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DEVELOPMENT OF THIN FOILS FOR USE IN GENERATING NEUTRAL PARTICLE BEAMS*

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Introduction

Approximately six months ago, the Isotope Research Materials Laboratory (IRML) was requested to prepare large-area, ultrathin aluminum and carbon foils for use in beam neutralization experiments. There were two major parts to this request. The first was to immediately provide a number of 5-cm-diam foils with thicknesses ranging from 5 to 20 $\mu g/cm^2$ for use in experiments at the Fusion Materials Irradiation Test (FMIT) facility and at Argonne National Laboratory (ANL). The second, longer-term request was to develop methods to prepare 25-cm x 25-cm, 10-$\mu g/cm^2$ aluminum neutralizer foils. Both parts of the request have been successfully met.

The IRML is part of the Isotopes Section in the Operations Division at the Oak Ridge National Laboratory. It was established in 1960 to fabricate research material samples primarily from stable and radioactive separated isotopes. These preparations are made on a custom-order basis with products being distributed around the world. During the period since 1960, IRML has prepared samples of most of the isotopes of the elements in the periodic table. Extensive expertise and capabilities in vacuum, metallurgical, and ceramic processing have been developed in IRML as a result of these activities. The IRML's broad experience in thin-film fabrication, gained primarily through the preparation of accelerator targets, resulted in this group being requested to fabricate large-area, ultrathin aluminum foils for use in hydrogen-beam neutralization.

Foil Fabrication Methods

Typical physical vapor deposition processes used by IRML in preparing thin films have included ion-beam and plasma sputtering, electron-bombardment evaporation, vaporization using radio frequency (rf) induction heating, and evaporation by resistance heating. Carbon foils are produced by IRML using arc sublimation, electron beam, and resistance heating with a limited amount of work having been performed on cracking methane in an argon/methane rf-induced plasma. After examining the immediate needs for 5-cm foils and, later, 25-cm x 25-cm foils along with the relative advantages and

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disadvantages of each thin-film method, resistance flash evaporation of aluminum foils from a ring filament was selected as the most promising method for current and future preparations.

Foils are prepared by first coating a clean glass substrate of the appropriate size with a water-soluble parting agent. Several parting agents, including soap, NaCl, CsI, and Betaine-sucrose, are available for the preparation of self-supported foils. The last, a solution of Betaine and sucrose in distilled water, was selected for our use since a wide range of surface texturing is possible with this parting agent. Droplets of the parting-agent solution are applied to the glass substrate and rubbed to achieve the desired distribution, thickness, and texturing. It has been found that as the desired foil thickness changes, the preparation of the parting agent must be adjusted. The substrate is then loaded into a 32-in. x 32-in. x 32-in. metal vacuum chamber evacuated by a 10-in. oil diffusion pump. Accurately weighed strips of aluminum foil are wrapped around an 8- to 10-in.-diam, multistrand tungsten wire circular vapor source. After the system has been pumped down to the 10^{-6}-torr pressure range, the filament is heated resistively, and the aluminum is flashed off in a matter of seconds.

The coated substrate is then removed from the vacuum system and placed on an incline in a large water-filled tank. As the water level is raised, the parting agent dissolves, and the foil floats on the surface of the distilled water. After complete separation of foil from the substrate, it is guided to the frame/grid assembly submerged vertically in the water. As the water is removed from the tank, the foil drapes onto the frame/grid assembly and is allowed to dry. The foil is then packaged and made ready for shipment to the customer.

Current Status of Development

A large number of aluminum foils and fewer carbon foils were prepared for Los Alamos National Laboratory and used at FMIT and ANL. Neutralization efficiencies of foils of various thicknesses have ranged from 37% to 56% in tests at ANL. Examinations of these foils have shown little or no detectable damage from the experiments. A frame design that permits tensioning of the grid over a 25-cm x 25-cm open area was developed, and many foils, typically 8 to 12 $\mu g/cm^2$, have been prepared and mounted on these frames.

Progress has been made on quantitative thickness and uniformity measurements on these thin films, which was a problem in early preparations. Though the combined use of microbalance-weighing techniques, quartz crystal thickness monitoring, alpha attenuation counting of self-supported foil samples, transmission electron microscopy, scanning electron microscopy, light transmission (densitometer), and actual accelerator data, reliable thickness and uniformity determinations are now thought to be possible. The IRML is currently preparing foils from 5 cm x 5 cm to 25 cm x 25 cm of various thicknesses for a number of organizations investigating foil neutralizers.

Future Needs

Several areas of foil preparation development have been identified separate from the needs that have been identified by other organizations concerned with foil/grid/frame property determinations. A more thorough characterization of foil thickness uniformity and structure is needed to define these neutralizers and correlate their performance. Scale-up of methods and equipment to prepare 1-m foils appears very feasible, but will require some development and engineering work. Finally, cursory efforts were just begun on the preparation of integral, vapor-deposited grids to eliminate the need for the separate nickel grid.