MEASUREMENTS OF THE TEMPERATURE ON CARBON STRIPPER FOILS BY PULESD 650KEV H- ION BEAMS

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Abstract

Thick carbon foils (>300 μg/cm2) has been used for stripping of H^- ion beam at the 3GeV Rapid Cycling Synchrotron (3GeV-RCS) of J-PARC, where foils with long lifetime against high temperature >1800ºK are strongly required for efficient accelerator operations. The key parameter to the foil lifetime is foil temperature attained during irradiation. We have recently developed a new irradiation system for lifetime measurement using the KEK 650keV Cockcroft-Walton accelerator with high current pulsed and dc H^- beam, which can simulate the high energy-depositions upon foils in the RCS. During irradiation tests by this system, the temperature of foil is measured by a thermometer in a dc mode, and by using a phototransistor in a pulsed mode. This paper describes the pulsed measurements with 3mA-peak current, 0.25msec duration and 25Hz repetition.

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], [3].

Although several calculated results have been reported on the foil temperature [4], [5], [6], 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 [7].

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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)	20mA/peak (10-25Hz, 0.1-0.3msec)
Max. Beam current (dc mode)	0.5mA/dc

EXPERIMENTAL SETUP

Figure 1 shows a target chamber which is placed in the 650keV energy beam line. A movable multiple target folder is installed in this target chamber, where four target frames are 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 two sets of electronic pyrometers. One model is the IR-AHU (900-3000ºC, λ=0.65μm) [8] for higher temperature and the other the FTZ9 (300-2000ºC, λ=0.8-1.6μm) [9] for lower temperature lower than 900ºC.

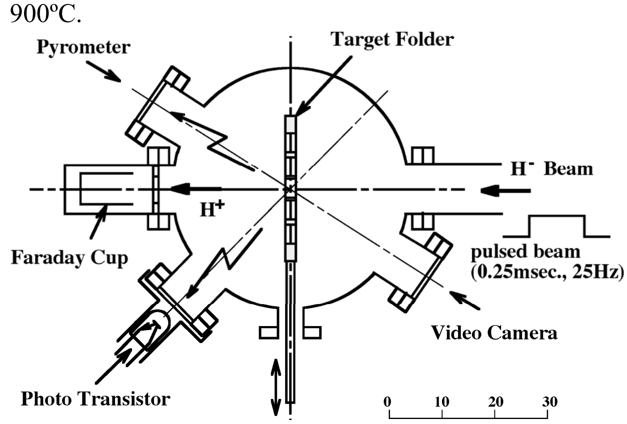

Figure 1: Experimental setup of a target chamber.

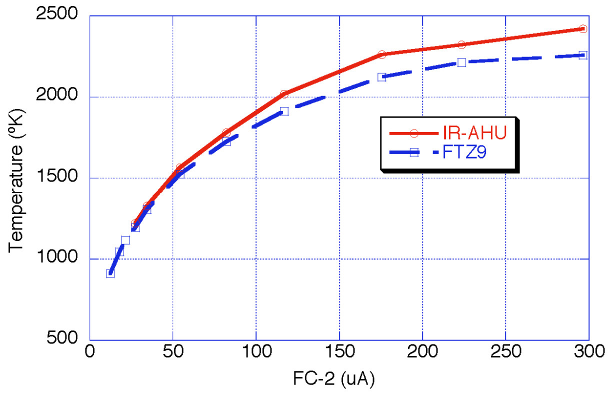

Figure 2: Brightness temperature on beam spot as a function of dc beam current during the irradiation.

By the pulsed mode, the maximum irradiated beam was a peak current of about 7mA (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 [7].

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) [10] is installed in target chamber to observe the time structure of light from the beam spot. An electric circuit of photo-detector with a phototransistor 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 [11].

By using this photo-detector circuit, the signal outputs from 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 foil temperatures with pulsed beam are deduced.

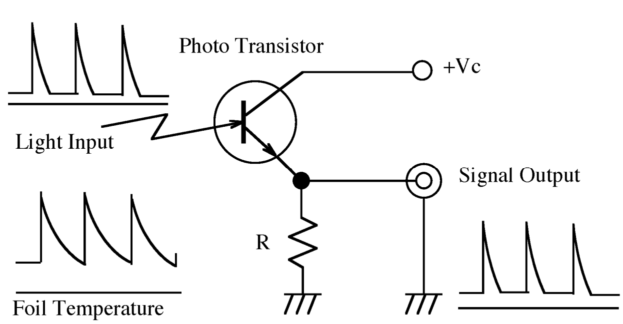

Figure 3: Electric circuit of photo detector

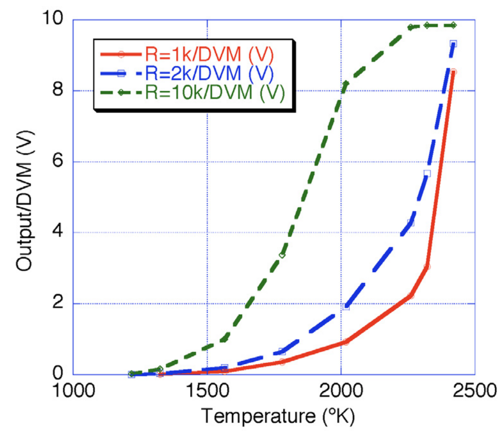

Figure 4: Photo-transistor output vs foil temperature by dc beams with R=1, 2, 10kΩ, respectively.

EXPERIMENTAL RESULTS

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

In pulsed irradiation, the observed waveform of the output signal from phototransistor and beam pulses are shown in figure 5. During the pulsed beam irradiation (250µsec, 25Hz), it was observed that brightness changed by time to time. The output signals from phototransistor 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 temperature was deduced by using R=1kΩ.

A pulsed temperature was deduced by using a correction curve in figure 4. The pulsed temperature on the foil is obtained by these relationship temperature-phototransistor output as shown in figure 6.

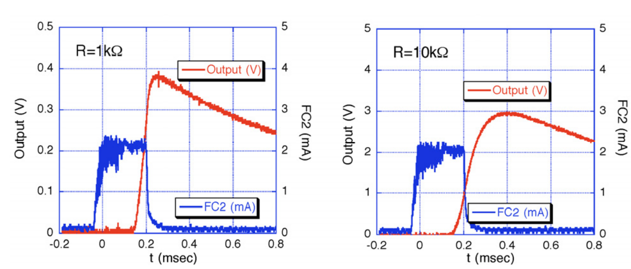

Figure 5: Beam pulses and output signals from a phototransistor by pulsed beam at various output resistors with R=1, 10 kΩ, respectively.

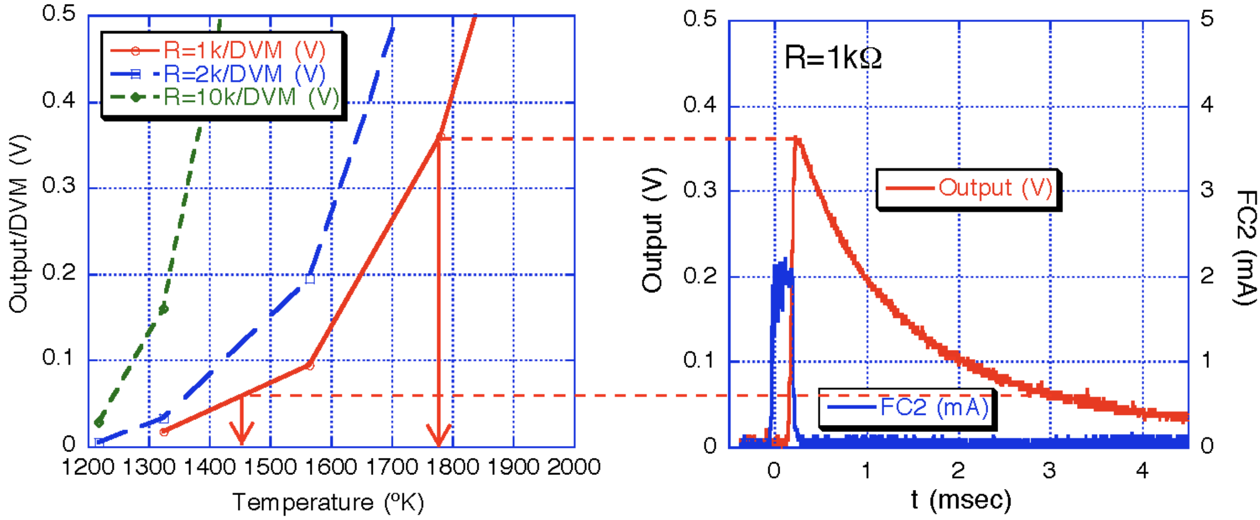

Figure 6: Foil temperatures and phototransistor output.

It shows that the maximum foil temperature is 1780ºK at pulsed beam of 2mA (0.25msec, 25Hz) in figure 6. The lower limited signal shows a lower limited value of about 1300ºK in this setup.

SUMMARY

We are developing the measuring method of the temperature using a phototransistor when a foil is irradiated by 650keV pulsed H$^-$ beam. Preliminary results are presented. The peak temperatures of beam spot on the carbon stripper foils at the pulsed irradiation were observed by using dc and pulsed beam. Furthermore experiments are needed to get more precise calibrated values about the fast temperature measurement.

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