

The status of the Target Preparation Laboratory at IFIN-HH Bucharest, Romania

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Abstract This paper describes present capabilities of the new Target Preparation Laboratory constructed at Horia Hulubei National Institute for Physics and Nuclear Engineering, Bucharest-Magurele, Romania. Self-supporting or backed targets are produced in the laboratory, using thermal evaporation, electron-gun evaporation, sputtering or cold rolling techniques. At present, it is possible to prepare layers with a wide range of thicknesses from several tens of $\mu\text{g}/\text{cm}^2$ to several hundreds of mg/cm^2 . As an example, we briefly describe a ^{40}Ca target preparation.

Keywords Enriched isotopic targets preparation · Thermal evaporation · Electron-gun evaporation · Sputtering · Rolling

Introduction

The Target Preparation Laboratory was commissioned in 2013 at Horia Hulubei National Institute for Physics and Nuclear Engineering (IFIN-HH), Bucharest, Romania. The laboratory was created in order to support the nuclear physics research activity performed mainly at the 9 MV FN

tandem accelerator in IFIN-HH, and other international research facilities where the research groups have scientific collaborations. This laboratory provides enriched isotopic targets for different types of nuclear structure experiments, such as measurements of lifetimes of excited nuclear states using different γ -ray spectroscopy techniques (Doppler shift attenuation, plunger, and fast-timing), nuclear structure studies using the activation technique and cross-section measurements of interest for nuclear astrophysical processes.

The success of the nuclear physics experiments is strongly influenced by the characteristics of the obtained target (purity, composition, thickness, uniformity, etc.). To assure good target quality, the target laboratory was equipped according to international standards set for this type of target laboratories [1–12].

In general, a target request specifies characteristics like: isotopic material, thickness, and target frame type. Design of the target frame determines the target surface area and shape (Fig. 1). One should also mention the type of target to be made (e.g. self-supporting, backed or sandwiched). In case of the backed targets one should specify the backing characteristics (material and thickness).

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Equipment for target preparation

The laboratory is equipped with two evaporation systems that are further described along with their design specifications (capabilities).

TE18-High Vacuum Deposition System, as shown in Fig. 2, is a physical vapor deposition device, used for creating self-supporting or backed targets by thermal evaporation, by electron-gun evaporation, or by sputtering.

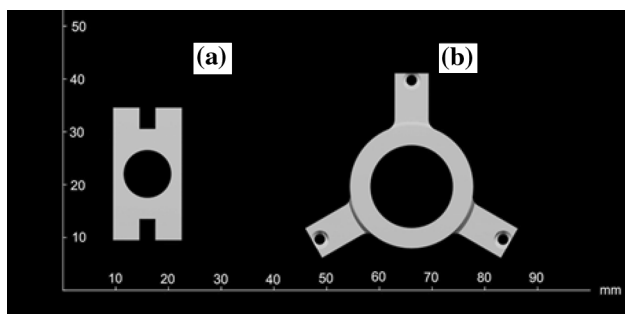


Fig. 1 Example of target frames used to mount the target foils: **a** usual frame for general nuclear structure experiments, **b** frame used mainly in lifetime measurements with the plunger technique

This vacuum deposition system is also used to produce targets by reduction-distillation method.

The system features a stainless steel cylindrical chamber (45 cm diameter and 53 cm high), placed on the top lid together with the rotary heater and the substrate (see Fig. 2B: a). The heater of the system is specially configured to reach a maximum temperature of 700 °C. The chamber includes a frontal 4-inch viewport that is placed in an ISO-KF DN100 flange. The chamber has a motorized hoist to raise and lower the top lid and the vacuum chamber.

Vacuum components are mounted on an “open architecture” chassis and the power supply and the control modules are placed on an independent cabinet. The setup is equipped with a high-vacuum system capable of pumping down the chamber to a pressure level below $3.5E-5$ Torr in <1 h.

The system has also one resistive evaporation kit (Fig. 2B: b) with a 3.6 kW power supply (6 V and 600 A)

for evaporation of materials with melting points not higher than 1,800 °C.

For making targets of high melting point materials (up to 3,800 °C) and dielectrics, the system is equipped with an electron-gun and a 4-pocket \times 2 cc volume rotary water-cooled copper crucible which allows sequential evaporation of up to 4 materials (Fig. 2B: c). The electron-gun has a 270° deflection angle, 5 kV acceleration voltage and 600 mA maximum current. The system is equipped with a XY sweep controller.

The equipment contains a 2.5 cm diameter water-cooled magnetron-sputtering source (Fig. 2d), mounted in the base plate of the chamber. The magnetron source is powered with a 300 W RF power supply and a 13.54 MHz plasma generator with manual matching network.

The system has an Inficon SQM160 Thin Film Deposition Monitor (Fig. 2B: e) for monitoring the thickness of the deposited material and the rate of deposition.

The second system is a *Quorum Technologies E6700 Bench Top Evaporator*, as shown in Fig. 3, equipped with power supplies for both carbon and metal evaporation. It includes sputtering, glow discharge, low angle shadowing, and film thickness monitoring. The work chamber with a diameter of 30 cm can be evacuated to less than 10^{-5} mbar. In standard operation we apply up to 10 V at 200 A for carbon coating and 20 V at 100 A for metal evaporation.

In addition, the target laboratory is equipped with an *electrically controlled Durston type DRM 100 rolling mill* with variable speed (Fig. 4). The rolls have a size of 100 \times 50 mm and are made of specially selected roll steel, heat-treated on the main working surface.

Auxiliary equipment is also used to provide support for the numerous other activities required for target

Fig. 2 **A** TE18-High Vacuum Deposition System produced by Intercovamex Company; **B** interior of the deposition chamber, showing: **a** rotating substrate holder; **b** thermal evaporation; **c** electron-beam evaporation system; **d** sputtering deposition system; **e** quartz crystal monitor; **f** shutter



Fig. 3 **a** Quorum technologies E6700 bench top evaporator; **b** vacuum chamber

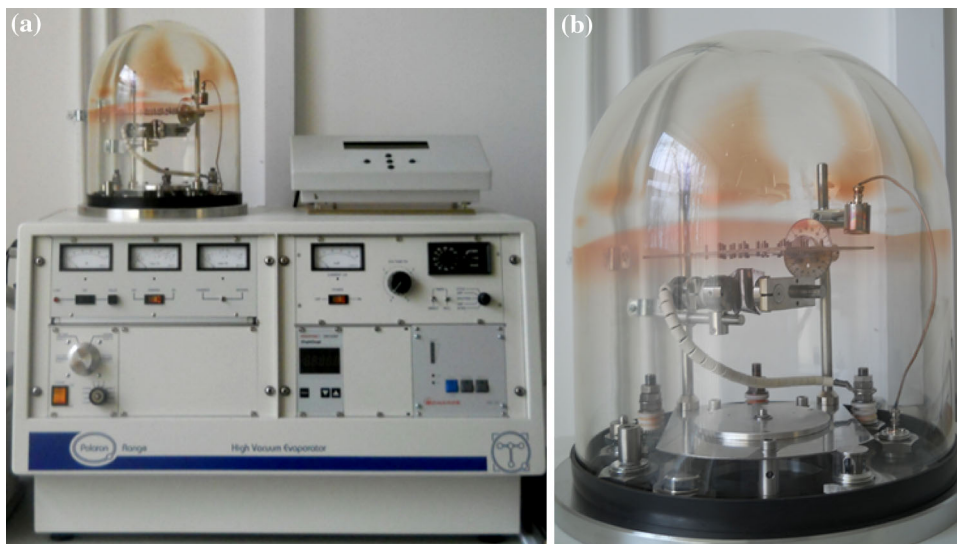


Fig. 4 Durston type DRM 100 rolling mill

fabrication. Most targets produced in the laboratory are characterized, with regard to their thickness, by α transmission using an α source containing a mixture of ^{241}Am and ^{244}Cm . The energy spectra of the transmitted α -particles through the studied foils are measured with a totally depleted silicon detector [13]. Obtained thicknesses are also checked and usually found consistent with the ones determined by weighing and dividing by surface area. For this purpose the laboratory is currently equipped with a dual range *analytical balance* (Mettler Toledo XS205) which allows to weight samples at different resolutions. A *tube furnace*, which can be operated at temperatures up to 1300 °C, is used for chemical processing of isotopic material. To prepare pellets from powder isotopic material used further for vacuum evaporation or reduction, a 5 t *hydraulic press* is used in conjunction with hardened steel

dies. An inert-gas *glove box* (Labconco) is available for handling of targets that may oxidize quickly. Targets are generally stored in *vacuum desiccators* containing desiccant, usually silica gel, which keeps the contents clean and free from moisture.

Produced targets

Based on the capabilities of the target laboratory, several enriched isotopic targets were produced during the last 2 years (Table 1). Thin-films were obtained according to different procedures described in INTDS literature [14–36].

An example of a more special target preparation is described in the following.

Preparation of sandwiched ^{40}Ca target

For lifetime measurements by the recoil distance Doppler shift (RDDS) method (plunger method) it is necessary to obtain very smooth targets without points or wrinkles when stretched. In this case ^{40}Ca (0.3 mg/cm^2) targets gold backings (4.5 mg/cm^2) were required, as depicted in Fig. 5 [17, 32, 33].

The ^{40}Ca target was prepared through a reduction-distillation method starting from CaCO_3 powder and with Zr metal powder as reducing agent. In order to produce metallic ^{40}Ca , about double the stoichiometric amount of high purity Zr metal powder was thoroughly grinded together with the required amount of CaCO_3 , in an agate mortar set. Obtained mixture was pressed into a pellet, which was then broken to smaller pieces and inserted into a

Table 1 Targets produced in the IFIN-HH target laboratory (2013–2014)

Target	Thickness (mg/cm ²)	Substrate	Thickness (mg/cm ²)
Resistively heated targets produced (on various substrates)			
⁸² Se	5	Ta	5
Reduction—distillation (on various substrates)			
⁴⁰ Ca ^a	0.3	Au	4.5
¹⁴⁰ Ce ^a	0.3	Au	3
¹²³ Sb ^a	0.5	Au	3
¹⁴⁹ Sm	1.3	Au	5
Target	Thickness (mg/cm ²)		
Rolling (self-supporting)			
¹¹⁰ Pd ^a	0.8		
¹⁰⁸ Pd	0.4		
¹³⁹ La	2.4		
^{114,118} Sn	4/4.5		
Au	2.5/10		
Ta	2.5/10		

^a Targets for lifetime measurements by the recoil distance Doppler shift method (plunger)

pinhole tantalum-boat. Both ends of the boat were pressed flat and fixed to the high current electrodes of the evaporation device (TE18).

A 4.5 mg/cm² gold foil prepared by rolling was glued to the plunger target frame, as depicted in Fig. 1b) and stretched over a cone. This gold backing was placed 4.5 cm above the tantalum-boat in the evaporator. It is crucial to get the appropriate distance between the source and the substrate, as this mainly determines the final thickness of the target.

After achieving a vacuum of 3.5×10^{-5} Torr at first a low current was applied through the tantalum-boat to assist the degassing of CO₂ which is released at ~ 850 °C. The current through the tantalum-boat was maintained at this

level until stabilization of the vacuum. Then, the current was slightly increased until the reduction temperature of 1,350 °C was reached. The evaporation process was carried out until the desired thickness was obtained, measured with the quartz deposition monitor, previously calibrated during tests with natural material.

Obtained ⁴⁰Ca layer was covered with a thin gold layer of 0.1 mg/cm² without breaking the vacuum, to protect the metallic ⁴⁰Ca against oxidation. This deposition was made with a tungsten basket, fixed at 9 cm distance above the substrate. In order to achieve good uniformity of the obtained layers, the substrate was rotated during all evaporation processes.

Sandwiched ⁴⁰Ca target was used to measure the lifetimes of several excited states in ⁴⁴Ti using the RDDS technique with the Bucharest plunger device coupled to the γ -spectroscopy array comprising HPGe and LaBr₃(Ce) detectors [37]. The target was kept in beam for 7 days, to cover a sufficient range of lifetimes and statistics in order to calculate lifetimes with high precision.

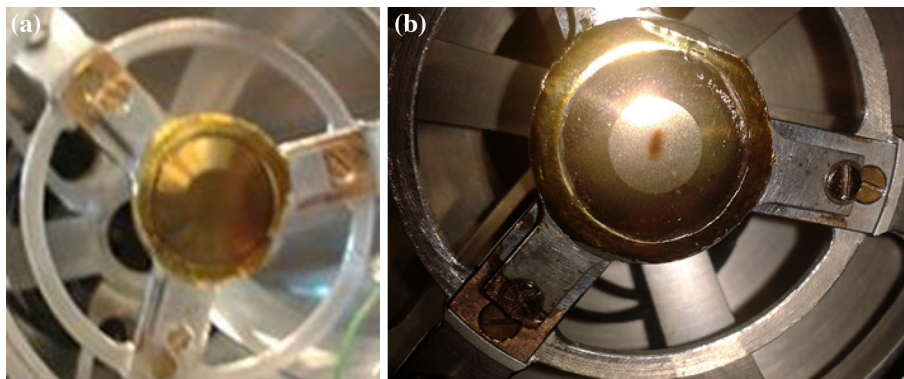
After the whole 7-days experiment the target did not suffer any surface modification.

Conclusions and perspectives

Targets for nuclear physics experiments performed at IFIN-HH laboratories are prepared in a dedicated target laboratory. The films are produced by thermal evaporation, electron-beam evaporation, sputtering and cold rolling. At present, it is possible to prepare layers with thicknesses ranging from several tens of $\mu\text{g}/\text{cm}^2$ to several hundreds of mg/cm². The targets prepared during 2013–2014 (Table 1), from a wide range of chemical elements and compounds, had characteristics that perfectly answered the requirements of the experiments.

To meet the demands of the experiments even better, the Target Preparation Laboratory will develop new target preparation recipes taking into account the different

Fig. 5 Sandwiched ⁴⁰Ca target: Au (4.5 mg/cm²)/⁴⁰Ca (0.3 mg/cm²)/Au (0.1 mg/cm²): **a** before experiment; **b** after experiment



physical and/or chemical properties of the raw materials. Additional characterization methods (e.g. PIXE, PIGE, RBS, AFM, and SEM-EDX) will be employed to determine the features of the obtained targets. To increase the yield of the reduction-distillation processes, a water-cooled substrate set-up will be installed inside the vacuum chamber of the TE18-High Vacuum Deposition System. Plans are in progress to further develop a target storage facilities that will then allow storage of the most reactive targets under high vacuum or controlled inert atmosphere. A more powerful electrical double-sided rolling mill will also be purchased.

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