LONG-LIVED CARBON STRIPPER FOILS FOR INTENSE HEAVY-ION BEAMS

H. Hasebe, H. Ryuto, M. Kase and Y. Yano
RIKEN (The Institute of Physical and Chemical Research)
2-1 Hirosawa, Wako, Saitama 351-0198, Japan

Abstract

Carbon foils with the thickness of 40μg/cm^2 were produced as charge strippers for intense heavy-ion beams. The lifetimes of the carbon foils were measured with 32 keV/nucleon $^{136}Xe^{9+}$ beam. The lifetimes more than 100 times longer than the foils on the market with the same thickness were attained by choosing the graphite materials.

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 expected to be very short when bombarded by intense low-energy heavy ion beams in the RIKEN RI beam factory (RIBF). For example, the lifetime is expected to be less than 1 minutes, when a 90 pμA uranium beam at 0.9 MeV/nucleon is bombarded. [1]

The production of C-foils in the thickness range of 10-100μg/cm^2 have been developed by selecting various parameters. The dependence of 40μg/cm^2 C-foil lifetime to the selection of the graphite material is taken in this work. The foils were produced by the AC/DC arc discharge method invented by I. Sugai et al. [2]

PRODUCTION OF CARBON FOIL

C-foils were produced using a high vacuum evaporation system (EBX-2000C by ULVAC). Figure 1 shows an inside view of the vacuum chamber. Two sets of carbon evaporation sources are placed in the middle of the vacuum chamber. One is for the AC discharge and the other is for the DC discharge. The discharge currents (I_d) are variable from 0-500A. The DC discharge is used only when thicker foil (60-100μg/cm^2) is produced. The angle (θ_{arc}) between the direction of arc discharge and the horizontal plane is variable from 0-45^o. The thickness of the C-foil was continuously measured by a quartz crystal thickness gauge. A resistance-heated evaporation source for releasing agent ($NiCl_2$) is placed at the side of the vacuum chamber. A substrate rotation mechanism was used in order to make the film thickness uniform. The angle (θ_{sub}) between the substrates and the horizontal plane is variable according to the position of the evaporation source.

40μg/cm^2 thick C-foils were made under condition that I_d=300A (AC), θ_{arc} =0^o and θ_{sub} =30^o. Eight kinds of graphite rods made by Toyo Tanso CO., LTD were used as graphite materials.

BEAM TEST

The durability of C-foils under beam irradiation was measured. A 32 keV/nucleon $^{136}Xe^{9+}$ beam with an intensity of 6.3 eμA was focused on a C-foil. The beam spot had a square shape with a size of 3 mm × 3 mm. The beam spot was carefully tuned to form a uniform density distribution observing the image on a quartz plate. The breakage of the C-foil was detected by the beam current measured at downstream of the foil and also observing the foil by a TV camera. Twenty C-foils on Al made holders are mounted in the vacuum chamber at the same time. Each C-foil can be moved one by one into the beam position by remote control. The commercially available C-foils (Arizona Carbon Foil Co.) with the thickness of 40μg/cm^2 were used as the standard in this work. Its lifetime was measured in the same condition to be 100 s.

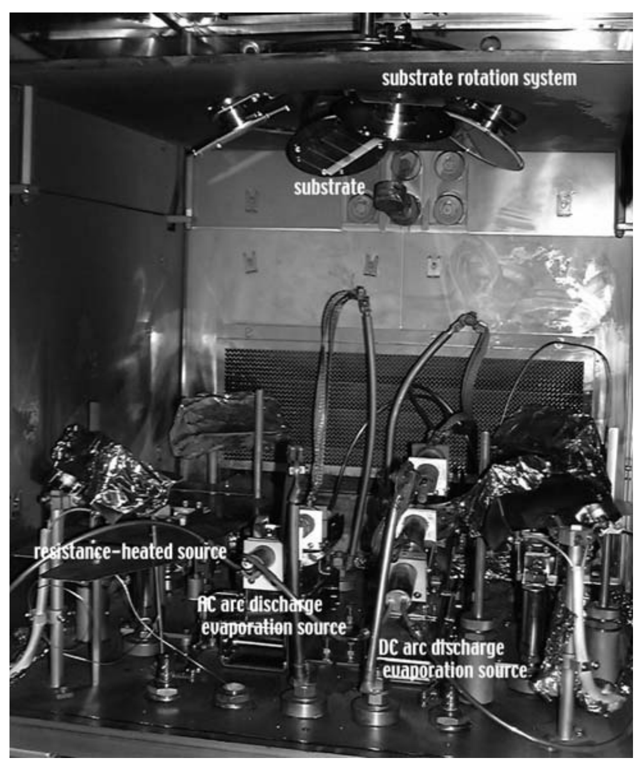


Figure 1: The inside view of vacuum chamber.

RESULTS

The measured lifetimes are the average values over two sheets of the C-foil made from each graphite rod. Table 1 shows the results of the lifetimes together with characteristic of the graphite rods. The distance between graphite planes was measured by the powder X-ray diffractometer. Figure 2 shows the dependence of graphite-planes distance, specific resistance, and lifetime, on the graphite material. The foil made with IG-710 was found to have 120 times longer lifetime than Arizona C-foil. The specific resistance and the graphite-planes distance have the similar tendency over the graphite materials. It seems that specific resistance will decrease if the graphite-planes distance are small. The graphite-planes distance of ideal pure graphite is well-known 3.354Å. It seems that the C-foil produced by the graphite rod whose graphite-planes distance is close to ideal one have longer lifetime except for ISO-880.

Lattice structure of two kind of C-foils, was investigated by the powder X-ray diffractometer. One is made from Arizona C-foil which has the shortest lifetime, and the other is the one made from IG－710, which has the longest lifetime. Figure 3 shows the results. The both results show the pattern of an amorphous carbon. A characteristic pattern of graphite was observed in the Arizona C-foil. Silicon is observed because the foil was stuck on the silicon board. Unknown peaks were observed with the C-foils (IG-710) produced in RIKEN. It is supposed that these peaks show the lattice structure, which is stable against the ion bombardment. Further investigation on such kind of structure is necessary to make the long-lived C-foil production more controllable.

A beam test using intense heavy ion beams at a few MeV/nucleon is scheduled.

Table 1: The results of the lifetimes together with characteristic of the graphite rods.

	Bulk Density	Shore Hardness	Specific Resistance	Bending Strength	Compression strength	Relative life time	Distance of between graphite planes
	g/cm^3		μΩm	Mpa	Mpa		Å
Arizona 40						1	(3.378)
ISO-880	1.95	92	15.0	114	217	49	3.364
SIC-120	1.75	65	14.6	43	98	51	3.380
IG-120	1.76	57	11.5	44	93	51	3.380
IG-100	1.68	45	12.6	31	59	56	3.372
IG-110	1.78	53	10.3	44	84	63	3.369
IG-510	1.90	61	8.8	52	110	68	3.364
IG-430	1.81	52	8.7	55	92	98	3.362
IG-710	1.82	58	10.4	51	105	121	3.367

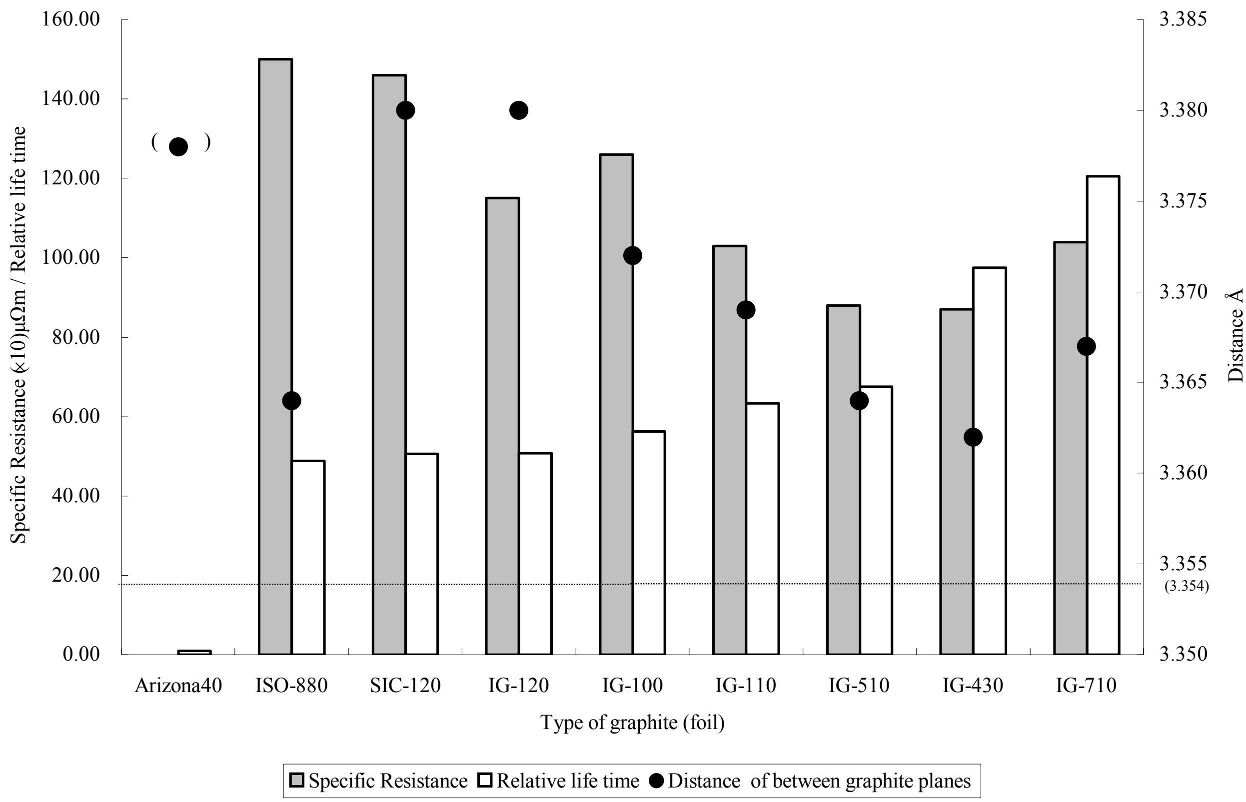


Figure 2: The dependence of graphite-planes distance, specific resistance, and lifetime, on the graphite material.

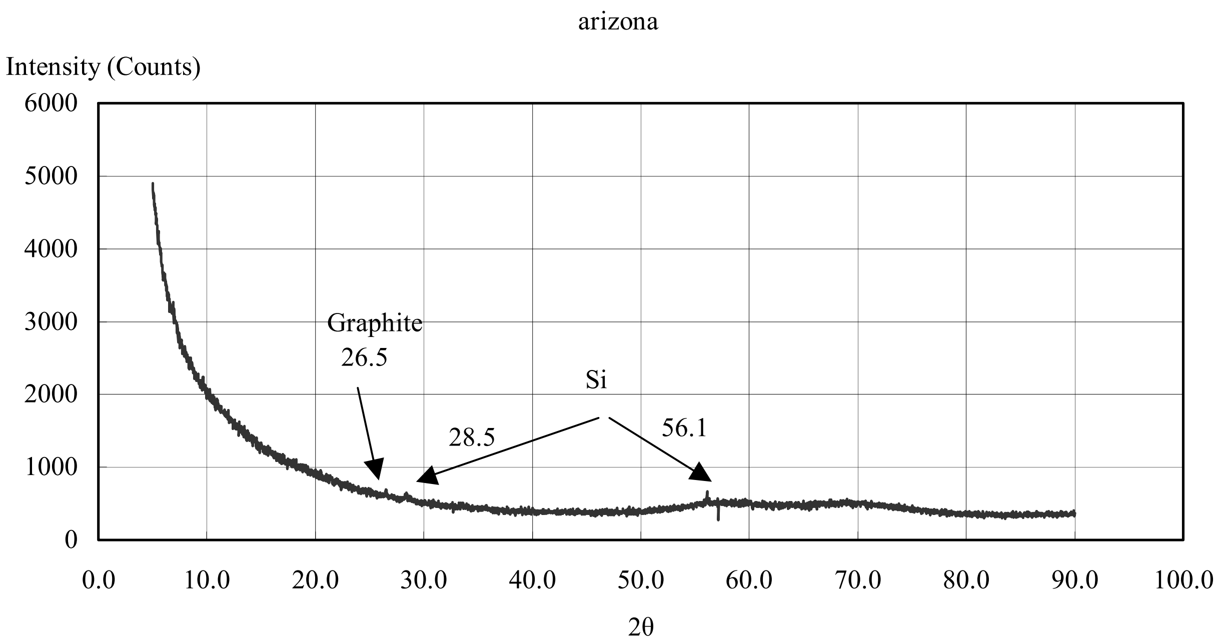
CONCLUSION

C-foils with a very long lifetime were successfully produced by selecting graphite rod. In order to produce the long-lived C-foil, the graphite material with a small graphite-plane distance should be selected for graphite rods. To make the selection easier, the graphite with a small specific resistance may be the good material as rods for C-foil production.

REFERENCES

[1] E. Baron: IEEE Trans. Nucl. Sci. 26, 2411 (1979).

[2] I. Sugai et al., " Development of Long-Lived Carbon Stripper Foils for the RIBF Project " in this proceedings.



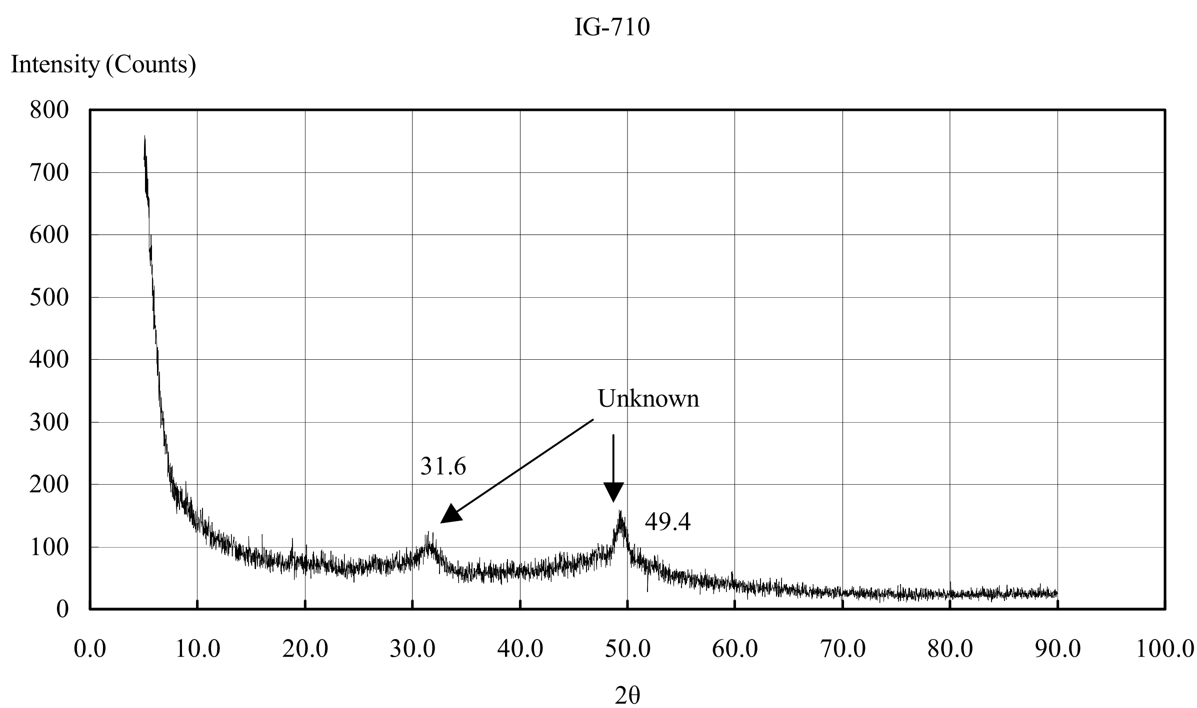


Figure 3: The result of the powder X-ray diffractometer.