LIFETIME MEASUREMENT OF HBC STRIPPER FOIL USING 3.2 MEV NE^+ FOR RCS OF J-PARC

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Abstract

In high intensity proton synchrotrons, the temperature of carbon stripper foil becomes about 1800K at peak due to the energy loss. However, present carbon stripper foils are not long-lived ones. So we developed new stripper foils (hybrid type boron doped carbon stripper foils: HBC-foil) at KEK.

We tested a HBC-foil by 3.2-MeV Ne^+ DC beam at Tokyo Institute of Technology. To compared with this, we also tested commercially available foils developed at ARIZONA Co. Ltd., Diamond like carbon foils developed at TRIUMF and nanocrystalline diamond developed at SNS (ORNL).

In this report the life time measurements with a 3.2-MeV Ne^+ beam are presented. Double layered HBC-foils showed a long lifetime

INTRODUCTION

The Japan proton accelerator research complex (J-PARC) requires thick carbon stripper foils for the H^- injection into the rapid cycling synchrotron (RCS). Stripper carbon foils undergo thickness reduction and shrinkage by high current beam, 333μA in average. Thus, new type carbon stripper foils with high durability at 1800K are indispensable for RCS [1] (Table 1). We have successfully developed hybrid type boron doped carbon stripper foil (HBC-foil), which showed long-lifetime, less thinning and shrinkage.

We calculated the energy deposition of foil thickness for energy deposition upon foil as function of foil thickness for low energy Ne^+ DC beam of 3.2-MeV and high energy proton pulsed beams of 200-MeV and 400-MeV. The results are shown in Fig.1. The thermal power of the 3.2-MeV Ne^+ DC beam is nearly the same with those of 200 and 400-MeV proton pulsed beam [2]. The peak temperature of foils with 200-300 μg/cm^2 thickness may reach about 1800K. So the lifetime measurement of foils using 3.2-MeV Ne^+ DC beam is very useful.

Table 1 Injection beam and stripper foil properties of 3GeV-RCS

Kinetic energy	181 MeV (first stage) 400 MeV (second stage)
Pulse length	0.5 ms
Repetition rate	25Hz
Average beam current	0.1mA (first stage) 0.333mA (second stage)
Beam size	10 mmϕ
Foil thickness	200 μg/cm^2(181 MeV) 300 μg/cm^2 (400 MeV)
Foil peak temperature	>1800K

HBC-FOILS

The cluster carbon stripper foils have long lifetime, which are prepared by developing of the Controlled AC/DC Arc-Discharge (CADAD) method [3]. But the maximum obtainable foil thickness is 140 ±30μg/cm^2.

HBC-foils are produced in an arc discharge method process, referred to as CADAD method. The cathode used a boron doped carbon rod of 10 mm diameter while

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the opposite electrode was a pure graphite rod of 15 mm diameter. The distance between the evaporation source and the substrate was 220mm. The deposited layer with the substrate was heated at 573K for 6 hour using Ta filament in vacuum. Concentration of boron is 20%-25% by weight, which was proven to be the best ratio for long lifetime and ease of handling [4].

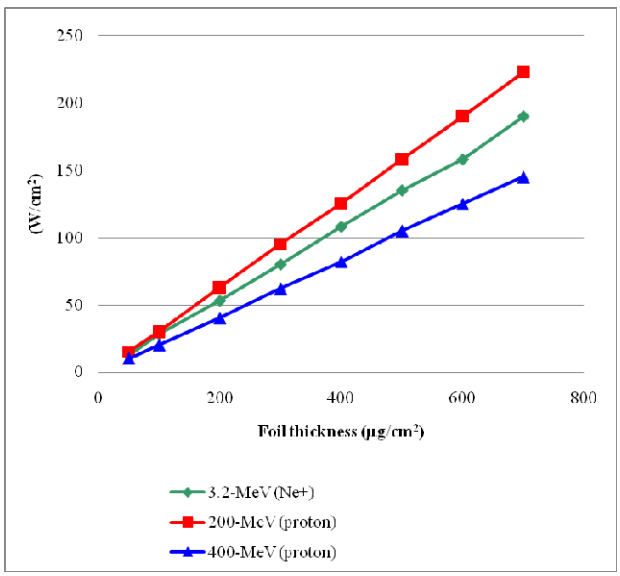


Figure 1: Energy deposition as a function of foil thickness for 3.2-MeV Ne^+ DC beam and 200, 400-MeV proton beam.

FOIL LIFETIME TEST AT TIT

The lifetime measurements were performed with 3.2-MeV Ne^+ beam of 2.5±0.5μA and 5.0 mmϕ beam spot in diameter, supplied from the Van de Graaff accelerator at Tokyo Institute of Technology (TIT). The experiment set-up for the lifetime measurement was shown in Figure 2. The base pressure was $2x10^{-4}$ Pa without beam and $5x10^{-4}$ Pa during beam irradiation. We observed the surface condition of the foils by means of a camera through viewing ports. The lifetime in this paper is defined as the irradiation time (hours) until the foil shows rupture or large deformation.

We measured the following foils.

- HBC-foil (single-layer)
- HBC-foil (double-layer)
- CM-foil (commercially available: ARIZONA Co. Ltd.)
- DLC-foil (diamond-like carbon: TRIUMF)
- NC-foil (nanocrystalline diamond: SNS)

Thicknesses of the HBC-foils were 200-400 μg/cm^2. All ribbon type foils of about 20 x 30mm without NC foils were supported by 10mm SiC fibers on aluminum frames. The NC foils size was 17 x20mm^2.

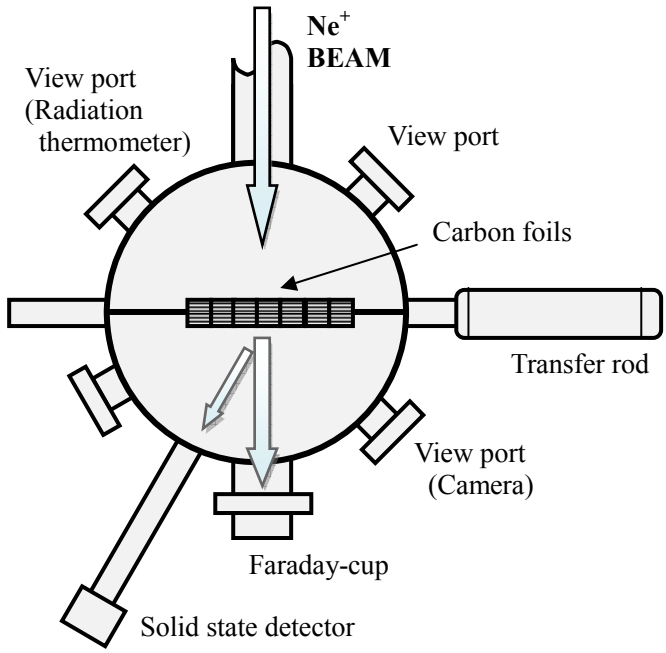


Figure 2: Experimental apparatus for lifetime measurement of various carbon stripper foils at Tokyo Institute of Technology

RESULTS

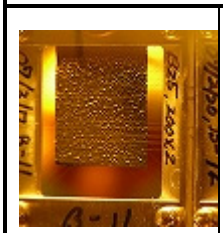
The temperatures of irradiated point on foils were 1300-1600K measured by two infra-red-ray radiation thermometers of IR-308 of KONICA- MINORUTA and PM-174 of YOKOGAWA companies in Japan. Figure 3 shows photographs of all sample foils. The CM-foils, DLC-foils and NC-foils showed strong shrinkage in a short time. And a large pinhole appeared in the CM foil. On the other hand, only small change was observed for single- and double-layer HBC-foils. However single layer HBC-foils had many pinholes.

Table 2 shows lifetime of the HBC-foils and other foils. CM-foils were damaged in almost an hour regardless of the foil thickness. DLC-foil was destroyed in 2 hours. The longevity of NC-foils was all different. Especially, a thick foil tends to short lifetime. The data sets of double-layered HBC-foils include the foils that were not ruptured or broken. The single and double layered HBC-foils showed a long lifetime of 21.7 and more than 43.6 hour hours, respectively. This corresponds to about

43 times longer lifetime than that of the CM-foils. The maximum lifetime was found to be extremely long; 360 times longer than those of CM-foils.

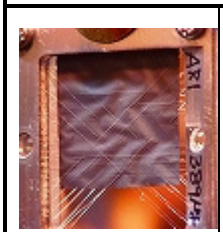
Un irradiated	10 hour irradiation	After irradiation

(a) HBC-foil (single layer)



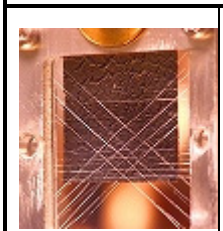
Un irradiated	20 hour irradiation	After irradiation

(b) HBC-foil (double layer)



Un irradiated	0.5 hour irradiation	After irradiation

(c) CM-foil



Un irradiated	0.5 hour irradiation	After irradiation

(d) DLC-foils

Un irradiated	2 hour irradiation	After irradiation

(e) NC-foils

Figure 3: Photographs of foils at before and after irradiation.

Table 2: Lifetime results of various foils

Type of foils	foil Thicknesses ($\mu g/cm^2$)	Average Lifetime (hour)	Number of files
HBC-foils (single layer)	**205 -516**	**21.7**	**11**
HBC-foils (double layer)	**400 -480**	**>43.6**	**7**
CM-foils	**100 -389**	**1.0**	**10**
DLC-foils	**330 -560**	**1.1**	**3**
NC-foils	**350 -500**	**4.0**	**3**

SUMMARY

We measured the lifetime for various types of carbon stripper foils of HBC-foils, CM-foils, DLC-foils and NC-foils by using the TIT 3.2-MeV Ne^+ DC beam. Double layered HBC-foils showed a longer lifetime than 43.6 hours. The longevity of foil varies widely. Therefore, it is a future task to have a good control of foil quality.

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