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STRIPPER FOILS LIFETIME MEASUREMENTS

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ABSTRACT

In the most recent batch of stripper foils installed in the high voltage terminal (≤ 8MV) of the Pelletron accelerator, about half were produced in Japan by the high power AC/DC carbon arc method (I. Sugai) . An on line test of these foils using low energy heavy ion beams is in course and a very good performance , even with ^{35}Cl beams, has been observed.

1. INTRODUCTION

Over the years many different methods to produce carbon stripper foil have been developed [1-4]. It is known that stripper foils produced by laser ablation [3] and by the high power AC/DC carbon arc method [4] are long lived and suitable for use in higher energy tandem accelerators. More recently, diamond-like carbon (DLC) foils were produced and have been used successfully [5] .

Some strippers produced in the target laboratory of the 8UD Pelletron accelerator showed reasonable lifetimes when using low atomic number (A≤ 18) ion beams, but very poor performance with ^{35}Cl beam. The performance of the AC/DC carbon arc stripper foils in the 8UD Pelletron accelerator ion beams will be discussed, particularly for the ^{35}Cl ions in comparison with the low power home made foils.

This paper is organized as follows: In section 2 we present a summary of the method developed in Japan, including one of us (I.S.), using a high power AC/DC carbon arc [4,7]. In section 3 some low power methods used in the 8UD Pelletron accelerator are shown. In section 4 a discussion of the beam exposure is presented. In section 5 the lifetime comparison among different stripper foils is shown. Finally the conclusions are presented in the section 6.

2. THE AC/DC HIGH POWER CARBON ARC METHOD DEVELOPED IN JAPAN

Sugai et al [4] and Takeuchi et al [2] developed new methods using a carbon arc to obtain evaporated carbon stripper foils. They observed the different aspects of the cathode and the anode after evaporation: The cathode surface is rough and the anode is smooth in a direct comparison. A systematic study of this observation was reported including fotomicrography where clearly the grain size of the particles produced in the cathode had a diameter of about 0.5 μm, whereas those emitted by the anode had ~0.03μm diameter.

Sugai et al [4] made a detailed lifetime measurement as a function of a parameter denominated R=Wc/(Wc+Wa), where Wc is the weight loss of the cathode and Wa the weight loss of the anode. Longer lifetimes are observed when R has a value between 39% and 91%. The longer lifetime of these foils were attributed to the mixed superposition of grains. It is thought that this mixing provides a flexible structure that relaxes the mechanical tensions and the shrinkage observed in the beam spot. The reproducibility of the appropriate experimental conditions to obtain the parameter R within the above mentioned range proved to be difficult, but there was a suspicion that an AC arc would provide small particles similar to those emitted by the anode in the DC arc.

A method to produce long lived stripper foils of a hybrid type using AC and DC arc discharge with high electric power was developed [7]. The DC arc was provided by an arc maintained constant at 20 V and 105 A during 3 to 5 seconds, to avoid undesirable cathode overheating. The AC arc was maintained at 20V 75A. Their lifetimes were measured in a 1 to 5μA $^{20}Ne^{+}$ ion beam of 3.2 MeV energy. The foils were left in the beam until break up. The mean lifetime measured through the total accumulated beam charge was longer, 28mC, compared to 2 mC lifetime of the commercially available foils.

3. SOME METHODS USED IN THE PELLETRON ACCELERATOR LABORATORY.

The hydrocarbon cracking method was installed in the target laboratory of the Pelletron accelerator [6] to try to reproduce the performance described in the literature [1]. Isobutane and argon used in gas filled detectors was mixed in various partial pressures and submitted to high voltage to produce the hydrocarbon cracking. Some strippers were obtained, but the reproducibility was seriously affected by the quality of the commercially available gas within the country. This method was abandoned.

Carbon arc was also used. Tests were made with pure carbon rods (3mm and 6 mm diameter) maintaining the discharge at ~20 V and 30 A by using a DC power supply. No water cooling for the electrode supports was available

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thus many successive evaporations were necessary so as to avoid overheating of the whole system [10].
The slackening of foils was obtained in the same manner as in München [8] , that is , by applying a partial vacuum to a wet and recently fished stripper foil . The stripper foil lifetime was twice that without slackening, however, the transmission became worse. Any small defect caused the rupture of the foil during the slackening process.
The careful selection of the fished and dried stripper foils has proved to be a good procedure. Such a selection was accomplished by looking for pin holes and residues or imperfections deposited on the foils. In the past, the stripper foils were examined over their entire surface using a microscope, so that all spoiled strippers were refused.
In 1990 an Univex 450 Leybold evaporation unit with a cryopump was installed in the laboratory [9]. An 6kV ESV6 electron beam afforded the evaporation of materials with high melting points. We had suspected that stripper foils obtained in this evaporation unit could have a longer life time. Foils of 5 to 8 $\mu g/cm^2$ and foils with thicknesses about 10 $\mu g/cm^2$ were carefully produced by excluding all stripper foils with either pin holes or other imperfections. The emission current is of the order of 60mA and the high voltage 8.5kV.
Carbon films of about 5 to 10 $\mu g/cm^2$ have been produced in the old low power Edwards E12E3 evaporation unit. Trials with different release agents and heating of substrate showed some progress. The best result was obtained with the detailed choice of foils. Nevertheless, none these home-made foils were acceptable for use with ^{35}Cl beams.

4. LIFETIME MEASUREMENTS AND ENERGY LOSSES.

It is seen in the literature [11] that lifetime tests are usually done in low energy accelerators by submitting the stripper foils to a high current heavy ion beam until they fail. The bombarding time and the beam current define the charge. In our laboratory, lifetime measurements are done using the data logged by the accelerator users during their beam time.
The lifetime may be proportional to the total amount of energy lost in the foil, but the radiation damage [12] and heat dissipation are also important parameters. Therefore, ion beam transmission through the accelerating tube and high voltage terminal vacuum may be important data to be observed during operation. It is plausible that there are differences between a long period low current total charge lifetime and short period high current lifetime with the same total charge. Different ion beams even with approximate total energy loss may result in different lifetimes.

5. COMPARISON OF LIFETIME USING STRIPPER FOILS OBTAINED BY DIFFERENT PRODUCTION METHODS.

All lifetimes presented in this section were obtained using the ion beam intensities and the stripper total usage time logged by the accelerator users. A relative performance comparison could therefore be done. In the experiments the ion beams were used as shown in figure1, during the last 5 years.
As the high power carbon arc foils showed much better performance, it was decided to spare these foils to be used with Cl beams. Only a few carbon arc foils were used with Li, B, C, O, F and Si ion beams, but a comparison with the home made strippers can be seen in fig. 2. These home made foils were obtained only in the low power Edwards unit and were very carefully chosen. The comparison for stripper foils lifetimes used in Cl beam can be seen in fig 3.
Lifetime data of home made low power stripper foils since 2000 were used. The home made films thicknesses are usually measured optically [10] and those made by arc are weighed in a precision Mettler UM3 microbalance [7].

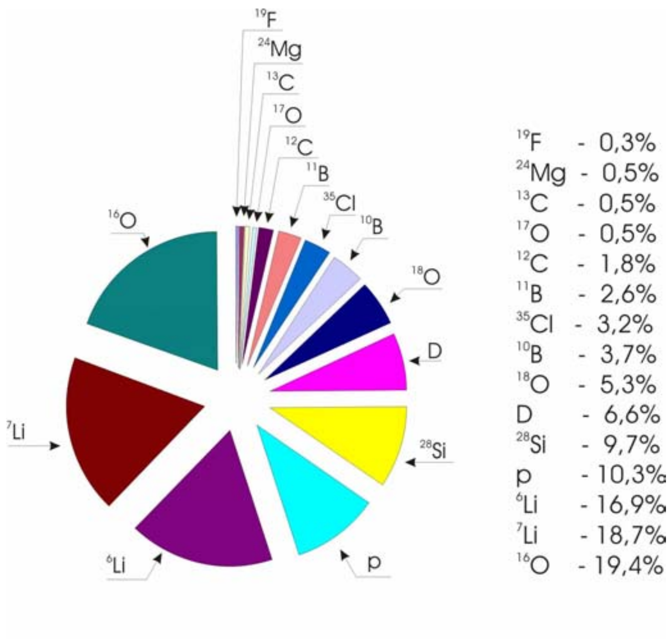

Figure 1 - Ion beam use in the last 5 years.

The ion beam transmission is obtained by the ratio of the beam currents measured after and before the beam reaches the stripper foil. The mean positive charge state of an ion beam after it passes through the stripper foil depends on the high voltage applied to the terminal .On the other hand, the focusing of the ion beam depends on its mass. Therefore, the total charge measured in the transmission measurement depends on the ion mass and mean charge state. The particle transmission in the Pelletron accelerator is of the order of 50% for oxygen ions and 90% for protons for 8MV on the terminal.
Figure 4 shows the measured beam transmission as a function of the lifetimes for ^{16}O and ^{18}O beams of 6 to 8 MeV. Stripper foils made in Edwards and Univex evaporation units are shown. The strippers from Japan were not included here for they have been used with different ion beams because of their long total lives. As expected, home made thin films yielded good transmission but shorter

lifetimes. The high power Japanese thin foils (5μg/cm^2) presented nearly the same transmittance but comparatively larger lifetimes.

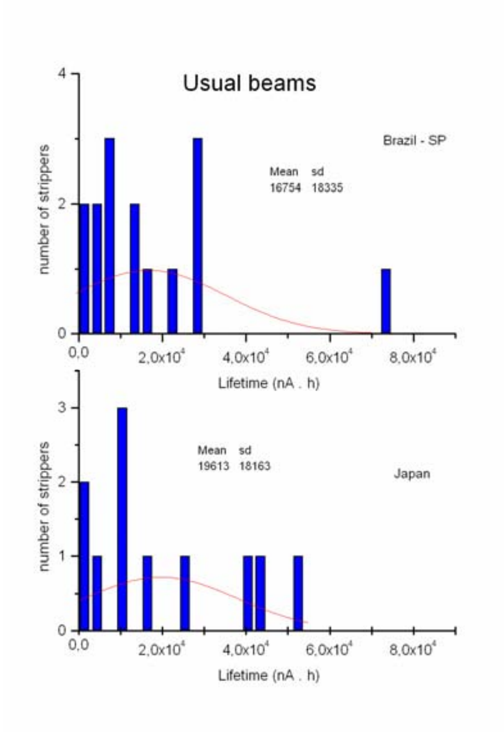

Figure 2 - Lifetime comparison of home made strippers with japanese AC/DC carbon arc strippers foils, used with Li to Si ion beams.

In figure 5 performance comparison of home made strippers and Japanese strippers for the Cl ^{35} beam is shown. Similar results are obtained with the ^{28}Si ion beam.

In these cases the high power foils proved to be more efficient than low power strippers, since they presented both better transmittance and lifetime.

6. CONCLUSIONS

The home made Edwards stripper foils, properly floated and carefully selected, showed long lives when used under low atomic number ion beam bombardment, e.g. H, ^{6,7}Li, ^{12}C, ^{14}N and ^{16} O. The high standard deviation value means that there are foils with both very long lifetimes and very short ones.

The stripper foils produced in the Leybold evaporation unit with thicknesses from 8 to 10 μg/cm^2 gave more reproducible results, even for the Cl beams, than the thinner films. Moreover, these foils are mechanically stronger than those made in the low power Edwards evaporation unit, in general.

The test with the high power AC/DC hybrid stripper foils show a longer mean life time (factor of ~2) with a relatively smaller standard error as compared to the other stripper foils as shown in the comparison above . The small standard deviation reflects the improved reproducibility and more uniform performance of these foils.

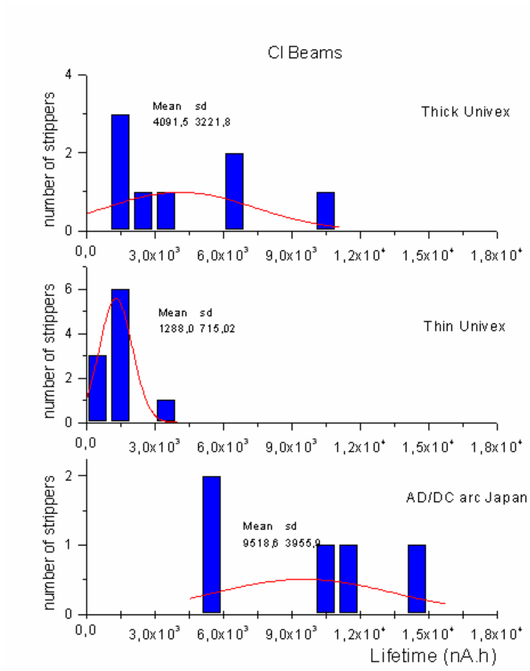

Figure 3 - Lifetime comparison among home made strippers evaporated using the Univex unit thick foils (~11μg/cm^2) , thin foils (6.7 to 8 μg/cm^2) and Japanese AC/DC carbon arc foils (5 μg/cm^2) under Cl beam bombardment.

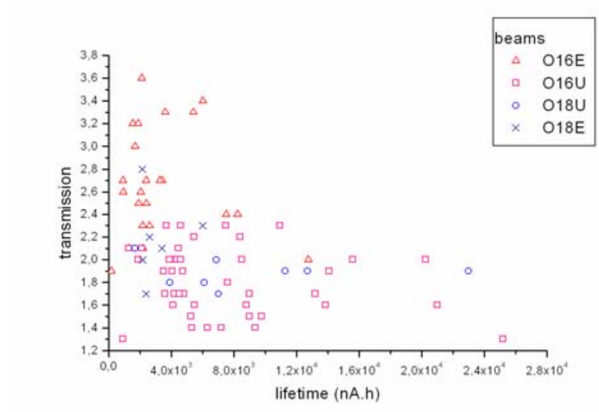

Figure 4 - The relation between ion beam transmission and lifetime for the home made strippers evaporated in the Edwards and in the Univex units under ^{16}O and ^{18}O bombardments.

It is remarkable that the high power AC/DC hybrid type stripper foils of 5 μg/cm^2 are more reliable for use in the 8UD Pelletron accelerator with heavy ion beams such as Cl. It has been pointed out that foils produced by heavy ion sputtering and by laser plasma ablation are long lived stripper foils [11]. It should be interesting to test them also.

We are planning to install a high power AC/DC carbon arc device in the target laboratory of the Pelletron accelerator.

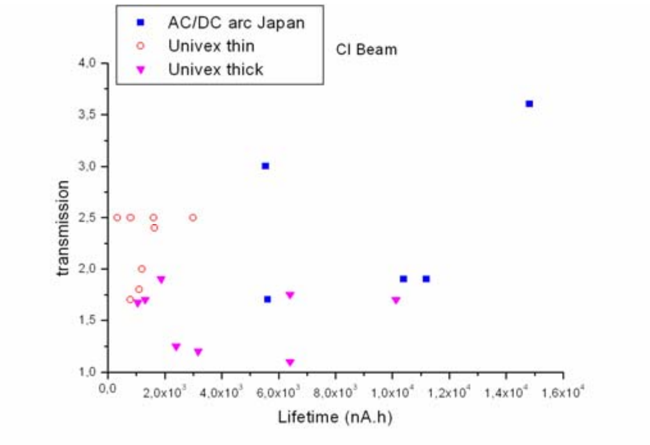

Figure 5 - Transmission against lifetime plotted for the strippers used under ^{35}Cl beam irradiation. Thin and thick home made Univex foils compared to the AC/DC carbon arc high power foils.

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