A simple method to prepare deuterated targets for experiments relevant to nuclear astrophysics

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Abstract

In this work, a simple and efficient thin (50 − 250 \( \mu g/cm^2 \)) deuterated polyethylene target preparation method is described. The method of easy removal of thin targets from casting surface without using any cryogenic freezing has been described. The difference in thermal expansion properties is used to separate films from glass slides. An idea about the amount of \( CD_2 \) material needed to prepare films with different thickness is also provided. \( 3\alpha \) radioactive source is used to measure the target thickness. The material property of the prepared targets is verified by Attenuated total reflection (ATR) method.

Keywords: Deuterated polyethylene, inverse kinematics, deuteron induced reaction, Attenuated total reflection (ATR)

1. Introduction

In low energy nuclear physics and astrophysics the study of deuteron induced reactions viz (d,p), (d,n), (d,t), (d,\( \alpha \)), (d, \( 3\text{He} \)) are important. Particularly the (d,p) and (d,n) reactions are useful to study neutron and proton transfer reactions in the framework of the ANC method and proton pickup reaction in the Trojan Horse method to study astrophysical reactions. All these reactions would require deuteron beams for relevant measurements. However many laboratories do not have accelerators that can deliver deuteron beams. Also in some reactions one of the reaction partners is radioactive and the target cannot be made out of it. In such situations, a deuteron target is essential and useful.

In the last 50 years, people are preparing these targets in the laboratory using various methods \[1\]- \[9\]. The solvent casting method has been mostly used. Recently Febbrarao. et. al. \[6\] has studied the preparation method of these targets in some details. Cryogenic freezing technique has been adopted by them for removal of very thin (\(< 100 \mu g/cm^2\)) deuterium films from the casting surface as otherwise removal is shown to be very difficult. In the present work, we described a more simplified and elegant method for the removal of thin deuteron film from the casting surface. As releasing agent sodium chloride was avoided as has been

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used by Arnison et al. \[4\] in order to prevent non-uniformity in the prepared foil. Besides, deuterated polyethylene (commonly known as \(CD_2\)) which is used for the preparation of the foil is a very expensive material and so the present work discusses the estimation of the amount of material required for a desired thickness.

2. Preparation Method

The deuteron target was prepared from deuterated polyethylene \((CD_2)\) which as per manufacturer is obtained from the deuteration of polybutadiene, rich in 1,4 addition. The solvent casting method was used for the preparation of the target. \(CD_2\) (melting point 125°C) is soluble in few organic solvents whose boiling point is more viz. xylene \((\sim 140^\circ C)\), Cyclooctane \((\sim 150^\circ C)\), Glycerol \((\sim 290^\circ C)\) etc. If glycerol is used, extra precaution should be taken as its boiling temperature is much more than \(CD_2\) and overheating of polyethylene can result in gel formation.

2.1. Preparation of the solution

The solvent used for the preparation of a solution of \(CD_2\) is p-xylene. Any other isomer such as o- or m-xylene or a mixture of all can be used. About 5 ml of p-xylene is used as a solvent which is sufficient to cover 4-5 micro slides (each having dimension 3" × 1"). In order to ensure minimal wastage of material during this preparation no contaminated by chemical or dust particles. The preparation was therefore undertaken in a cleanroom under a controlled environment. Ambient room temperature should be under control as xylene is flammable above 25°C. The boiling of the solution was undertaken inside an enclosure with an exhaust as xylene vapour may cause health hazards \[7\]. For heating the solution, a beaker with as small volume as possible was chosen to avoid wastage of material from sticking of the material to the glass surface. The amount of \(CD_2\) taken is 55 mg with 5 ml xylene for an estimated target thickness \(\sim 50\mu g/cm^2\). The heating was carried out using a double boiler arrangement, as described in \[6\] and shown in Figure 1. The maintenance of the temperature of the xylene in the upper beaker is very crucial. The boiling of the xylene in the lower beaker generates xylene vapours which in turn heats the xylene in the upper beaker at constant temperature (at boiling point). The upper beaker is covered with an aluminium foil so that the xylene vapour does not escape and the complete xylene was heated to dissolve the \(CD_2\) in the above beaker. The solution was heated for almost an hour until the solution in the upper beaker is clear in appearance. An extra 10-15 minutes heating was continued after the solution looks clear, in order to be sure that there is no residual material in the upper beaker. The xylene in the lower beaker should also not be exhausted before heating is stopped and complete dissolution of \(CD_2\) has taken place. About 40 ml of xylene in the lower beaker was sufficient for the purpose.

2.2. Casting on glass slides

The upper beaker is removed from the hot plate after the complete dissolution of \(CD_2\) in xylene. A clean thin glass rod was used to mix the solution further to ensure a completely
homogeneous mixture. The solution is poured onto four micro-slides placed side by side on a levelled surface. Continuous pouring is very important for the uniformity of the prepared. These steps have been done within a minute to avoid any chance of precipitation of the $CD_2$ material in the solution. Slides are then left for 5-10 minutes in the air to allow evaporation of xylene leaving a thin layer of $CD_2$ material.

2.3. Removal of films

Mechanical removal of films from the casting surface is quite difficult for thinner targets ($50 - 150\mu g/cm^2$). Micro slides are placed on the hot plate($> 140^oC$) for 30-60 seconds. Slightly heated slides are carefully emerged inside a large water beaker at once with the help of a tweezers for 15-20 seconds. Due to different thermal expansion of glass and $CD_2$ material, removal of films from the glass slide will be easier. A sharp tweezers has been used to remove the films mechanically. Removal of films has been done inside water. Targets of thickness range ($50 - 250\mu g/cm^2$) has been done successfully by this method [Figure 2(a) and Figure 2(b)].

3. Analysis of prepared films

Thickness of the prepared targets has been measured using $3-\alpha$ radioactive source and energy loss simulation software SRIM [9]. Target preparation method involves the use of
chemical, heating several times, emerging inside water. A proper analysis of target mate-
rial is essential to ensure no chemical degradation or contamination happened during the
preparation. Attenuated total reflection (ATR) test has been performed at IACS, Kolkata.
Results of ATR indicates conditions of C-H and C-D bonding inside the film material. In
Figure.3 absorbtance variation with wave number has been shown. Each peak represents
different stretching and bending of molecular bonds. $CD_2$ stretching and bending peaks are
dominant over $CH_2$ and the isotopic shift is also very clear.

4. Summary and discussion

A very easy and efficient method has been discussed to prepare thin $CD_2$ targets with
using any cryogenic freezing. Uniformity of prepared targets highly depends on the homo-
genity of the prepared solution and pouring consistency on the sides. Prepared $CD_2$ foils
are little ivory in color, this coloration according to the manufacturer is because of the trace
amount (finger prints) of the Wilkinson catalyst used while preparing the target material.
Film thickness uniformity of the films largely depends on the flatness surface where micro
slides are placed. In the described set up the amount of $CD_2$ material used to prepare
$50\mu g/cm^2$, $150\mu g/cm^2$ and $250\mu g/cm^2$ are $\sim 55$ mg, 80 mg and 100 mg respectively.
Figure 3: ATR result of sample which shows different bonding of elements.

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