DEVELOPMENT OF LONG-LIVED CARBON STRIPPER FOILS FOR THE RIBF PROJECT

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Abstract

Long-lived thin carbon stripper foils (15±5μg/cm^2) are strongly and urgently required for charge stripper of the RIKEN RI beam factory project. Conventional carbon foils including commercially available ones, which are prepared by means of thermal evaporation-condensation at high temperature, have very short lifetime.

In order to overcome this problem, we have applied the controlled DC arc-discharge (CDAD) method, and have successfully developed long-lived carbon stripper foils. We measured the lifetime of the foils made by the CDAD method using a 0.25 MeV/ u $^{136}Xe^{9+}$ beam with 1.1 pμA. The results showed that the lifetimes of foils are 22 times longer than on average those of commercially available best foils.

We report the foil preparation procedure and the results of the lifetime measurements.

INTRODUCTION

Carbon stripper foils made by an evaporation–condensation method are widely used as a charge stripper for heavy ion accelerators. By recent and great improvement of the ion source in accelerators, the beam intensity becomes significantly increasing. Thus, the lifetime of the carbon stripper foils becomes very short in the RIKEN RI beam factory (RIBF).

Therefore, the development of long-lived carbon foils is urgent and indispensable for the RIBF project.

For this purpose, we have been searching for long time the best preparation method considering lifetime, reproducibility, mechanical strength, smooth surface, pin holes, limitation of the foil thickness and its area. The foils with the best combination of these properties were selected. Lifetime measurements of these foils made by various methods were performed using 3.2 MeV, Ne^{+} ion beams.

By a systematic study of the lifetime measurement, we found reliable and reproducible methods to prepare not only long-lived, but also mechanically strong carbon stripper foils following five methods, as listed in Table1. In order to confirm the lifetime of foils made by the CDAD method [1-3] shown in table 1, we performed lifetime measurements using $^{136}Xe^{9+}$ heavy ion beam including of carbon foils obtained from Chalk River in Canada and Arizona C-Foil Corporation in USA for a comparison.

LIFETIME MEASUREMENT

The irradiation was carried out by using a 0.25 MeV/ u $^{136}Xe^{9+}$ heavy ion beam with an intensity of 1.1 pμA. The beam spot has rectangular shape with a size of 5 mm x 5 mm. The lifetime (min) of the foils was defined until rupture or down to one third to initial beam current. The beam current of $^{136}Xe^{21+}$ analyzed by a magnet, was measured by a Faraday-cup at downstream of the carbon foil in a vacuum chamber and the foils was watched by a TV camera. The carbon foils of twenty sheets were mounted to the target holder, which was able to move in the chamber automatically. The thickness of the foils to be tested are 15±5μg/cm^2. Some foils (marked by strobe) were surface treated by using a flashlight of camera to extend the lifetime.

Table 1: Preparation methods of long-lived carbon stripper foil successfully developed.

Method	Foil (thickness)
Controlled DC Arc Discharge (CDAD) method	Cluster Carbon Foil (5-50 μg/cm^2)
Controlled AC/DC Arc Discharge (CADAD) method	Hybrid Carbon Foil (50-130 μg/cm^2)
Mixed Ion Beam Sputtering (MIBS)	Sputter Foil (5-50 μg/cm^2)
Heavy Ion Beam Sputtering (HIBS)	Sputter Foil (5-30 μg/cm^2)
Ion Beam Sputtering with Reactive Nitrogen (IBSRN)	Nitride Carbon Foil (10-40 μg/cm^2)

RESULT AND CONCLUSION

Results of all foils measured are listed in Fig.1. The mean and the maximum lifetimes of the foils made by the CDAD method named as DC-300 were 312 min, and 560 min, respectively, which correspond to approximately 13 and 22 times longer than these of best commercially available Arizona foils.

The mean lifetime of best Arizona foils was 25 min, and that of the Chalk river was 15 min (except for strobe). Figure 2 shows a picture with shrinkage, but not broken foil made by the CDAD method taken from a view port under $^{138}Xe^{9+}$ beam irradiation. Figure 3 shows a relation between beam current of $^{136}Xe^{21+}$ and irradiation time (h). As shown in the figure, the beam current rapidly decreased with the beam irradiation time due to thickness reduction by sputtering of Xe heavy ion.

In conclusion, the foils made by the CDAD method showed long lifetime even when using heavier ion $^{136}Xe^{9+}$ as well as $^{20}Ne^{+}$ ion irradiation [1-3]

Further lifetime improvement of the foils by the CDAD method is being performed extensively by one of co-workers (H.Hasebe), as reported elsewhere in this conference.

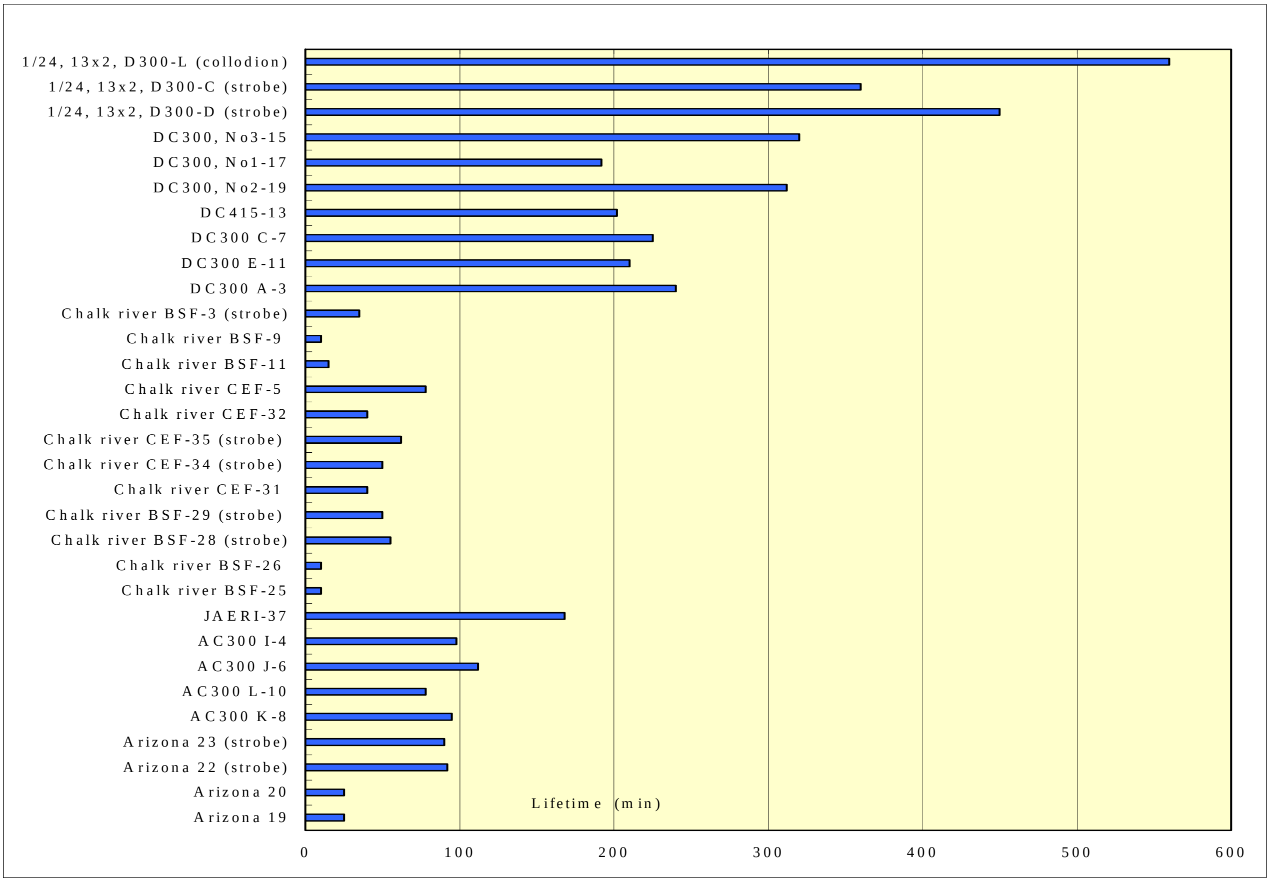

Figure 1: Comparison of the lifetimes of various carbon foils under bombardment with a 0.25 MeV/u, $^{136}Xe^{9+}$ of 1.1 pμA and 5 × 5 mm in beam spot.

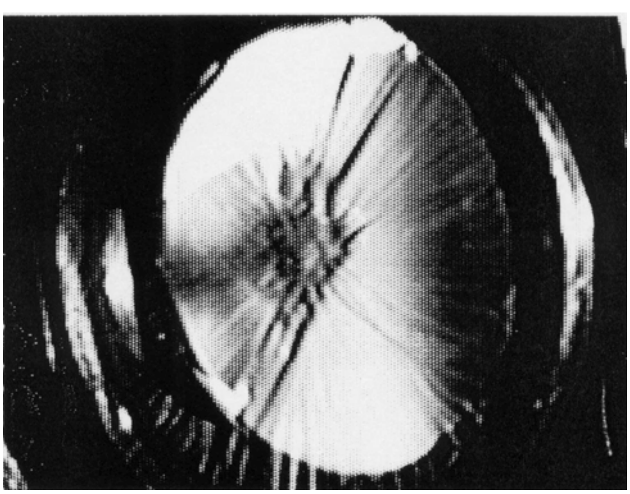

Figure 2: A picture of foil (15 μg/cm^2) made by the CDAD method under $^{138}Xe^{9+}$ beam irradiation.

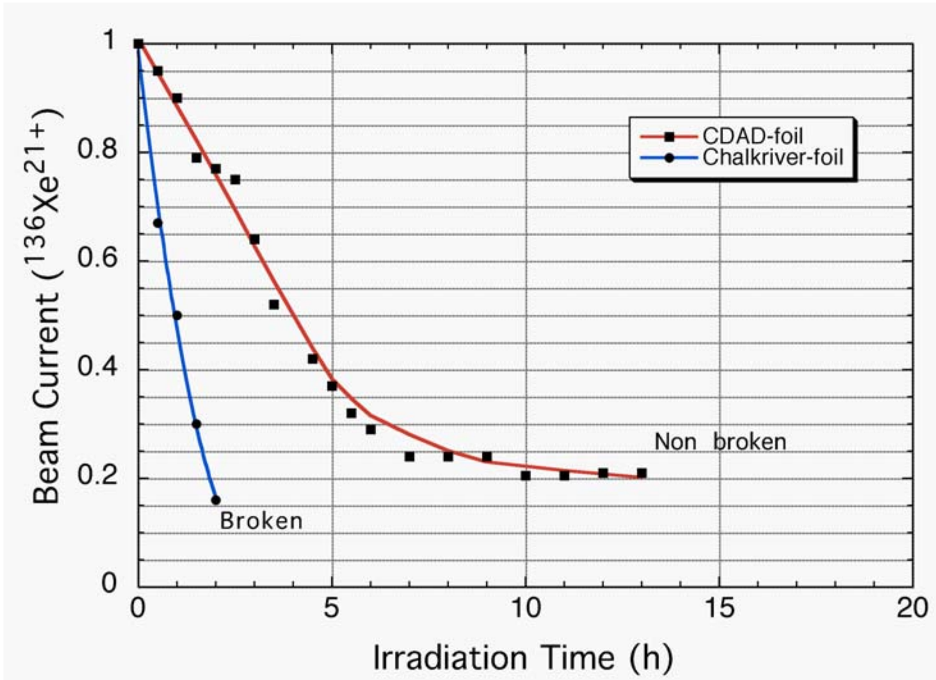

Figure 3: Relation between beam current of $^{136}Xe^{21+}$ and irradiation time (h).

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