Proceedings of the 9th International Conference on Cyclotrons and their Applications
September 1981, Caen, France

NEW MEASUREMENTS ABOUT CARBON FOIL BEHAVIOUR UNDER HEAVY ION BOMBARDMENT

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Abstract. - Carbon stripping foils produced at Strasbourg have been tested with 0.39 MeV/A iodine ions accelerated by the Strasbourg MP tandem. The foils were prepared by carbon arc evaporation or glow discharge cracking on various substrates and their surface was either flat or slackened. The goal was to estimate the 20 μg-cm^{-2} foil lifetime at the lowest GANIL energy at the stripper. The results are presented and an attempt is made to extrapolate to the GANIL conditions.

I. Introduction. - Although a gas stripper could be adequate for GANIL for light ions only, its stripper is designed to operate with foils in all cases. The GANIL beam characteristics are different according to the ion mass :
- the energy at the stripper ranges from 0.5 to 8 MeV/A for light ions and from 0.5 to 1 MeV/A for heavy ions.
- the intensity on the stripper may vary from 2.10^{13} p.p.s. for C ions to 2.10^{11} for U ions.
The design of the beam transport system between the two separated sector cyclotrons is such that the beam cross-section on the foil will be of the order of 1cm^2. Since these conditions are different from those at the terminal of tandem accelerators, where the foil behaviour has been extensively studied in the recent years our goal was to check if the conclusions reported by different tandem laboratories could be extended to the GANIL case.

2. Experiment. - In the experiments reported here, 20 μg-cm^{-2} carbon foils were bombarded by a 0.39 MeV/A iodine beam issued from the Strasbourg M.P. Tandem ; this energy is slightly lower than the lowest GANIL energy at the stripper.

In a series of previous experiments [1]), both the foil behaviour and the transmitted beam could be observed ; a magnetic spectrometer allowed to measure the angular straggling and the energy spread connected to the foil thickness variations. Only flat, arc evaporation carbon foils were used ; typical results gave a 2 h average lifetime for 20 μg-cm^{-2} foils bombarded by a 0.5 MeV/A, 4.10^{11} p.p.s. iodine beam with a 1.3 mm^2 cross-section.

For the present experiments, only a Faraday cup connected to a current integrator was used to measure the transmitted intensity, but the foil behaviour could be observed both visually and through a T.V. camera. We tested foils prepared by arc evaporation or by glow discharge cracking in ethylene [2]) ; the foils were either flat or slackened (16 different foils). The characteristics of the 0.39 MeV/A iodine beam were 3.10^{11} to 2.10^{12} p.p.s. over a 1 to 2 mm^2 area, and the test consisted in determining the number of microcoulombs to rupture the foil inside the beam spot.

3. Results. The diagram illustrates the results ; it is divided into two graphs because, in the course of the experiment, a re-tuning of the optical elements of the accelerator had to be done, which might have slightly affected the size of the beam on the target. Solid bars refer to slackened foils, dotted bars represent unslackened foils ; in each case, the production process is indicated, followed sometimes by the substrate and release agent used. All foils were 20 μg-cm^{-2} thick with a single exception clearly indicated on the figure (5μg-cm^{-2}).
From these results , we can draw the following conclusions :
a) when unslackened, the foil lifetime appears to be independant of the preparation process : as compared to the carbon-arc discharge method, the cracking of hydrocarbons does not seem to bring any improvement. This is quite in contradiction with many other results obtained for 3-10 μg-cm^{-2} foils at lower energies : for example , J.L. Gallant et al [3]) report a lifetime improvement factor of 3 when glow discharge foils are used (10.5 MeV iodine ions), while N.R.S. Tait [4]) mentions a factor of the order of 12 (1.2 MeV argon ions).
b) slackening of the foils, independant of the carbon film production process, brings approximately a 5-fold improvement factor, which is of the same order of magnitude as J.L. Gallant's results in his comparisons between flat and slackened cracked foils (factor 3.7). However, mention should be made of the poor behaviour of the two cracked foils deposited on a composite NaCl + Betaïn F substrate.
c) a few 5 μg-cm^{-2} foils were also irradiated (only one example is shown on the diagram) and exhibited a much shorter lifetime than the corresponding 20 μg-cm^{-2} foils, some of them lasting only a few seconds. Less attention was paid to these thicknesses which will not be used at GANIL.
d) an average lifetime of the slackened foils can be given for this experiment : when exposed to a 8.10^{11} p.p.s., 0,4 MeV/A iodine beam of 1 to 2 mm^2 cross-section, the foils become inefficient for stripping after 4 hours.

The observation of the foils during and after irradiation shows that rupture can be initiated either inside or outside the beam spot, independant of the preparation of the foil.

4. Conclusions for the GANIL stripper. - As for the use of carbon foils for GANIL, it appears that the slackening process would improve the lifetime by a non negligible factor for low-energy, medium mass ions.

A reasonable value of 10^{11} iodine ions is to be expected on the GANIL stripper foil (8 times less than in the present experiment) at 0,5 MeV/A ; if the beam spot size is 1 cm^2 (at least 50 times more than in our tests) and under the assumption that the lifetime is inversely proportional to the current density, the GANIL foil will last for several hundred hours.

Trying to extrapolate to the case of 2.10^{11} p.p.s. uranium ions traversing 1 cm^2 of the foil at 0.5 MeV/A the lifetime (admitedly inversely proportional to the squared atomic number) would be about 3 times shorter than in the iodine case, which still amounts to more than 100 hours.

A final remark must be made concerning our definition of the lifetime : if the stripping process is still efficient until the foil ruptures at the location of the beam impact, it is not obvious that the modifications of the beam characteristics (angular spread and energy straggling) brought by the foil in the course of its life are independant of the preparation process. Therefore, and this will be our final conclusion, if we are now convinced that slackening of the foils will improve the lifetime, it is not yet clear that arc discharge and cracked foils are equivalent in this respect.

Aknowledgements.-
It is a pleasure for the authors to thank Mrs. A.Méens for the preparation of the carbon foils.

References.

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