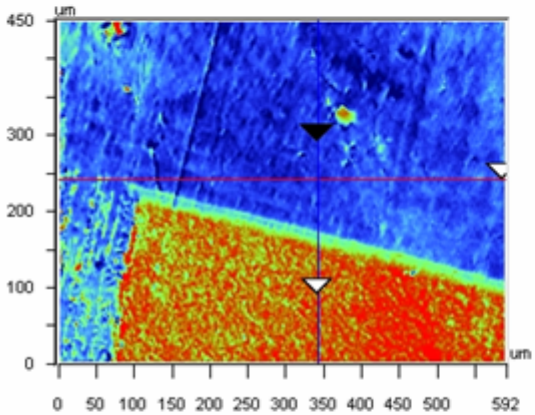
ready target: measurements of the radioactivity

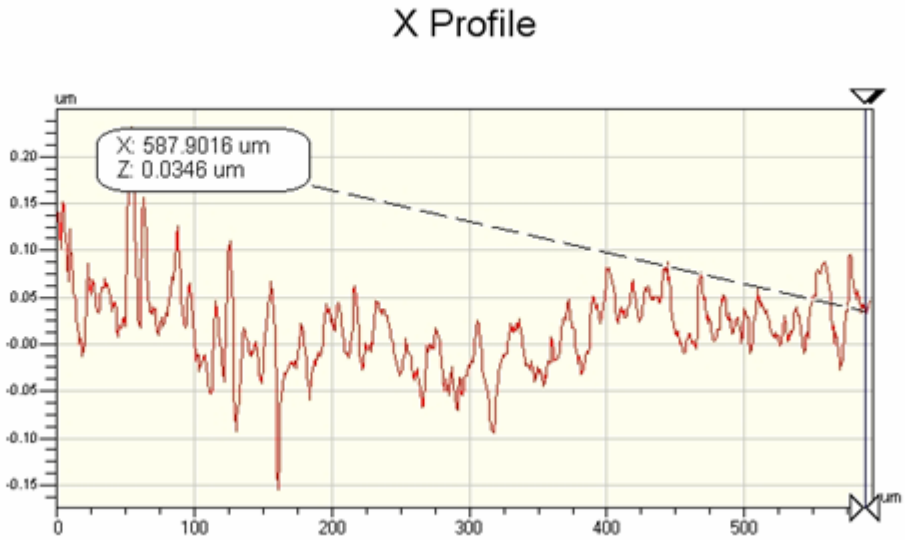
thickness homogeneity by radioactivity scan across the target area



Surface characterisation

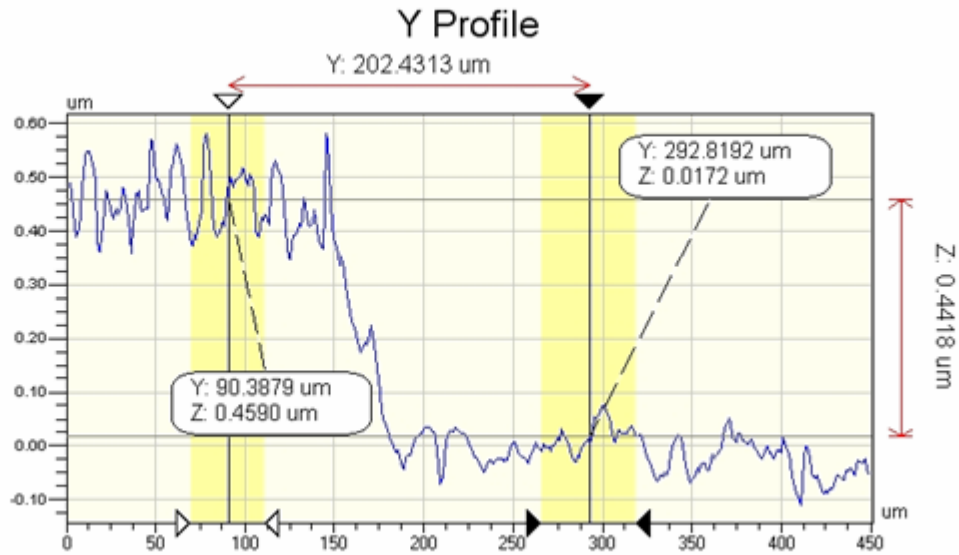
Veeco





Rq	0.05	um		
Ra	0.03	um		
Rt	0.39	um		
Rp	0.23	um		
Rv	-0.16	um		

Angle	0.00	mrad		
Curve	0.56	m		
Terms	None			
Avg Ht	0.02	um		
Area	10.22	um2		

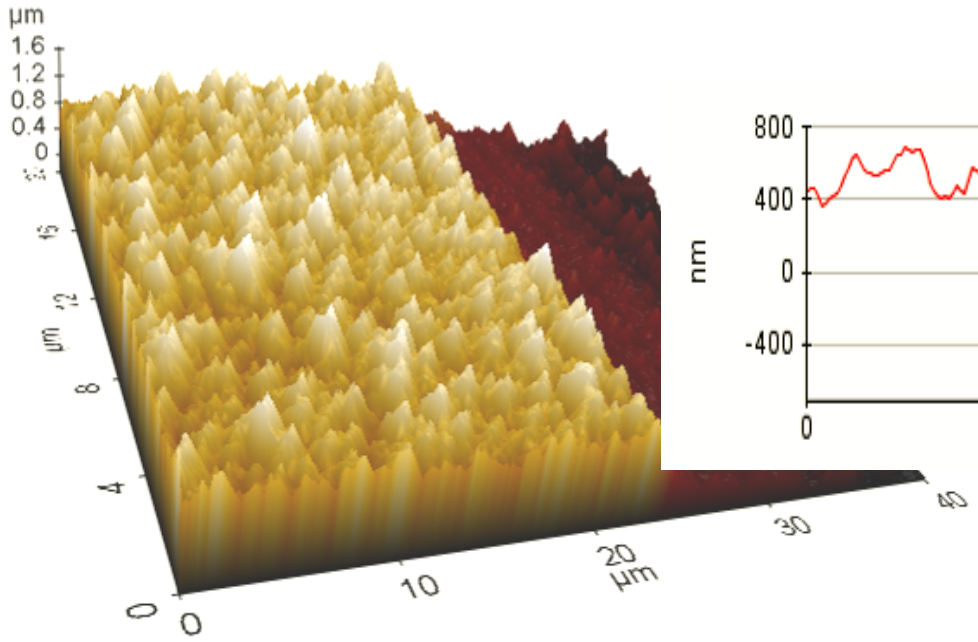


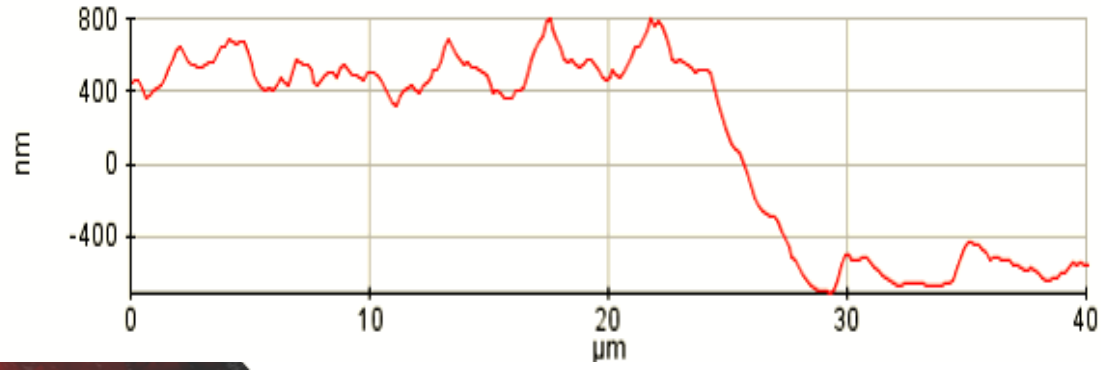
Rq	0.21	um		
Ra	0.19	um		
Rt	0.65	um		
Rp	0.58	um		
Rv	-0.07	um		

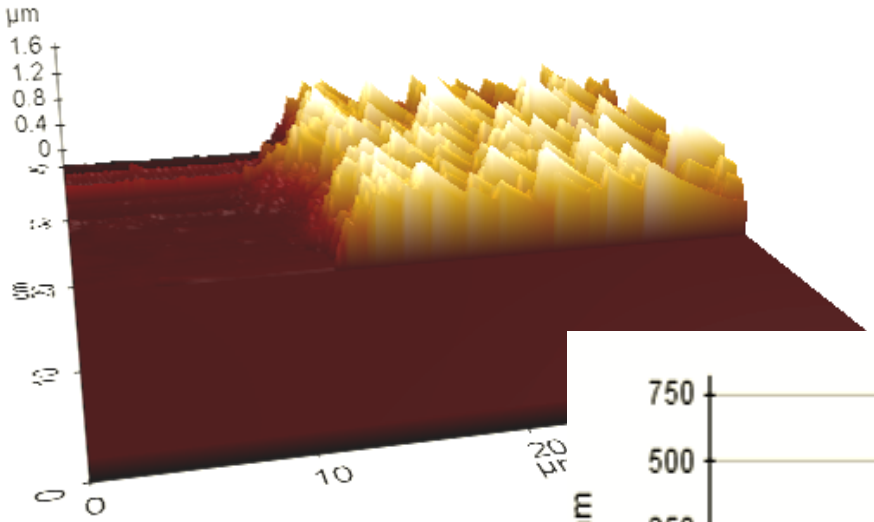
Angle	-2.31	mrad		
Curve	22.77	mm		
Terms	None			
Avg Ht	0.16	um		
Area	32.59	um2		

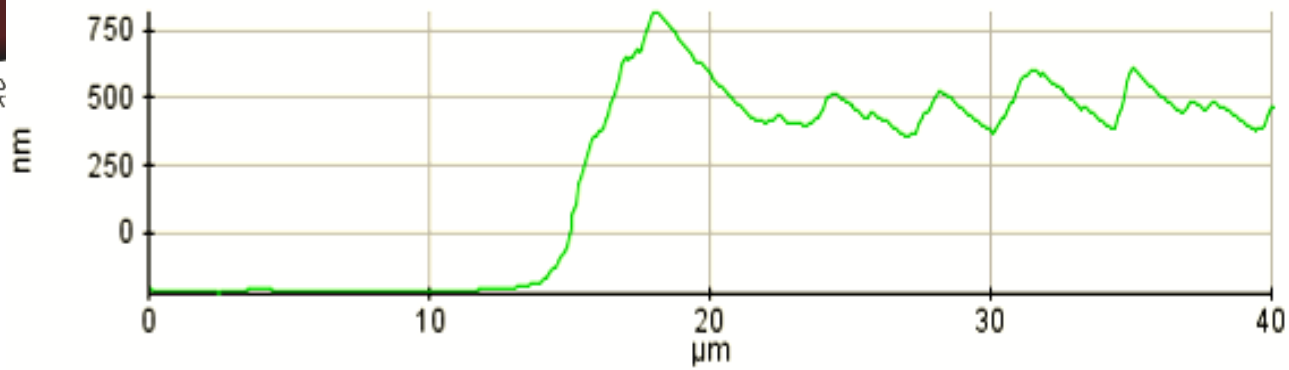
X	342.28	-	-	um
Y	240.53	-	-	um
Ht	-0.02	-	-	um
Dist			-	um
Angle			-	°

Title:



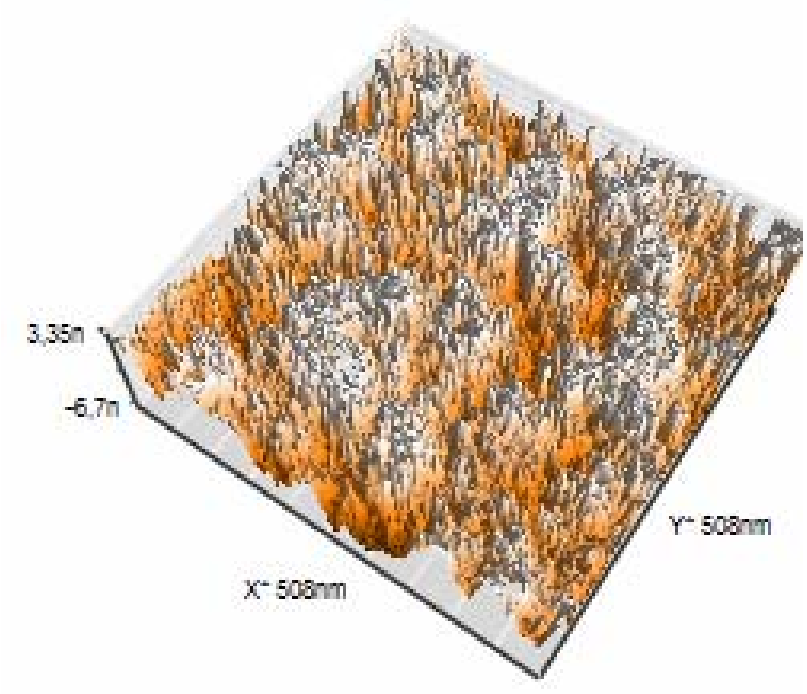


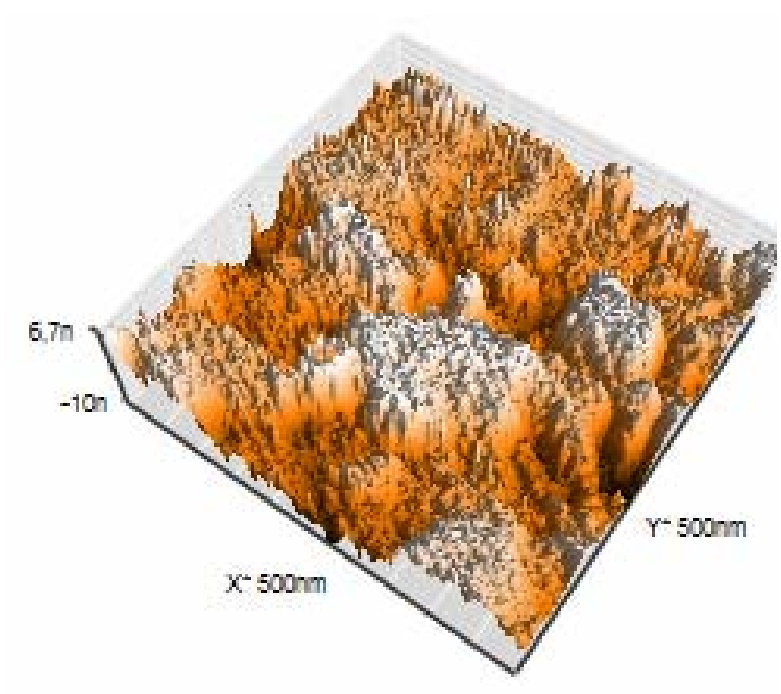




AFM images of tristearin layer (target of 'solid' hydrogen)

Surface characterisation





AFM topographic images of
thin alu layer

by e-gun

by RH (resistance heating

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.

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