Introduction

Foil strippers of carbon are commonly employed in electrostatic accelerators for electron stripping of ion beams. Carbon foils have the advantage of being stable in vacuum at high temperatures, in combination with good electrical and thermal conductivity. Carbon has the further advantage of being the material with the lowest Z that can be fabricated into a very thin foil to minimize multiple scattering and energy straggling of the transmitted ions. In many energy ranges, lower-Z materials also can lead to higher average charge states compared with higher-Z materials [1]. However, the significant disadvantage of foil strippers is their limited lifetime due to irradiation effects, for example the thickening and shrinkage observed in carbon foils (see for example [2] and references therein. These effects both deteriorate the stripper quality, especially under heavy-ion beams, and lead eventually to the rupture of the stripper foil, with the lifetime being strongly dependent on ion mass, energy, beam density, and the vacuum environment in the terminal as well.

Preparation of Carbon Stripper Foils

Carbon Stripper Requirements

A good stripper foil should have a constant and satisfactory ion yield during the experiment. In more detail, carbon stripper foil requirements can be summarized as follows:

1. optimum thickness from the point of view of ion yield and transmission through the acceleration tube,
2. long irradiation lifetime,
3. high mechanical strength,
4. amenability to mass fabrication.

It is clear that these requirements are all related somehow to the foil thickness and preparation technique. As reported in [3, 4], the optimum thickness of a carbon stripper foil for maximal transmission at a terminal voltage of 5–10 MV is about 10 µg/cm² for light ions (Z ≤ 6), several µg/cm² for
medium-heavy ions, and less than $2\,\mu\text{g/cm}^2$ for heavy ions ($Z > 16$). However, standard commercial foils with a thickness of several $\mu\text{g/cm}^2$ may appear impractical for terminal stripping, since they typically break in minutes when irradiated with heavy ($Z \geq 16$) ions [1,5] under normal accelerator conditions. A significant improvement in the foil stripper quality can be achieved by (a) slackening foils, and (b) preparing them by the proper technique for the optimum structure. If successful, a combination of the two methods can produce more than one order of magnitude increase in the lifetime compared with standard foils. A brief description of various preparation methods is given below for carbon strippers in the thickness range of $2$–$10\,\mu\text{g/cm}^2$, together with some comparative data.

**Procedure**

The majority of preparation methods for carbon stripper foils are based on deposition of the material onto a glass slide, coated with a water-soluble parting agent. The resultant film is floated off the slide and mounted on a suitable frame. The thickness of the foils (areal density) is usually measured by a light transmission method at suitable wavelengths [6]. A variety of parting agents are known from the literature [7, 8]. The parting agent may influence not only the yield of usable foils but also their stripping efficiency and lifetime [9]. Most target laboratories use detergent-like parting agents, for example Teepol 610, RBS 25 Creme-Cotec, or potassium oleate ($\text{C}_{18}\text{H}_{33}\text{O}_2\text{K}$). Another large group of commonly used parting agents is the halides [9], in most cases chlorides. These have the advantage of being much more thermally stable than organic parting agents. The third group of parting agents in use are sugars, for example betaine-sucrose [10]. An important advantage of betaine-sucrose is that carbon foils produced on such a parting agent are very flexible and have a very high mechanical strength. This is due to the highly corrugated structure of the foil, which obviously replicates the significant surface roughness of the parting agent. A drawback of betaine-sucrose as a parting agent is that the covering process must be done in a humidity of near 40% to keep the proper crystallite structure of the layer [11]. Also, the nonhomogeneity of the stripper foil caused by this parting agent should not be neglected for certain experiments requiring high energy and time resolution. Free-standing carbon stripper foils of $2$–$5\,\mu\text{g/cm}^2$ are usually reinforced, prior to picking up in a suitable frame, by means of collodion (cellulose nitrate) or formvar films. The plastic coatings will evaporate in a short time when exposed to the beam.

**Evaporation–Condensation Methods**

The thermal evaporation of carbon in vacuum is carried out by three different techniques: (i) resistance heating of carbon filaments, (ii) arc evaporation,