Nuclear Instruments and Methods in Physics Research A 381 (1996) 567–568

ELSEVIER

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

Fabrication of thin scintillator foils

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Received 22 April 1996; revised form received 13 June 1996

Abstract

Self-supporting scintillator foils with thicknesses between 10–80 μm can be fabricated reliably using the spin coating technique.

It has been shown that a scintillator foil–CsI phoswich provides an inexpensive and compact detector to identify charged particles from $Z = 1$ up to $Z = 18$ with unit charge resolution [1]. Due to its low cost and ease of use, scintillator foils have been incorporated as the first elements in many modern charged particle arrays [1–5]. Thin scintillator foil backed by photomultiplier tubes only, have also been used successfully to detect fission fragments [6].

As foils with thickness less than 100 μm are quite fragile and not available commercially, they must be manufactured individually. Typically, solutions containing plastic scintillator dissolved in toluene or xylene are used. Very thin foils (<4 μm) can be obtained by evaporating the scintillator solution in vacuum [6] or by solvent dissolution by flotation of the scintillator solution on water [7,8]. Uniform foils with a wide range of thicknesses (2–80 μm) can be produced by spinning the scintillator solution on a rotating plate [1,9]. The thickness of the foils depends on the viscosity of the solution as well as the angular velocity used in spinning.

In the past few years, 4 mg/cm^2 (40 μm) scintillator foils have been fabricated regularly at the National Superconducting Cyclotron Laboratory. They are mainly used in the Miniball/Miniwall array, a 4π low threshold charge particle array used in many intermediate energy heavy ion experiments [1,2]. The procedure used in fabricating these foils is described here. In order to facilitate mass production of foils reliably, we have determined the relationship between the viscosity of the scintillator solution, the speed of the rotating surface and the thickness of the resulting film. Each of the foils produced with the current method typically has an area of 7×7 cm^2. Each foil is highly uniform to within 2% and is self supporting without the need of mylar substrate. Even though most of the foils produced are about 4 mg/cm^2 thick, foils within the range of 1–8 mg/cm^2 with the same quality can be fabricated.

The scintillator foil is spun using a solution of Betapaint, BC-498X plastic scintillator dissolved in xylene. Typically, a 40% by weight solution is purchased from the Bicron Corporation, Newbury, Ohio. This commercially available solution is then diluted with xylene to a solution with the appropriate viscosity, depending on the thickness of the foils desired. To standardize the viscosity measurements, Cannon-Fenske 500 viscometers, calibrated at 40°C, are used in the present work. Fig. 1 shows the relationship between the viscosity (ν) in poise of the BC-498X solution as a function of the concentration of plastic scintillator by percent weight (W). The data points in Fig. 1 can be best fitted by the relationship

$$\nu = 2.72 \times 10^{-8} W^{6.22}. \quad (1)$$

Previous work has shown a relationship between the thickness and the angular speed used in spinning [1].

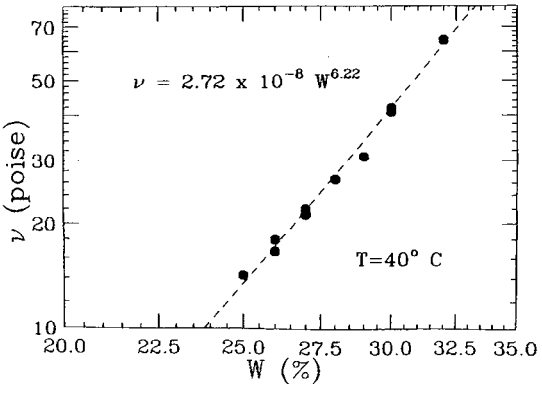

Fig. 1. The viscosity (ν) of the BC-498X solution as a function of the concentration of plastic scintillator by percent weight (W).

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PII S0168-9002(96)00779-6

Unfortunately very few data points were taken, thus a general quantitative relationship between the viscosity, angular speed and thickness could not be obtained. In the present study, we obtained a large number of data points from solutions with viscosities between 10–60 poise. Each solution was spun at various speeds to obtain foils with different thicknesses. Fig. 2 shows the experimental relationship between the thickness of the foil and the spinner angular velocity. For a solution with a fixed viscosity, the experimental relationship between the foil thickness (t) in mg/cm^2 and angular speed (ω) of the spinner in rpm follows the power law [1]

$$t = k(\nu)\omega^{-0.61}\,; \tag{2}$$

$$k(\nu) = \exp(3.49\nu^{0.11})\,. \tag{3}$$

Contrary to Ref. [1], only one exponent of −0.61 for the angular velocity (ω) is needed to fit all the data in Fig. 2. At low viscosity (<10 poise), $k(\nu)$ deviates slightly from Eq. (3). Much lower rotational speeds than that discussed in Ref. [9] are used since lower angular speeds allow better control of the spinning process resulting in more reproducible fabrication of the foils.

Eq. (1) or Fig. 1 can be used reliably to prepare a solution of the desired viscosity. The solution must be thoroughly mixed with a magnetic stirrer, and left undisturbed overnight to remove any bubbles introduced in the mixing process. The viscosity is very sensitive to the exact amount of xylene solution used in diluting the scintillator solution or the amount of xylene lost due to evaporation. It must be measured accurately just prior to spinning. Since spinning is done at room temperature which is not accurately controlled, the constants used in Eqs. (2) and (3) may change slightly. The optimum speed should be determined by spinning a couple foils at various speeds.

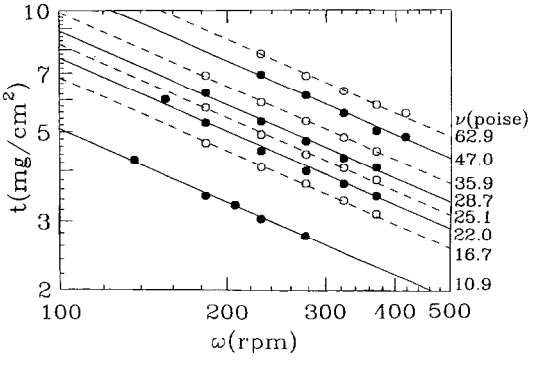

Fig. 2. The experimental relationship between the thickness of the foil and the spinner angular velocity for various values of viscosity.

Approximately 7 cm^3 of the solution is poured onto the center of a 23 cm glass plate which is mounted on a spinner (a horizontal disk attached to an electrical motor drive). To facilitate eventual removal of the foil from the glass plate, the plate must be thoroughly cleaned with ethanol and distilled water before applying a final coating of Teepol 610 which acts as a releasing agent. After spinning the scintillator solution for 4 minutes, the plate is removed from the spinner and stored in a flow of dry nitrogen until completely dry (about 2 days). Once dry, the foil can be peeled from the glass plate.

Uniformity of these foils is determined by scanning each foil in vacuum using 8.78 MeV alpha particles from a collimated ^{228}Th sources. The thickness of the foil can be determined from energy loss of alpha particles [10] as well as by weight. Typically, the thickness of most foils is uniform to better than 2%.

Before large quantities of foils are produced, a foil with thickness greater than 4 mg/cm^2 is made from each bottle of the purchased Beta paint. The quality of the Betapaint is monitored by measuring the light output of the foil using 5.48 MeV alpha particles from a collimated ^{241}Am source which will stop in a 4 mg/cm^2 foil. The light output from these foils typically is 30–40% of the light output of a 23 cm^3 anthracene crystal.

Acknowledgements

This work was supported by the National Science Foundation under Grant No. PHY-92-14992.

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