LIFETIME TEST OF CARBON STRIPPING FOILS BY 650KEV INTENSE PULSED H$^-$ ION BEAM

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Abstract

We have recently developed a new irradiation system for lifetime measurement using the KEK 650keV Cockcroft-Walton type of high voltage accelerator with high current pulsed negative hydrogen ion beam, which can simulate the high energy-depositions upon foils in the RCS. It is found that, by adjusting the peak intensity and the pulse length of the hydrogen ion beams appropriately, the energy deposition becomes equivalent to that exerted by the incoming hydrogen ions and the circulating protons at the injection process of the RCS. The most important factor that affects the foil lifetime is the foil peak temperature. During lifetime tests by this system, the temperature of foil is measured by a phototransistor or a photodiode as a fast thermometer in a pulsed mode (650keV, 3mA, 0.25msec, 25Hz).

INTRODUCTION

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

We have been developing carbon stripper foils of 350 ∫g/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 drastic improvements not only in the lifetime, but in the thickness reduction and shrinkage at high temperature during long beam irradiation [1]. For this purpose, an irradiation system has been developed for the lifetime test with 650keV negative hydrogen beams (H$^-$) of dc and pulsed operations [2],.

Although several calculated results have been reported on the foil temperature [3], [4], no direct measurements have been reported on the thermal radiation from foil in a pulsed mode. The new photo-detector is installed in this irradiation system to observe the time structure of the radiation [5].

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650KEV H$^-$ ION SOURCE

A high current multi-cusp negative hydrogen ion source is installed in the accelerating column of the KEK 650keV Cockcroft-Walton accelerator (pre-injector). This ion source is based on 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 at the surface of the converter electrode, which is coated with some metal vapor of cesium, and are extracted from an anode hole of the ion source.

Table 1: Parameters of the 650keV Pre-injector

HVT voltage (Acc. Voltage)	-630~-650kV
Beam energy at beam irradiation	630~650keV
Accelerated particle	H$^-$ ions
Type of ion source	Multi-cusp surface H$^-$
Max. Beam current (pulsed mode)	10mA/peak (10-25Hz, 0.1-0.3msec)
Max. Beam current (dc mode)	0.5mA/dc

EXPERIMENTAL SETUP

Figure 1 shows a target chamber where placed in the 650keV energy beam line. A movable multiple target holder is installed in this target chamber, where four target frames are re-mountable. The H$^-$ ion beam irradiation for several carbon foils were performed by dc and pulsed beam. The temperature of beam spot on the carbon foil was measured by an electronic pyrometers. One model is the IR-AHU (900-3000ºC, λ=0.65µm) [6]

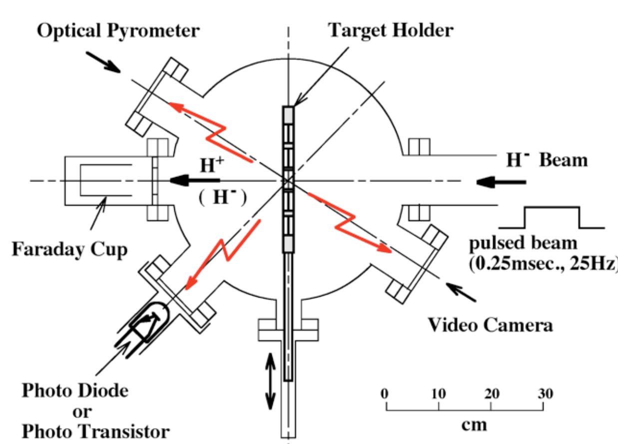


Figure 1: Experimental setup of a target chamber.

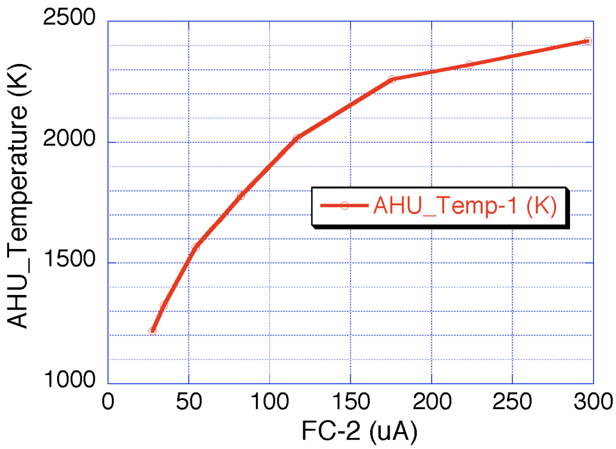


Figure 2: Brightness temperature on beam spot as a function of dc beam current during the irradiation.

By the pulsed mode, the maximum irradiated beam was a peak current of about 3mA (width: 0.25msec, Repetition rate: 25Hz). The average temperatures of beam spot were measured by the electronic pyrometer during both dc and pulsed mode irradiations [5].

In dc beam mode, the irradiated beam currents were 20~300 μA. The maximum brightness temperature at the beam spot of 2-3 mm diameter was 2400 ºK as shown in fig. 2.

A photo-detector with a phototransistor (Stanley, PS3022) [7] and a photodiode (Hamamatsu, S1336) [8] are installed in target chamber to observe the time structure of light from the beam spot. Some electric circuits of photo-detector is shown in figure 3. A large non-linear signal output is expected from the relationship between the temperature and the intensity of thermal radiation [9].

In photo-detector circuits, the signal outputs from a photodiode or a phototransistor are read by DVM (digital voltage meter) for dc beam or by an oscilloscope for pulsed mode.

By using relationship between dc and pulsed signal about the temperatures, a correction curve is obtained. And then the peak temperatures of beam spot on the carbon foil with pulsed beam are deduced.

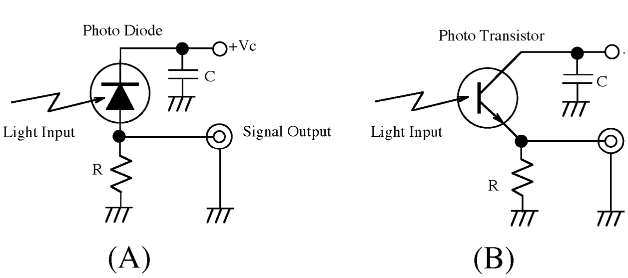


Figure 3: Electric circuits of photo detector (A)Photodiode (B)Phototransistor

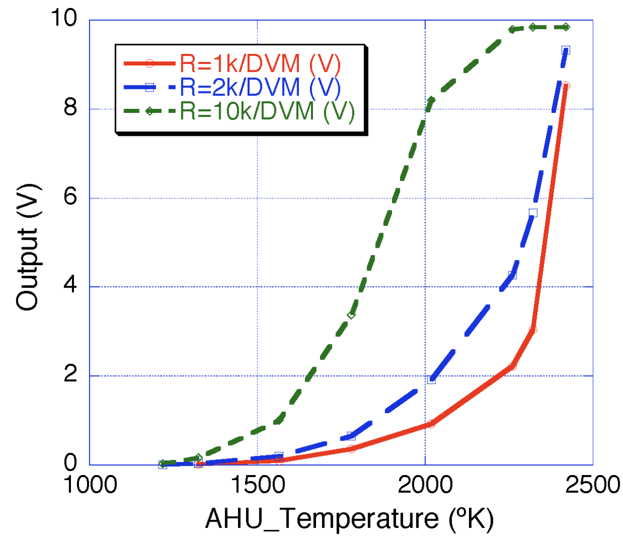


Figure 4: Phototransistor(PS3022) output vs foil temperature by dc beams with R=1, 2, 10kΩ, respectively.

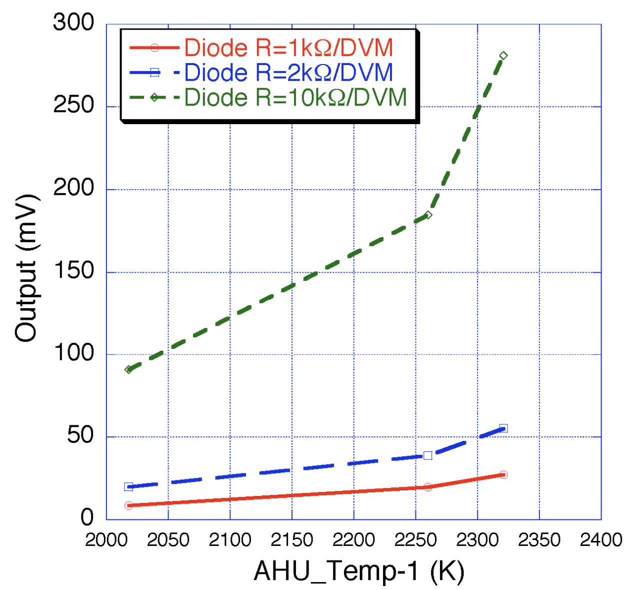
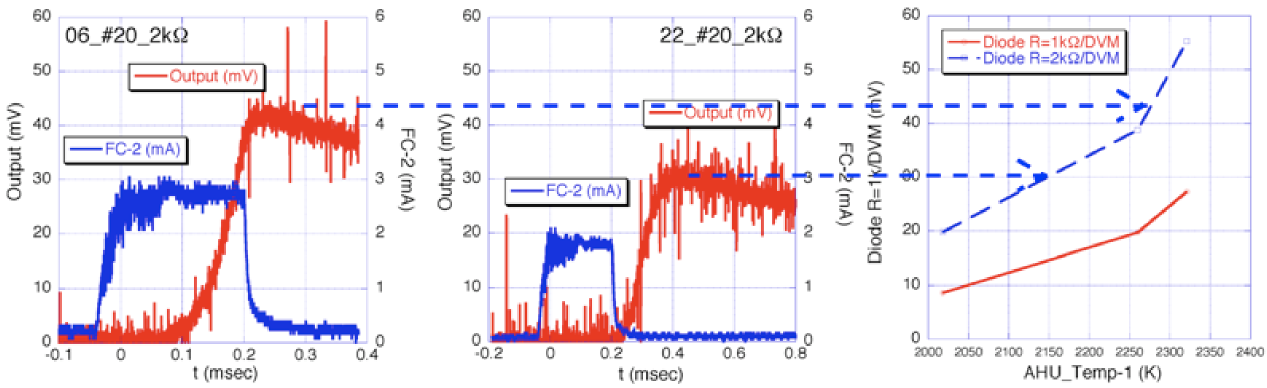


Figure 5: Photodiode(S1336) output vs foil temperature by dc beams with R=1, 2, 10kΩ, respectively.

EXPERIMENTAL RESULTS

Signal outputs from the phototransistor and the photodiode are shown in figure 4 and figure 5 as a function of observed foil temperatures at the dc beam irradiations in respectively.

During the pulsed beam irradiation (250μsec, 25Hz), it was observed that brightness changed by time to time. The output signals from photo detectors were measured by various values of output resistor. It was observed that higher level output but slow response with R=10kΩ. Output signal with R=1kΩ showed a good time response for temperature rise and suitable level of voltage. The pulsed temperatures were deduced by using R=2kΩ in this case as an example.



(a) R=2kΩ:2.8nA / 2150K (b) R=2kΩ:1.8nA / 2270K (c) Reference temperature cure

Figure 6: Peak temperatures of beam spot on the foil from photodiode output calibrated by dc beam.

A pulsed temperature was deduced by using a correction curve in figure 5. The pulsed temperature on the foil is obtained by these relationship temperature-phototransistor output as shown in figure 6.

It shows that the maximum foil temperature are 2270ºK at pulsed beam of 2.8mA (0.25msec, 25Hz) in figure 6(a), 2150ºK at pulsed beam of 1.8mA (0.25msec, 25Hz) in figure 6(b), in respectively.

SUMMARY

We are developing the measuring method of the peak temperature using a photodiode and a phototransistor when a foil is irradiated by 650keV pulsed H^- beam. The peak temperatures of beam spot on the carbon stripper foils at the pulsed irradiation were observed by using the data from dc and pulsed photo-signal.

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