Development of Long-Lived Carbon Stripper Foils

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Abstract

Long-lived carbon foils have been developed for the RIKEN RI beam factory project. The lives of C-foils produced by a new method were 40 times longer than the foils produced by a conventional method.

1 INTRODUCTION

Carbon foils (C-foils) are extensively used as charge strippers for heavy-ion beams. However, the C-foils have serious disadvantage of short life with a high-intensity heavy-ion beam. The C-foil lifetime is very short in the RIKEN RI beam factory (RIBF). Therefore, the production of long-lived C-foils is urgently required for the RIBF project. Large progress has been made in developing long-lived C-foil production techniques [e.g.1]. We are planning to produce a self-sufficient number of long-lived C-foils according to the techniques presented in Ref. [1].

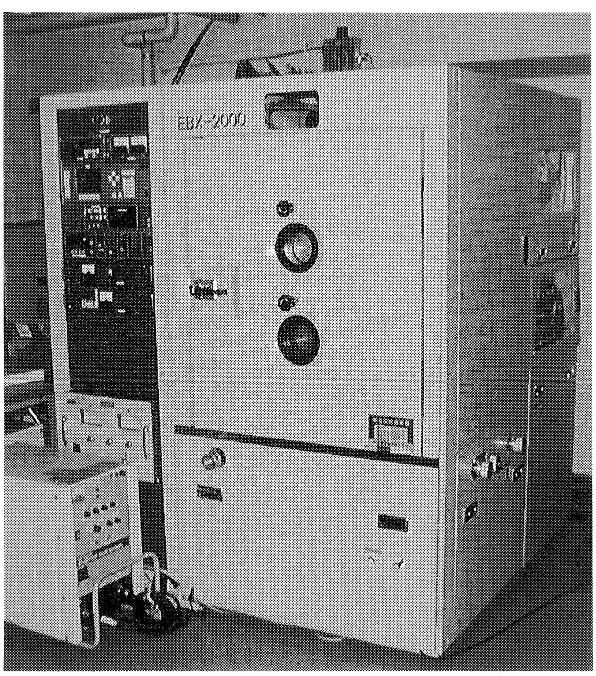

Fig. 1: High vacuum evaporation system (EBX-2000C by ULVAC).

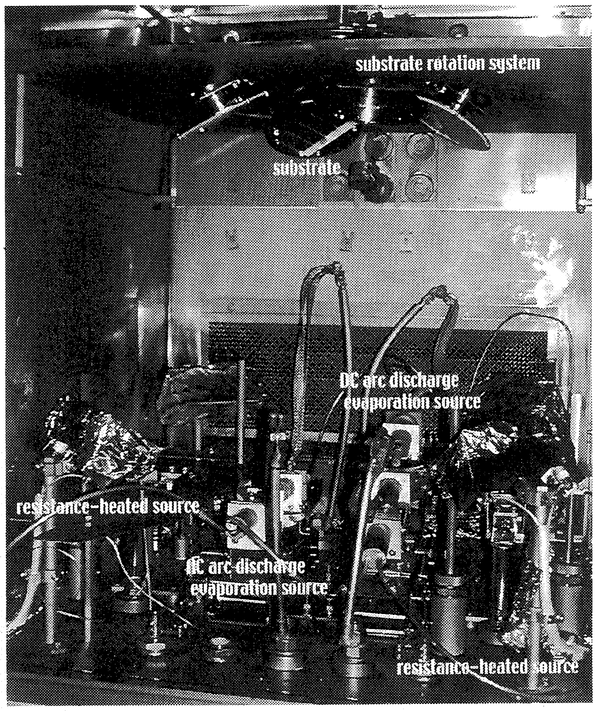

Fig. 2: The inside view of vacuum chamber.

2 PRODUCTION OF CARBON FOIL

C-foils with a thickness of 10 $\mu g/cm^2$ were produced by the arc discharge evaporation method. The arc discharges were generated by AC voltage as well as DC voltage. Figure 1 shows a external view of the high vacuum evaporation system. A rectangular vacuum chamber with a dimension of 750 mm $\times$ 750 mm $\times$ 900 mm is evacuated by two oil-sealed pumps and a 5000 l/s cryogenic pump. The ultimate vacuum pressure of the vacuum chamber is 1.0×10^{-5} Pa, and it takes less than 15 minutes to evacuate the chamber from atmospheric pressure to 1.3×10^{-4} Pa. It was typically 1×10^{-3} Pa while the evaporation was performed. Figure 2 shows a inside view of the vacuum chamber. The AC and DC arc discharge evaporation sources are placed in the middle of the vacuum chamber. The angle between the direction of arc discharge and the horizontal plane was varied from 0 to 45 degrees. The discharge currents were varied to be 300A, 350A, 400A, 450A, and 500A. The thickness of the C-foil was continuously measured by a quartz crystal thickness gauge. The gauge was calibrated by measuring the mass and the area of a C-foil. Two resistance-heated sources for releasing agent are placed in both sides of the vacuum chamber. A substrate rotation mechanism was used in order to make the film thickness uniform. The angle between the substrates and the horizontal plane was varied according to the position of the evaporation source.

3 BEAM TEST

The durability of C-foils under beam irradiation was measured. A 32 keV/u $^{136}Xe^{9+}$ beam with an intensity of 1.1pμA from a 500kV terminal was focused on a C-foil. The beam spot has rectangular shape with a size of 5 mm × 5 mm. The beam spot was carefully made to form a uniform beam. The break of the C-foil was detected by the beam current measured at downstream of the foil also and observing the foil by TV camera. Figure 3 shows a C-foil mounted on an aluminum folder in vacuum chamber. This chamber was set on beam line. The C-Foil folders of 40 sheets were moved in the chamber automatically. The lifetime of commercially available C-foils (Arizona Carbon Foil Co.) with the same thickness were measured to be 60 s on average. Its lifetime is taken as the standard in this work

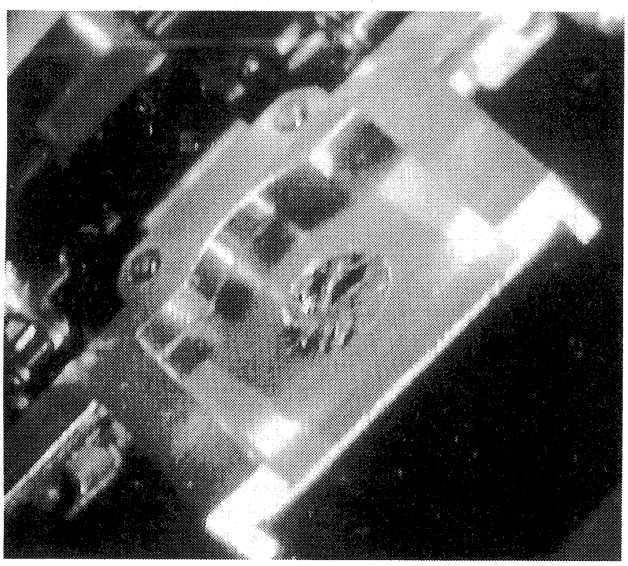

Fig. 3: This photograph is C-foil folder in vacuum chamber. 10 μg/cm^2 C-foil was mounted on the folder.

4 RESULTS

Figure 4 shows the result of the lifetime of the C-foil depending on the angle between the direction of the arc discharge and the horizontal plane. The C-foils had longest lifetimes when the angle was set to 0 degree in the case of the AC discharge and 30 degrees in the case of the DC discharge, respectively. Table 1 shows the dependence of C-foil lifetime on the types of graphite rods. The best results were obtained by OT-5200N (S) in the case of AC discharge and EG-20SH in the case of DC discharge. Figure 4 shows the dependence of the C-foil lifetime upon the discharge current. The C-foils had longest lifetimes when the current was 450A in the case of the AC discharge, and 300A in the case of the DC discharge. The lifetime of C-foils also depends upon the releasing agent. Three releasing agents, $LaCl_3$, NaCl, and $NiCl_2$, were tested, and $NiCl_2$ was found to be preferable. The lifetime was improved by 20% when a DC arc discharge was applied with N_2 gas flow. We successfully produced C-foil whose lifetime is 40 times longer than the commercial foil when the discharge was made by AC 450 A, 0 degree between the direction of the arc discharge and the horizontal plane, OT-5200N(S) graphite rods, and using a releasing agent of $NiCl_2$.

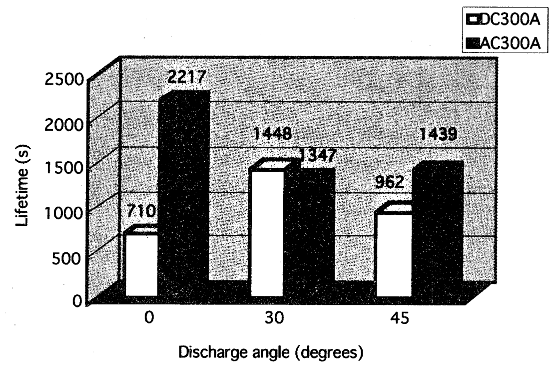

Fig. 4: C-foil lifetime dependence on the angle between the direction of arc discharge and the horizontal plane.

Table 1: The dependence of C-foil lifetime on the type of graphite.

Type of graphite	AC 300A (s)	DC 300A (s)
EG-20SH	1719	1539
EG-30XSH	1572	1590
ER-38NSH	1509	1436
ER-38SH	453	966
OT-5200N(S)	1597	1634
G140	1489	1439

5 CONCLUSION

The conditions for production of a long-lived C-foil have been searched. We successfully produced C-foils with a lifetime 40 times longer than the commercial one. The preparation of thicker C-foils with 80 μg/cm^2 is in progress. We will soon test this C-foil with a few Mev/u intense heavy-ion beam in the realistic case for the RIBF.

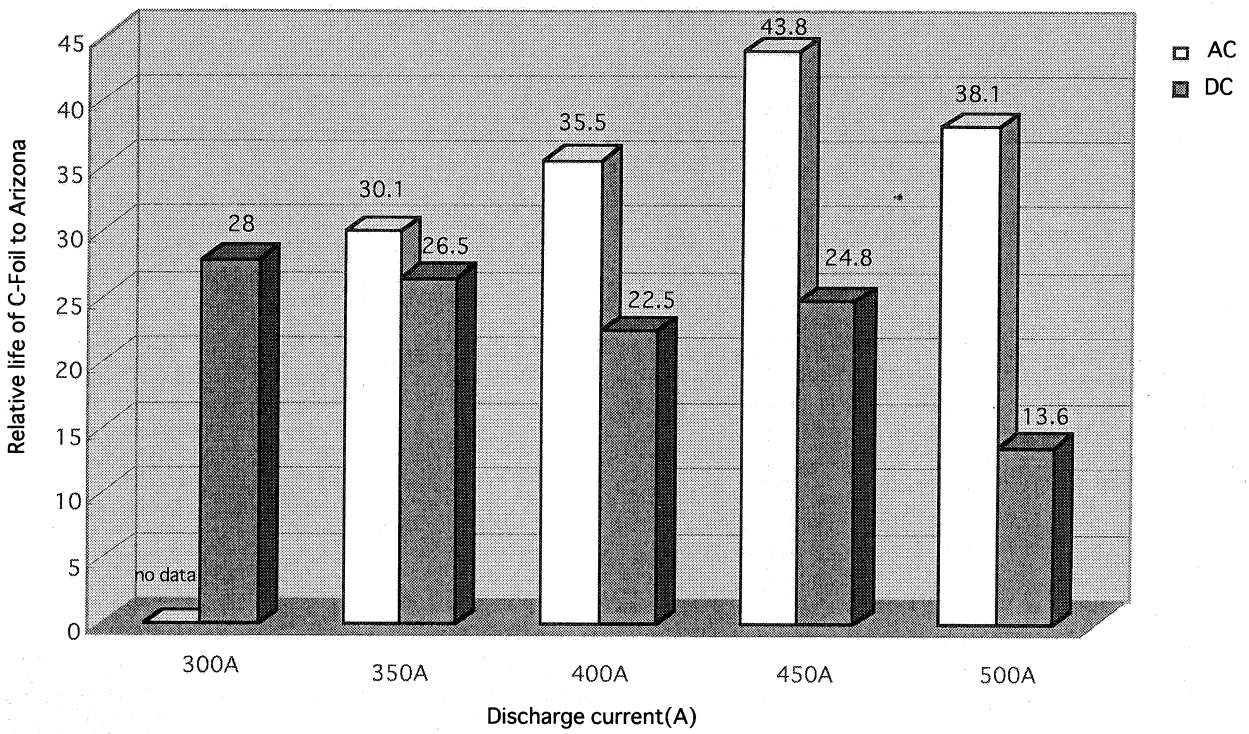

Fig. 5: The dependence of C-foil lifetime on the discharge current.

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