COMPARATIVE STUDY ON LIFETIME OF STRIPPER FOIL USING 650 keV H^- ION BEAM*

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Abstract

Thick carbon stripper foils of >300μg/cm^2 will be used as a stripping of H-ion beam for 3GeV Rapid Cycling Synchrotron (3GeV-RCS) of the J-PARC. The carbon foils with long lifetime even at >1800ºK are required. For this purpose, we have developed a new irradiation system for the lifetime measurement using high current pulsed and dc H^- beams of the KEK Cockcroft-Walton accelerator. These high power 750keV H^- Ion beams can simulate the high energy deposition in carbon stripper foils at the J-PARC RCS. An automatic data acquisition system is also developed for recording the data of foil temperature and irradiated beam current. The Hybrid Boron mixed Carbon (HBC) stripper foils, which are developed at KEK are irradiated by high current H^- ion beam up to 2000ºK. A few SNS-diamond and commercially available carbon (CM) foils are also tested for comparing with HBC-foils. The results of the lifetime measurement of HBC and SNS-diamond including CM stripper foils are reported.

INTRODUCTION

The Japan-Proton Accelerator Research Comprexes (J-PARC) requires thick carbon stripper foils (250-500μg/cm^2) to strip electrons from the H^- ion beam supplied by the linac before injection into the RCS (Rapid Cycling Synchrotron) [1]. The 200MeV H- ion beam from the linac has a pulse length of 0.5msec with a repetition rate of 25Hz and an average beam current of 335μA. For this high-energy and high-intensity beam, conventional carbon stripper foils will break in a very short time and even a diamond foil will be ruptured at around 1800ºK by the MW class accelerator. Thus, thick carbon stripper foils with high durability at 1800ºK produced by energy deposition in the foil are indispensable for this accelerator.

For this purpose, we have been developing carbon stripper foils of 350μg/cm^2 by means of both the controlled DC and AC/DC arc-discharge method. Recently, we have successfully developed hybrid type thick boron doped carbon stripper foils, which showed a drastic improvement not only with respect to the lifetime, but also with respect to thickness reduction and shrinkage at high temperature during long irradiation [2],[3],.`

By this purpose, we have been developed an irradiation system for the lifetime test at the high temperature above 1800ºK with 750keV negative hydrogen beam (H-) of dc and pulsed operation [6].

HIGH VOLTAGE ACCELERATOR

There are two set of 750keV H- pre-injectors in the KEK-12GeV proton synchrotron. After shutdown of 12GeV-PS, an irradiation system in the 750keV low energy beam line of the second pre-injector. The 750keV pre-injector consists of a high voltage generator, a high voltage terminal and an accelerating column.

The parameters of the 750keV Cockcroft-Walton accelerator are shown in table1. The high voltage generator is one of the Cockcroft-Walton type which can generate dc voltage of 800kV(max.) The nominal maximum output voltage of the high voltage generator is -800kV, but the actual maximum voltage of the accelerating column is -720keV.

A high current multi-cusp negative hydrogen ion source is installed in the accelerationg column of the KEK 750keV pre-injector. This ion source is based on the the surface-production mechanism. A converter electrode is inserted in the central part of plasma chamber of ion source. The high current of negative ions are produced on the surface of the converter electrode whigh is coated with some metal vapor of cesium and extracted from an anode hole of the ion source.

Table 1: Parameters of the 750keV pre-injector

C-W output voltage (nominal)	-800 kVmax
C-W output current (nominal)	5 mAmax
HVT voltage (Acc. Voltage)	-720keVmax
Beam current (pulsed mode)	30mA/peak (20Hz, 0.2msec)
Beam current (dc mode)	1mA/dc
Type of ion source	Multi-cusp surface H^-
Beam energy at beam irradiation	640keV

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TARGET CHAMBER AND TARGET FOLDER ARRAY

Figure 1 shows a target chamber which is placed in the 750keV low energy beam line. A movable target folder array is installed in this target chamber, and four target folders are mountable on the target array.

The H- ion beam irradiation for several carbon foils were performed by dc beam mode. The temperature of beam spot on the carbon foil was measured by an optical pyrometer. The irradiated beam currents were 40~280 μA. The maximum temperature of beam spot on the foil was reached up to 2000ºK with beam spot of 2-3 mm diameter.

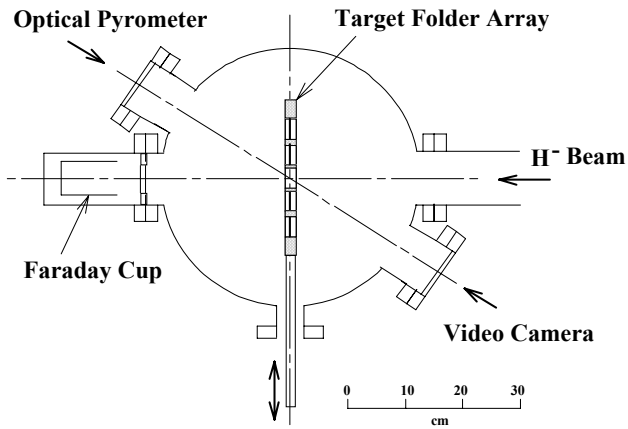


Figure 1: Target chamber

EXPERIMENTAL RESULTS FROM KEK-HBC AND SNS-DIAMOND FOILS

Some of KEK-HBC foils[4],[5] and SNS-diamond foils[7],[8],[9] has been tested. The recent experimental results are shown in table2 and table 3.

Table 2: Parameter of the KEK HBC Foil irradiated with a 640keV H- Beam

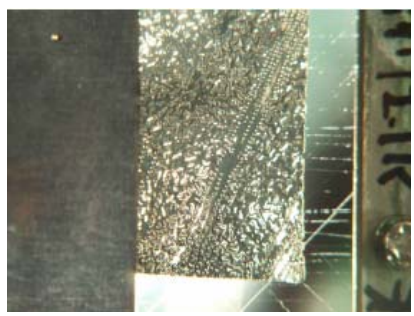
Type	M (μg/cm^2)	Beam (μA)	Temp (K)	Time
HBC-1	280x1=280	280	1960	115h 20m
HBC-4	280x1=280	210	1920	85h 10m
HBC-3	300x2=600	60-40	1860-1800	151h
HBC-C	210x2=420	120	1980~1870	71h 16m
HBC-D	210x2 =420	90	1850	197h 47m

Table 3: Parameters of the SNS Diamond Foil (Single-edge) irradiated with a 640keV H- Beam

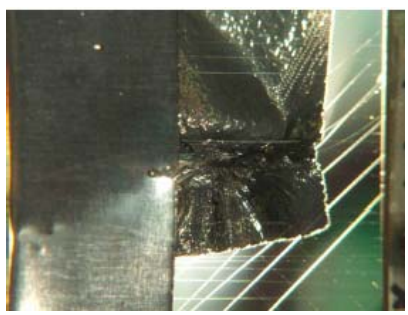
#	M(μg/cm^2)	U/L	Beam(μA)	Temp (K)	Time
#607	500	L	100	1950	28h49m
		U	180	2200	3h55m
#510	383	L	110	1900	10h39m
		U	110	1900	13h36m
#592	333	---	120	1970	12h40m
#586	362	L	110	1950	13h
		U	80	1850	6h31m
#527	433	---	130	1930	20h57m

An example of photograph of KEK-HBC foil is shown in figure 2. Before irradiation, the surface condition of HBC-foil was flat. But after 151 hr of ion beam irradiation, a large distortion was observed around a beam spots as shown figure 2 (A).

The case of the SNS-diamond foils, the original visibility of diamond foil was failed after beam irradiation started as shown in figure 3.



(A) Just after started irradiation.



(B) After 151 hr irradiated.

Figure 2: Photograph of HBC-3 foil in table 2, (A) Just after 5sec, (B) After 151 hours.

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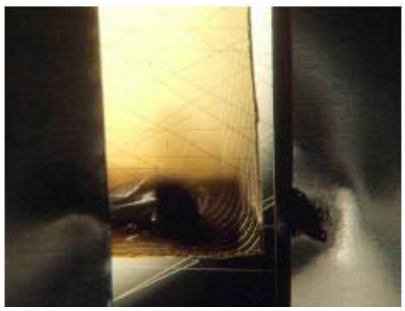
(A) Before irradiation



(B) After 13 hours

Figure 3: Photograph of SNS-#586-L diamond foil in table 3, (A) Before irradiation start, (B) After 13 hours.

SUMMARY

Some of stripper foils were irradiated by dc H^- ion beam for the lifetime test of foils. The high durability of HBC foil and SNS-diamond foil at 2000 ºK was investigated. Furthermore tests are needed to estimate the exact lifetime of KEK-HBC and SNS-Diamond foils.

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