BEAM STUDY RESULTS WITH HBC STRIPPING FOILS AT THE 3-GeV RCS IN J-PARC

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Abstract

The Hybrid type thick Boron-doped Carbon (HBC) stripping foils are installed for the beam injection at the 3GeV RCS (Rapid Cycling Synchrotron) in J-PARC (Japan Proton Accelerator Research Complex). The RCS started user operation with a high power beam of 120kW for the MLF (Material and Life science Facility) experiments since November 2009. However, the noticeable deterioration of the HBC stripping foil could not be seen even after a long beam irradiation. In order to examine the characteristics of the HBC foils, we made the following various beam studies. Namely, the beam-irradiated spot at the foil was measured by scanning the foil setting position, thickness uniformity of the foil was estimated from the beam loss caused by the foil scattering, the effect of the SiC fibers supporting the foil mounting was checked with different mounting foils, and the charge exchange efficiency was evaluated with various thickness foils. Results of beam study with the HBC foils will be presented including the outgassing from the foil and the deformations on the foil during the beam irradiation.

INTRODUCTION

The HBC foils are developed by Sugai group in KEK, which improved drastically the lifetime [1]. Aiming the higher power beam operation, the HBC stripping foil has been installed in the J-PARC RCS on September 2008. Through the improvement of the charge exchange system has been finished on March 2009, the stripping foils can be replaced with another one in vacuum remotely and automatically [2]. In order to examine the characteristics of the HBC foils, the various foils were installed on October 2009 and the beam studies with those foils were carried out.

RCS HBC FOILS

In the J-PARC RCS, a ribbon type HBC stripping foil is mounted on a C-shaped Al foil holder as shown in Fig. 1. One edge of the foil of 40mm x 110mm is supported by the holder and the other edge is sandwiched by 10 μm diameter SiC fibers. In order to examine the characteristics of the HBC foils, especially an effect of the beam scattering on the foils, the foils of the different thickness were installed. The thickness of the HBC foils were summarized in table 1 and these foils were produced with the thickness error of about 10%. On the other hand, extra-mounting foil for the beam study was set up as shown in Fig. 2. The foil edge was hanged on the upper side of the C-shaped holder, and has the following four areas: (1) nothing, (2) SiC fibers only, (3) HBC foil + SiC fibers, and (4) HBC foil only. Thus the difference between a HBC foil scattering and a SiC fiber scattering can be made clear by controlling the irradiation position.

Table 1: HBC Foil Thickness

	Foil thickness [$\mu g/cm^2$]					
normal mounting	92	196	288	392	487	634
extra-mounting	215					

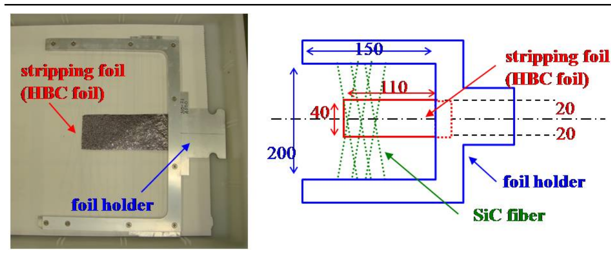

Figure 1: Schematic diagram of the operational foil mounting on the C-shaped holder.

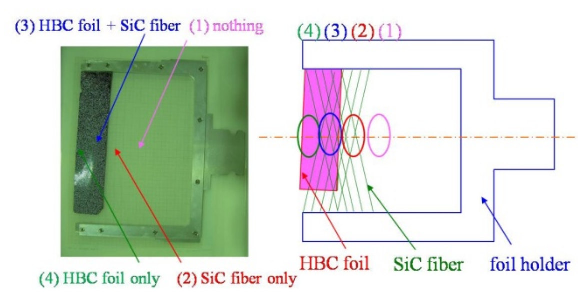

Figure 2: Schematic diagram of the extra-mounting foil to examine the effect of SiC fibers. This foil has following four areas: (1) nothing, (2) SiC fibers only, (3) HBC foil + SiC fibers, and (4) HBC foil only.

BEAM EXPERIMENT

Foil Scanning

The beam irradiated spot at the foil was measured by scanning the foil setting position. When the foil is pull out

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from the injection beam, the circulating beam intensity decreases. Fig. 3 (a) shows the circulating beam intensity observed with a RCS DCCT. An injection beam profile at the foil can be obtained exactly by differentiating the plot in Fig. 3 (a).

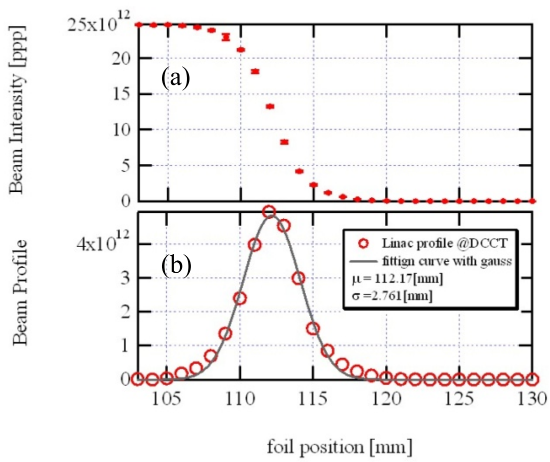

Figure 3: Typical result of the foil scanning. (a) shows the circulating beam intensity as a function of the foil position. (b) is the injection beam profile obtained by differentiating (a).

Thickness Uniformity

Thickness uniformity of the HBC foil was estimated from the beam loss caused by the foil scattering. In order to divide between an injection beam foil scattering and a circulating beam foil scattering, the RCS was operated in the single-pass extraction mode. Fig. 4 shows the variation in the measured beam loss as a function of the irradiation position on the foil. Error of the thickness uniformity is found to be kept within +/- 11% along a scanning range of 70mm.

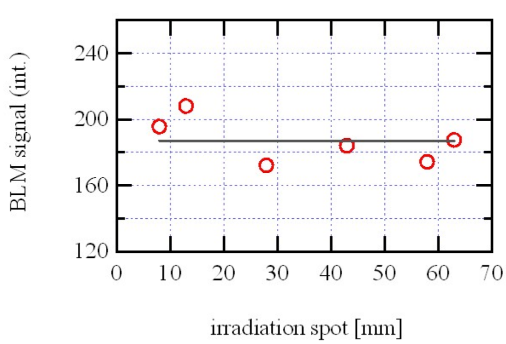

Figure 4: Result of the thickness uniformity measurement.

Effect of the SiC Fiber

The effect of the SiC fibers supporting the foil mounting was checked with extra-mounting foils. The RCS was operated in the single-pass extraction mode, and the beam loss was measured by changing the irradiation spot in four areas. Measurements result shows in Fig. 5, and the effect of the SiC fiber is less than 10% of the HBC foil.

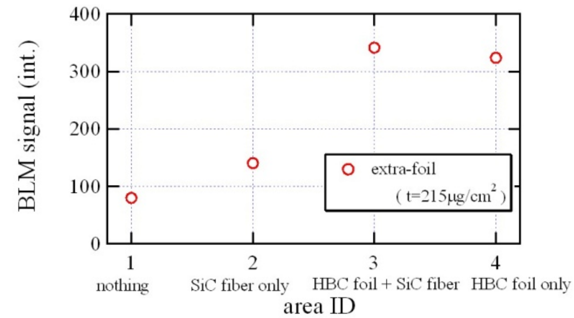

Figure 5: Measurement results of the SiC fiber effect.

Beam Survival with the Foil Thickness

The charge exchange efficiency was evaluated with various thickness foils. Fig. 6 shows the circulating beam intensity measured by Wall Current Monitor (WCM). In this beam condition, beam injection into the RCS has finished at 50 turn. Thus the charge exchange efficiency was saturated with the foil thickness around 250μg/cm^2. On the other hand, closed orbit bump magnets were turned off at the end of the 500 turn and thus the circulating beam did not hit the foil henceforth. Beam survival rate, obtained from the ratio of the beam intensity at 500turn to the beam intensity at 50turn, was proportioned to the foil thickness as well as the measurement was consistent with the simulation [3]. Since them, the HBC foil with thickness of 196μg/cm^2 was adopted as an operational foil.

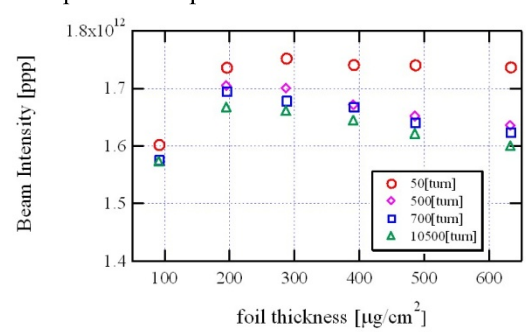

Figure 6: Typical results of the charge exchange efficiency and beam loss caused by the foil scattering as a function of the foil thickness.

OUTGASSING AND FOIL DEFORMATION

The variations in the outgassing from the foil as a function of the foil thickness were measured as shown in the Fig. 7. Pressure increments of the vacuum right after the first beam irradiation and 40 minutes later are shown.

The outgassing from the foil was in proportion to the foil thickness.

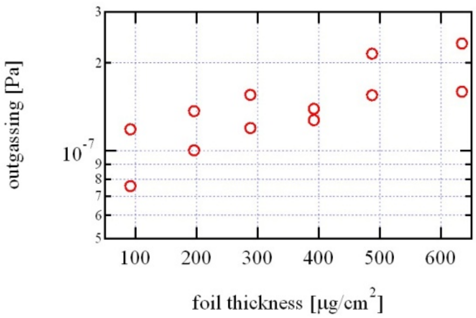

Figure 7: Pressure increments of the vacuum right after the first beam irradiation and 40 minutes later as a function of the foil thickness measured with beam.

The beam irradiation to the new stripping foil with thickness of 196μg/cm^2 was started since RUN26 on October 2009. The outgassing from the HBC foil and the foil deformations during the beam irradiation were summarized in Fig. 8. The upper graph in Fig. 8 shows the trend of the vacuum pressure around the HBC foil, and total irradiation particle in every run cycle. The outgassing from the HBC foil was decreased and it seems to be stable after the RUN29. The lower photos in Fig. 8 show the deformations of the HBC foils during the beam irradiation. A surface condition of the HBC foil, including a form and a texture, was varied quickly until RUN28, for which about 2.5x10^{20} particles were irradiated on foil. And afterward, it seems the process of the foil deformation has stopped. Up to now, the noticeable deterioration of the stripping foils could not be seen, after about 7.0x10^{20} particles irradiation,

SUMMARY

The beam studies with the HBC stripping foils were carried out in focusing on the beam scattering with HBC foils. Error of the thickness uniformity is kept within +/-11%, and the effect of the SiC fiber is found to be less than 10%. Beam survival dependence on the foil thickness was measured and the beam loss caused by the foils scattering was consistent with simulation. Even after about 7.0x10^{20} particles irradiation, the outgassing rate from the foil was stable and the foil deformation did not become worse, and also no noticeable deterioration of the stripping foils could be seen.

REFERENCES

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[2] M.Yoshimoto et. al., in this proceedings.
[3] P.K. Saha al., in this proceedings.

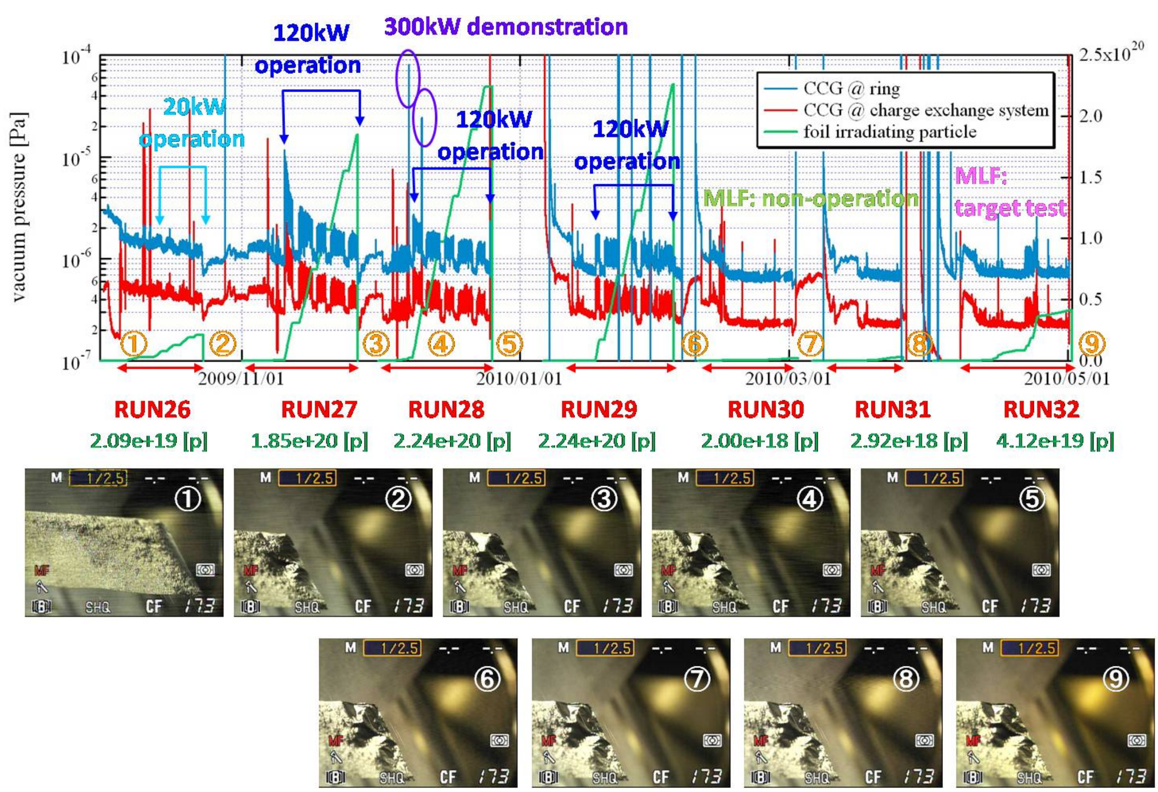

Figure 8: Trends of outgassing from the foil and the deformations on the foils during the beam irradiation. The upper graph plots the vacuum pressure measured by the CCG around the stripping foil and the total irradiated particle every run cycle. The lower photos show the deformations of the HBC foils during the beam irradiation.