CARBON FOILS AS HEAVY ION STRIPPERS*

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Thin carbon foils are useful as strippers in the terminal of a tandem electrostatic accelerator. In the case of heavy ions, the energy of the beam emerging from the accelerator is substantially higher for foil stripping than for gas stripping. In addition, for heavy ions foil stripping will avoid some of the operational difficulties which can be expected from the use of gas strippers.

There are some distinct disadvantages if one uses foil strippers. The minimum usable foil thickness is about 3 $\mu g/cm^2$, which is considerably in excess of the thickness needed to achieve charge state equilibrium. This excessive thickness contributes an increase in multiple scattering and energy straggling which results in a deterioration of the beam quality. For the usual experiments in nuclear spectroscopy this is not a serious drawback, but if the tandem is to be used as a multiply charged ion source for an energy booster it may well be an important consideration. The deterioration of the beam quality increases with time because the foil thickness tends to increase with time during bombardment. The most serious limitation is the foil lifetime when used for heavy ions ($A \geq 32$). If one wishes to have a high beam intensity through the tandem, which is especially necessary for a tandem used as injector in a post accelerator, the lifetimes for thin carbon foils at tandem terminal energies are very short.

A summary of approximate lifetime for a number of heavy ions at various energies is shown in Fig. 1. In order to plot the lifetimes observed experimentally for various heavy ions at a number of energies on the figure, we have assumed that the foil lifetime is inversely proportional to the particle density incident on the target. In the case of an oscillating target we have taken the dimension of the beam spot rather than the dimension of the area swept by the beam. The ordinate, therefore, is given in particle μa min/mm^2. In order to accomodate the variety of particles and energies, we have assumed that the ion velocity is the relevant parameter and therefore used units of MeV/A. The points for non-heated stationary foils are fairly well accomodated by a straight line. It is uncertain to what extent the lifetime is a function of foil thickness. At low ion velocities the foils usually had a nominal thickness from 2 to 10 μg/cm^2, while in the 1 MeV/A region the foil thickness was of the order of 25 μg/cm^2. It is, of course, possible that the apparent increase in lifetime is also associated with the increase in foil thickness.

The carbon foils tend to increase in thickness in the area exposed to the beam and also show a marked increase in non-uniformity. In part, this increase in thickness can be ascribed to the cracking of hydrocarbons on the foil surface. It is probable that there are also beam-induced effects which contribute to the foil thickening. The low energy A point was obtained by Ferguson at Harwell in the exceptionally good vacuum of about 10^{-9} Torr with a negligible amount of residual hydrocarbon vapor pressure. The foil thickening effect can also be controlled to some extent by target oscillation.

A substantial increase in the lifetime of carbon foils exposed to a 4 MeV Ni^+ beam was obtained by radiative heating of the foil to a temperature of approximately 500°C. The increase in observed lifetime was about a factor of 40. If the heating was coupled with a slow motion of the foil, which increased the effective area of the foil by a factor of 6, the lifetime was more than 200 times longer than that of an unheated foil. The experimental point corresponding to the latter experiments is shown on the top of Fig. 1.

The possibility of increasing the lifetime of carbon foils by annealing at 1000°C prior to use and then use them without heating in situ has also been investigated. There was no substantial difference between annealed and non-annealed foils.

Electrostatic effects can have a very destructive influence on the foils. During bombardment there is a significant current flow through the foil. Since the foil is rather thin this current flow results in a high current density in the foil itself. The current and temperature gradients in the foil can result in rupture of the foil near the edges of the foil holder. If insulators with surface charges are in the vicinity of the foil, the foil can be blown off the frame almost instantaneously.

In some of our experiments we have evaporated a very thin layer of Au on the foil. This increased the foil lifetime by about 50%.

On the other hand, similar experiments at Chalk River with thin layers of Al resulted in a substantial decrease in foil lifetime. The most likely solution to the foil lifetime and thickening problem is to use a thin oscillating stripper foil heated radiatively to about 500°C in the tandem terminal.

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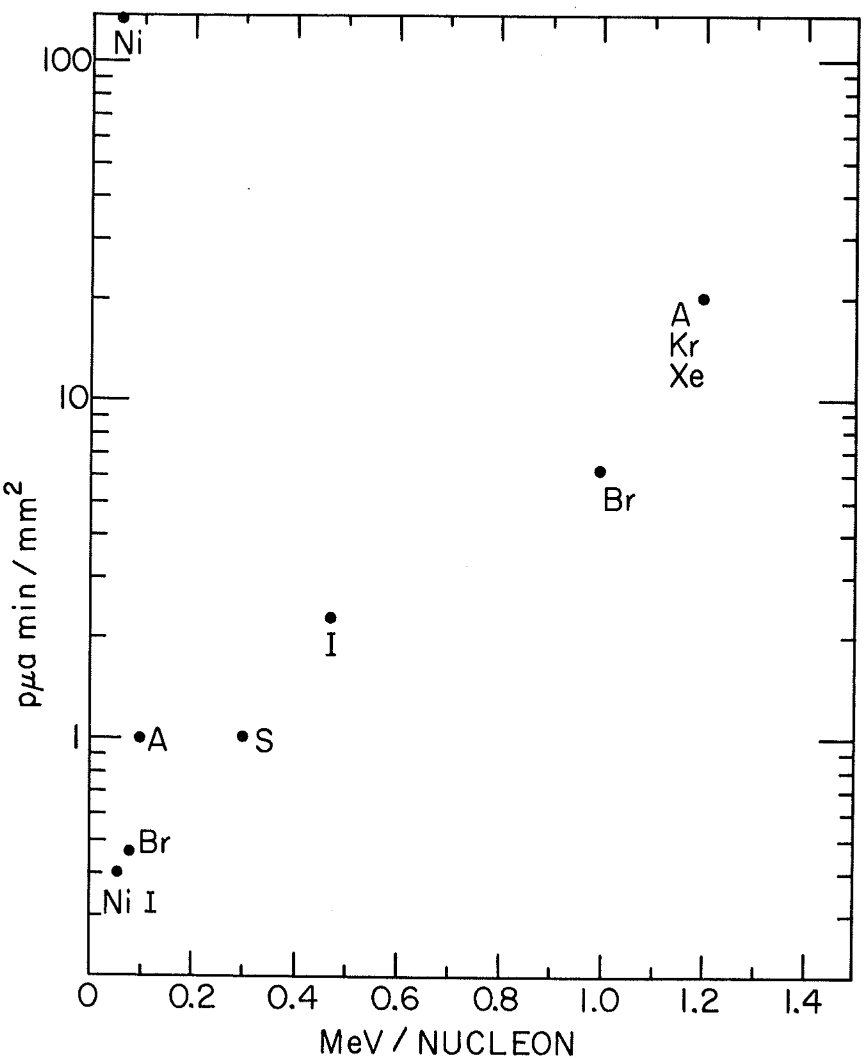
Ni
100
10
1
pμa min / mm²
A
S
Br
Ni I
I
Br
A
Kr
Xe
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
MeV / NUCLEON

Figure 1