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Stripper and Target Foil Techniques at GSI Darmstadt*

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Abstract

Techniques of stripper and target foil production used at GSI Darmstadt, West Germany are described, with comments given by Helmut Folger of GSI.

Introduction

Accelerators require charged particles so that electrostatic and magnetic fields will guide and accelerate the particles. The usual procedure in an accelerator system such as the Bevalac or the Unilac is to start with a moderate charge state from a convenient ion source, and when the particle energy is high enough for the process to be efficient, strip the ion to a higher charge state. There may be several steps of acceleration and stripping. Many experiments require specific charge states, or fully stripped ions.

Energetic ions may be stripped by collisions with atoms in a gas or a thin sheet of material called a foil. The usual foil is carbon. Targets are also made as foils, sometimes supported on carbon. The foils considered here range in thickness from 2 to 1000 micrograms per square centimeter.

In response to questions at LBL concerning foil production, we asked about GSI's techniques while there recently. This report describes the foil class given by Helmut Folger at GSI, with comments and answers to questions brought from LBL.

At GSI foils are used for stripping only the heaviest elements, typically lead and up. The usual stripper is 15 mm diameter, for a beam about 5 mm diameter at about 1 microamp. Lighter elements are stripped with a gas cell. Target foils are made in a variety of sizes and shapes.

Foils are made by vacuum deposition of carbon or target element onto a substrate. The substrate must be treated with a release agent before deposition to allow removal of the foil. Usually, a water soluble release agent is used, and the foils are floated off in a water bath as the release agent dissolves.

Deposition

Vacuum deposition is accomplished by evaporating the material to be deposited, and allowing it to condense on a substrate. Carbon may be evaporated by resistance heating, electron beam (EB) heating, a carbon arc, or sputtering. A hydrocarbon gas such as ethylene may be cracked by heat or

radio frequency power to make a deposit. These procedures may be used for many materials. At GSI, the arc is not used because of poor control and spraying of particles. Cracking of gas is not used because this has produced foils with very short life in the accelerator. Resistance heating is used for thin carbon foils, EB heating for thick carbon foils and many target materials, and sputtering for high melting point and expensive target materials.

Resistance heating of a 3 mm dia. carbon rod is used to produce foils up to 50 $\mu\text{gm/sq cm}$. Thicker foils have been made with multiple runs, but with problems of overheating the release agent and delaminating of the layers. With the substrate about 10 cm from the rod, and a starting current of 16 amps, a 40 $\mu\text{gm/sq cm}$ foil takes 30 seconds. 8 substrates 3 by 3 inches are coated in a run, the substrates are not moved during the run. Thickness is controlled by time. The foils will contain about 20% hydrogen.

The EB gun is used for making foils of thickness from about 50 $\mu\text{gm/sq cm}$ to 1000 $\mu\text{gm/sq cm}$. The deposition rate is about 5 $\mu\text{gm/sq cm/sec}$, with a cooldown period required for films thicker than about 300 $\mu\text{gm/sq cm}$. The foil has only about 10% hydrogen, and is not as strong as the resistance heated foil. GSI uses a Veeco evaporator with a Balzers E gun giving up to 12 kV and 500 mA with focus to about 50 KW/sq cm. The substrates are about 25 cm away from the crucible and rotated during deposition. A quartz crystal monitors thickness and deposition rate. The crucible has 4 holes, and may be rotated under vacuum to produce a layered foil. If the material to be evaporated is granular, or non-conducting, the E beam must be scanned. Target foils might start with a mounted 40 or 100 $\mu\text{gm/sq cm}$ carbon foil, and be plated with up to 1000 $\mu\text{gm/sq cm}$ target material, and then a protective layer of carbon, titanium or gold.

A Danfysik argon beam sputter coater is used for high melting point and expensive target materials. GSI modified the argon feed for active control, and changed to a turbo pump to eliminate oil. They recommend this unit with these modifications. The mounted carbon foil is placed very close, about 2 cm away, and not rotated. The thickness is monitored by integrating the current to a Faraday cup. They wonder why LBL has been asking about this unit for years, and doesn't have one yet. Fig. 1,2.

Generally GSI prefers trapped diffusion pumps for coating, because of ease of cleaning and rapid cycling.

Release Agent

GSI uses 1 part betaine ($C_5H_{11}NO_2 \cdot H_2O$ from Merck, article no.1827) and 6 parts sucrose, in a saturated solution. It can get microbes and decompose - it smells when bad - but the solution I used was several months old. The mixture is very pale yellow, and slightly less viscous than baby oil. This release agent imparts a texture to the foil, which reduces cracking and improves life. Other agents are required if a 'mirror like' foil is needed, but then cracking of thick foils during release and very short life are problems.

Making a Foil

We watched and practiced the making of about 40 $\mu\text{gm/sq cm}$ foils. Starting with a cleaned 3 by 3 in. glass plate about 1/8 in. thick, apply release agent to form a puddle about 1 cm diameter. Spread with a folded Kleenex (they use industrial wipes that are like home Kleenex, as opposed to Kim-Wipes). Spread evenly all over, wiping in parallel strokes, and at 90 degrees. With a fresh Kleenex, continue wiping until the film appears dry. The trick is to fold the Kleenex loosely so that about 1 in. width contacts the plate evenly, wipe in parallel strokes, alternate at 90 degrees, and wipe lightly and slowly. Wiping may take about 1 minute. When done properly, the plate looks like finely frosted glass, with only slightly visible streaks. Fingerprints on the glass interfere with adhesion. I could see my finger sharply through the plate when contacting the back of the plate, but only a blur when my finger was about 1 cm away. Fig. 3.

Relative humidity is important. About 50% is ideal. At 40%, the foil will release only slowly, and over 55% the release won't dry. They recommend a thicker release for 40%, and don't know if it works at all if it is drier.

The plate is now ready for coating with carbon. It is put into a holder which protects the back and 3 of the edges - like a card holder. Any film on the back or edges would interfere with the released foils.

For 40 $\mu\text{gm/sq cm}$, we used resistance evaporation. A rod of carbon (Charbons pour Spectrographie, Le Carbone-Lorraine, 37-41, rue Jean-Jaures, 92230 Gennevilliers, France) 3 mm dia. and about 10 cm long is clamped vertically in the coater chamber, and the plates in holders mounted around, vertically in a horizontal circle. 8 plates fit evenly, nearly edge to edge. After pump down, current was run up to about 16 amp, giving a bright white heat. The current fell somewhat during the run, and was shut off after 30 seconds.

After 15 minute cool-down, the chamber was backfilled with dried air, and the plates removed. Fig. 4. The film is scribed with a vernier caliper for the size foils desired.

The plates are released one at a time in a deep dish about 20 cm diameter and 10 cm high. A wire frame holds a plate at about 30 degrees from horizontal in the dish, carbon side up. A flask of pure water, with a stopcock and hose, is mounted on a ringstand behind the dish. Water is let in slowly until it reaches the lowest part of the carbon, and after that very slowly to float the carbon off. Fig. 5. The humidity that day was 42%, dry for them, and so the water was allowed to advance about 1 inch per hour along the plate. Go fast, and the foils tear. The line of release will be below the level of the water, but the carbon is only wet on the bottom. This depression wasn't allowed to exceed about 2 mm. They use a little suction pipe vacuum cleaner to pick up debris and bad foils from the water surface.

The foil frames have been ultrasonically cleaned, and fingerprints should be avoided. A frame is held with tweezers, lowered into the water, and raised in a vertical position under the edge of a floating foil. The trick is to have the foil end up folded over the edge of the frame. The frame is vertical throughout the lifting. The foil is applied to the side of the frame that the punch for the frame hole contacted first - thus the foil is against a rounded hole corner. Surface tension pulled the foil slightly through the hole, so that when it is dry, it is slack. Further slackening has not been needed. The frame is set aside to dry.

After drying, some of the foils must be glued to the frame. They glue all foils over 35 $\mu\text{gm/sq cm}$. The glue is carbon glue, of the type used in electron microscopy, in butyl acetate, and is applied around the edge of the foil with a small brush.

Foil thickness is measured with a spectrophotometer for each foil. They use tungsten light at 800 nm, but point out that carbon has no spectroscopic peaks from 250-800 nm. Absorption is calibrated by weighing, and finally by performance in the accelerator. For production work, a microprocessor is connected to the spectrophotometer, with the absorption vs. thickness curve in ROM, to get a direct readout in $\mu\text{gm/sq cm}$. The finished foils are marked with thickness, sorted, and stored for use.

XBC 850-9568

Fig. 1. Danfysik argon sputtering coater. The substrate holder is loaded with mounted foils, and sits on the round stage visible near the center of the glass vessel. The crucible for the material to be sputtered is barely visible at the center of the stage. The argon beam source is at the top. The glass vessel is about 15 cm in diameter.

XBC 850-9569

Fig. 2. Substrate holder for the sputter coater. The mounted foils are held by the screws, and the sputtered material passes through the holes in the holder to the foils.

XBC 850-9570

Fig. 3. Slides coated with betaine-sucrose release agent. The slide at the left has a fingerprint at the left, and streaks at the top - a reject. The slide at the right is correct. The visibility of the printing on the Kleenex box, which the slides are resting against, shows the texture of the coating.

XBC 850-9566

Fig. 4. Resistance heating carbon coater. The two plates closest to the camera, coated with $40 \mu/\text{sq cm}$ carbon, have been removed to show the (used) carbon rod at the center.

XBC 850-9567

Fig. 5. Releasing foils from the slide. The coated and scribed slide is on a wire frame in the dish. The water level has reached the bottom of the coating. The water filling rate has just been adjusted at the stopcock for the slow release. Visible at top left is a second release station, and a squeeze bottle of release agent. At the lower extreme right is an extra wire frame to hold slides.