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Target preparation method and characterisation

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ABSTRACT

The activities in the target preparation laboratory (TPL) at Daresbury Laboratory, including the range of targets and the techniques used over the last two years are reported. The new and upgraded equipment used in the laboratory and how it is applied to monitor and improve the quality of the targets are described.

1. Alpha particle measurement system

The standard method for measuring the thickness of a target foil is to divide its mass by the measured surface area. A second method is required that can additionally check the uniformity of the foil [1]. This can be achieved by looking at the change in energy of energetic charged particles from a source as they pass through a target foil.

The following set-up was constructed in the TPL, which is shown schematically in Fig. 1. A 3 kBq unsealed mixed alpha source containing Pu^{239}, Am^{241} and Cm^{244} was deposited onto a stainless steel disc over a 7 mm active area. This was mounted in a small vacuum chamber onto a holder that which had interchangeable covers to allow the source to be used also for collimated measurements. The vacuum chamber was pumped by a diaphragm pump down to a pressure 2×10^{-1} Torr. A foil holder followed by a silicon surface barrier detector was mounted above the alpha source. The detector was connected to a charge sensitive pre-amplifier which is attached to a power supply and a high voltage power supply. A shaping amplifier is connected to the computer with an Analog to Digital Convert (ADC) card and the spectrum from the alpha source is displayed on the monitor enabling the particle energy to be measured [2] (Fig. 2).

With this system we are able to perform general target foil thickness measurements as well as collimated measurements.

To test the system and prove that it was working correctly, a natural nickel foil was purchased commercially with the following data: thickness 0.0002 cm ± 10%, 2.5 cm × 2.5 cm linear dimensions +2%/−1%. The measured mass of the foil was 0.0105 g. This gave a calculated foil thickness of 0.00168 g/cm^2. The thickness of the foil was then checked by using the alpha particle measurement system. Without the foil present, the vacuum chamber was pumped down to a vacuum of 2.0×10^{-1} Torr. Then the high voltage power supply was turned on and 30 V applied to the detector. Using the software to start the acquired sequence, a spectrum was produced on the screen. The software tools then allowed the selection of the peaks and input of the energy of the alpha particle. This information was saved to calibrate the system. The detector was then turned off and the system vented.

After this the Ni foil was placed on the foil holder above the alpha source and the same procedure was carried out. However, this time the software tools were used to measure the energy of the peaks produced so that the energy loss could be calculated.

From Table 1, the average energy loss was 796.33 keV. Using the Srim2008 software [3], the energy loss in a Ni foil of 0.00019 cm was calculated to be 790 keV. As a check, the mass is calculated with the theoretical density of Ni=8.895 g/cm^3 and the volume of the Ni foil of $(2.5\times2.5\times0.00019)$ 0.00119 cm^3 to 0.01058 g, which is in good agreement with the measured mass of the foil (Tables 2 and 3).

To produce collimated measurements using this system, a 10 mm thick mask with a 1 mm hole is placed on the alpha source. This greatly reduces the efficiency of the system; as the surface area of the alpha source is reduced, the number of counts is reduced; hence greatly increases the time taken to collect sufficient counts to make a measurement.

The alpha particle measurement system has been used to measure the thickness of CH_2 target foils and investigate their uniformity. This has helped to refine the manufacturing technique [4] and improve the quality of the targets.

2. Production of CH_2 target foils

To produce CH_2 target foils a defined amount of CH_2 powder was mixed with xylene and then the solution was heated until the CH_2 dissolves into the solution. A glass substrate was prepared by cleaning using propan-2-ol and then coating it with a release agent. Afterwards the CH_2 xylene solution was applied to the substrate and the xylene was allowed to evaporate, thus leaving

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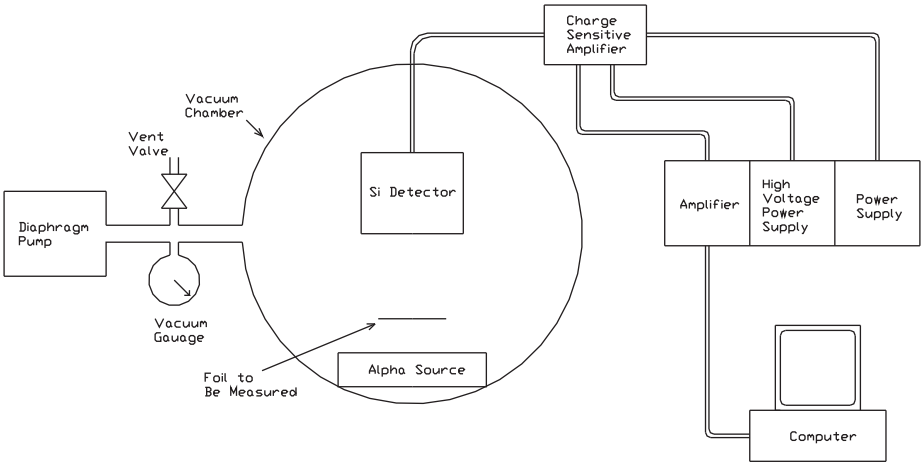

Fig. 1. Diagram of alpha source measurement system.

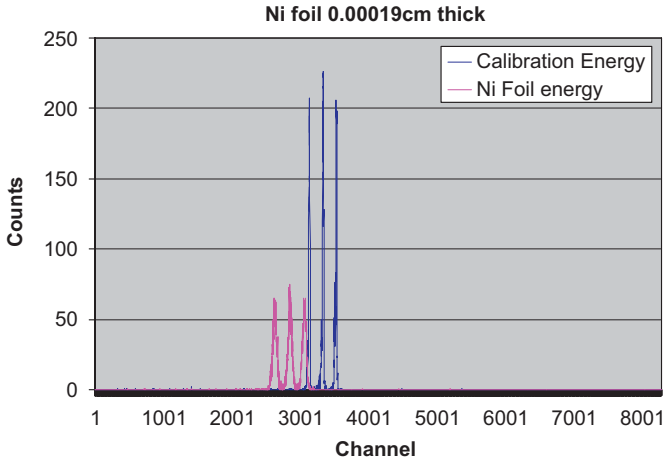

Fig. 2. Alpha particle energy spectrum after traversing the Ni foil.

Table 1
Measured alpha particle energy loss in a Ni foil of 0.0002 cm nominal thickness.

Alpha source	Energy (keV)	Energy (keV) Ni foil	Energy loss (keV)
Pu^{239}	5155	4348	807
Am^{241}	5486	4684	802
Cm^{244}	5805	5025	780

Table 2
Results of thickness measurements on CH_2 foils from room temperature to 150 °C to produce foils of thickness 150 μg/cm^2.

Sample temperature (°C)	Thickness at point 1 μg/cm^2	Thickness at point 2 μg/cm^2	Thickness at point 3 μg/cm^2	Thickness at point 4 μg/cm^2	Range compared with 150 μg/cm^2
Room temperature	165	130	170	120	+20, −30
50	130	145	145	165	+15, −20
100	135	160	155	150	+10, −15
150	140	100	125	165	+15, −50

the CH_2 foil on the substrate. Measuring these foils with the alpha particle system showed how non-uniform the foils were, typically ±2 on 100 μg/cm^2. As a result, it was decided to investigate techniques to improve the quality of the target foils.

The part of the manufacturing method that was decided to be investigated was the formation of the foil on the glass substrate.

Table 3
Results of thickness measurements on CH_2 foils from 100 °C to 150°C to produce foils of thickness 150 μg/cm^2.

Sample temperature (°C)	Thickness at point 1 μg/cm^2	Thickness at point 2 μg/cm^2	Thickness at point 3 μg/cm^2	Thickness at point 4 μg/cm^2	Range compared with 150 μg/cm^2
100	130	155	160	135	+10, −20
110	165	140	145	165	+15, −10
120	140	145	155	150	+5, −10
130	140	155	140	165	+15, −10
140	170	130	155	165	+20, −20
150	180	160	170	140	+30, −10

The factors affecting the formation of the foil on the glass substrate are the cleaning technique, the release agent, its application to the substrate and the temperature of the substrate.

Since the cleaning process and the application of release agents are standard procedures the dependence of the foil homogeneity on the temperature of the substrate was investigated at first. Initially tests at four different temperatures—at room temperature, at 50 °C, at 100 °C and at 150 °C were set up where the substrates were all cleaned the same way and the same release agent was applied to each one. A solution of xylene and CH_2 to produce foils of 150 μg/cm^2 was then applied to the each substrate. At 150 °C a sign of bubbling could be observed as the xylene evaporated off, which is also reflected in the uniformity results below. The foils were then removed and measured using the alpha particle system with the collimated source to make four individual point measurements on each foil to determine the uniformity.

The results show an improvement in the uniformity up to 150 °C. So, a second set of tests was set up in the temperature range from 100 to 150 °C using the same set-up and method as before.

The results show that the uniformity of the target thickness can be improved by heating the substrate. The optimum temperature was found to be 120 °C and this is now implemented in the method of producing CH_2 target foils. It will also be tested for the production of CD_2 foils, for which the same method is used.

References

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