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The Target Preparation Laboratory at Daresbury

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Abstract

The Target Preparation Laboratory at Daresbury Laboratory is described. This laboratory provides targets for the UK Nuclear Physics community whose experimental programme is performed in several laboratories worldwide. Details are given of its present capabilities and range of targets produced.

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1. Introduction

The Target Preparation Laboratory (TPL) was developed to support the Nuclear Structure Facility (NSF) at Daresbury Laboratory in the making of thin-film targets and foils of enriched isotopes for nuclear physics experiments. Following the closure of the NSF in 1993 the TPL became part of the new Nuclear Physics Group based at Daresbury Laboratory. The TPL now provides targets and foils for the UK nuclear physicists who are engaged in experiments around the world. The TPL provides a range of targets of elements throughout the periodic table and is the only facility available in the UK.

Target preparation is often crucial to the success of nuclear physics experiments and it is therefore of the utmost importance that the target conforms to what is required regarding purity, composition, thickness, etc. The TPL has a range of equipment and materials available for general use and is equipped to carry out many of the techniques associated with the production of targets and foils. The main items of processing equipment currently in the TPL are as described in Section 2.

The physicist requests target foils from the TPL by specifying certain characteristics namely, the isotopic material, the thickness, uniformity and target frame type. The frame type determines the surface area of target foil required; a typical target frame is shown in Fig. 1.

2. TPL equipment for target preparation

2.1. Vacuum-deposition sources

The TPL has three general-purpose vacuum coaters. One of the units is used exclusively for carrying out the reduction of certain isotopic materials while the other two are used for vacuum deposition for the production of targets via general thermal evaporation applying resistance-heating methods. Each has a base plate with 15 vacuum feedthroughs which can be configured as required, for example using electrical connections, water cooling, thermo couple and thickness monitor above a 100 mm diffusive pump, a 300-mm-diameter glass bell jar and a 0.9 kW built-in power unit for resistance heating.

2.2. Electron-beam guns

Electron-beam guns are widely used in vacuum evaporation processes, when contamination from thermal sources is a problem or where high temperatures and evaporation rates are required. The TPL has a 5 kW, 270° electron-beam gun with a 3 kW power supply and 8 cm^3 hearth,

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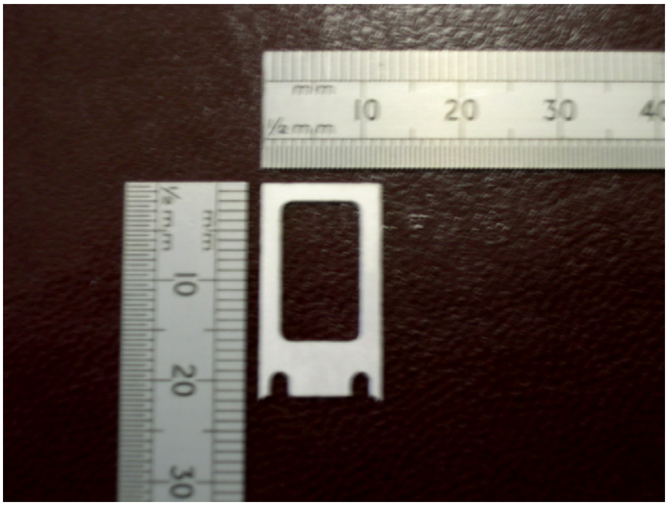

Fig. 1. Example of target frame used to mount target foils.

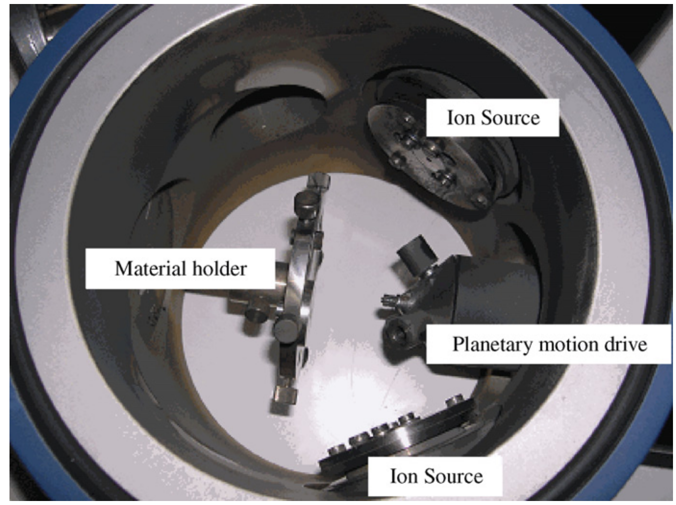

Fig. 3. Ultra-fine grain dual-ion source.

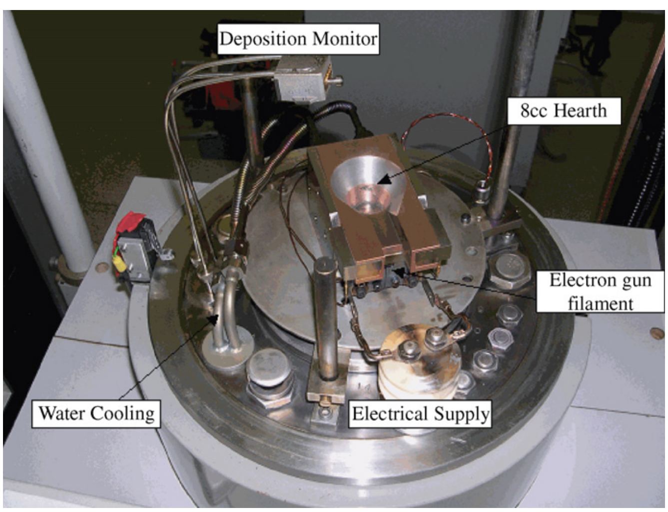

Fig. 2. Electron-beam gun.

fitted into a coating rig. The basic elements of an electron-beam gun are shown in Fig. 2.

2.3. Sputter sources

In sputter deposition [1], material is removed as atoms or molecules from a target by energetic ion bombardment and deposited as an atomic layer on a substrate. They provide an efficient mechanism for depositing certain materials, which, due to their vapour pressure, are difficult to evaporate by conventional methods. There are several sputtering devices available on the commercial market but most of these have inadequate beam focusing. Good beam focussing is necessary due to the small amount of target material normally used. The sputtering system used in the laboratory is an ultra-fine grain dual-ion source unit (Fig. 3), which produces a focussed beam of 3.5 mm positive argon ions at a working distance of 25 mm, giving a beam current density of 1200 $\mu A/cm^2$/source. Each unit produces beam energies in the range 1.6–8.5 keV. They can hold up to six target materials and have planetary motion drives to hold the substrates.

2.4. Rolling equipment

A set of powered rollers is used for preparing relatively thick targets and foils. This is an extremely efficient method of production in terms of usage of material. The electric rolling mill, consisting of two hardened and polished rollers of 124 mm face width by 60 mm diameter is driven by DC motor.

2.5. Balances

The specific thickness of a target is of crucial importance in many experiments and one of the most reliable methods of determining this is by weighing [2] and dividing by surface area. This is the only method available in the TPL at the present time for characterising a target's specific thickness or for calibrating other equipment used for this purpose. The laboratory is currently equipped with two microbalances for general use in the processing of nuclear targets, each of which covers a specific weighing range. The first unit has a maximum weight of 5 g, with an accuracy of 1 μg and the second unit has a maximum weight of 30 g, with an accuracy of 0.1 mg.

2.6. Fume cupboards

The TPL has four fume cupboards that conform to UK control of substances hazardous to health (COSHH) safety regulations and are used for general target preparation and chemical handling.

2.7. Furnaces

There are currently two furnaces in general use. A tube furnace, which can operate at temperatures up to 1300 °C, is used for chemical processing of isotopic material or for chemical conversions involving the use of gases. An additional small vacuum furnace is used for more specialised work.

2.8. Hydraulic press

A 0–25 t hydraulic press is used in conjunction with hardened steel dies to prepare pellets from isotopic material to assist processing in areas such as vacuum evaporation, reduction and sputtering.

2.9. Thickness monitors

These devices are extremely useful in monitoring not only the thickness of the material deposited but also the rate of deposition, which is an important factor in terms of success or failure when it comes to producing self-supporting targets. The TPL has one oscillating quartz crystal device suitable for monitoring deposition. This is currently assembled as part of the electron-beam gun coating system and is able to control the electron-gun power in relation to rate of deposition and to turn off the gun once the required thickness is reached.

2.10. Target storage

Targets are generally stored in one of several dry boxes. These are sealed boxes containing a desiccant, usually silica gel, which keeps the contents clean and free from moisture. The more reactive targets are stored under vacuum or in an inert atmosphere. The vacuum storage unit is capable of storing up to 600 targets at a pressure of 2.0×10^{-2} bar using a scroll pump to stop oil contamination.

3. Examples of targets produced

The targets produced in the last three years in the TPL by various techniques are listed in Table 1.

Table 1
Targets produced in the TPL

Element	Target thickness (mg/cm^2)
Thermal evaporation	
Si	0.1
Bi	0.5
Au	0.1
Pb	8
^{24}Mg	0.3
^{208}Pb	0.5
^{144}Sm	0.5
^{106}Cd	0.4
^{207}Pb	0.5
^{58}Ni	0.5
Ca	0.3
Si	1
^{144}Sm	0.5
Au	1
Au	2
^{207}Pb	0.5
^{40}Ca	0.3
^{24}Mg	0.5
^{82}Se	0.5
^{82}Se	1
^{109}Ag	0.75
^{109}Ag	1
Rolling	
Ni	1.5
^{96}Zr	1.5
^{92}Mo	0.5
^{100}Mo	0.5
^{105}Pd	0.5
Ti	1
Ta	0.45
Ta	1
^{106}Cd	1
^{58}Ni	1
^{58}Ni	0.75
Al	2
^{120}Sn	2
^{124}Sn	1.5
^{100}Mo	10
^{98}Mo	10
Sputtering	
^{112}Sn	0.4

4. Performance and quality control

The quality and performance of the targets and films produced are monitored by using feedback forms, which are given to the physicist requesting and using the targets. The physicist is asked to comment on the thickness, uniformity, purity and in-beam performance.

When performing a reduction or working with a difficult target material, a sample or test piece is sometimes taken to the National Centre for Electron Spectroscopy and Surface Analysis (NCESS) [3] at Daresbury Laboratory where the technique of high resolution X-ray photo-electron spectroscopy is used to determine the elemental composition of the surface layers of the target. This information is particularly useful when a new target is being developed.

5. Future developments

Several improvements are planned at the Daresbury TPL. There is a plan to develop the electrical-deposition method to produce target foils by electrolysis. This technique involves passing an electrical current through an electrolyte solution to cause a chemical change or decomposition and depositing the resultant material on a cathode.

Plans are in progress to further develop the sputtering process, to produce a wider range of targets.

The TPL is setting up a target thickness and uniformity system using a collimated alpha source and Si detector to measure the thickness and also uniformity of target [4].

Further information on the TPL is available from the TPL website [5].

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