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Improvement of the High Fluence Irradiation Facility at the University of Tokyo

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A B S T R A C T

This paper reports the modification of the High Fluence Irradiation Facility at the University of Tokyo (HIT). The HIT facility was severely damaged during the 2011 earthquake, which occurred off the Pacific coast of Tohoku. A damaged 1.0 MV tandem Cockcroft-Walton accelerator was replaced with a 1.7 MV accelerator, which was formerly used in another campus of the university. A decision was made to maintain dual-beam irradiation capability by repairing the 3.75 MV single-ended Van de Graaff accelerator and reconstructing the related beamlines. A new beamline was connected with a 200 kV transmission electron microscope (TEM) to perform in-situ TEM observation under ion irradiation.

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1. Introduction

The High Fluence Irradiation Facility at the University of Tokyo (HIT) is an accelerator facility located in Tokai-mura, Ibaraki, Japan. This facility has two electrostatic accelerators: a 1.0 MV tandem Cockcroft-Walton accelerator and a 3.75 MV single-ended Van de Graaff accelerator. It has been in operation since 1984 and has been used especially to perform investigations into irradiation damage in metallic materials [1].

At 14:46 on March 11, 2011, the historic M9 earthquake struck Japan. During the main shock, the HIT facility, located 270 km from the epicenter of the main shock, was not severely damaged to both accelerators. In addition to the main shock, a M7.9 aftershock at 15:15 seemed to have caused severe damage as its epicenter was closer, at approximately 70 km, to the HIT. The major damages sustained due to the earthquake are summarized in Fig. 1.

During the earthquake, the Cockcroft-Walton accelerator collapsed from its supports, fracturing the accelerating tube. The connecting bellows between the accelerator and the other components were also fractured. As a result, practically all of the SF_6 contained inside the tank escaped into the atmosphere through the fractures in the accelerating tube and bellows. The inner shell covering the high voltage terminal of the Van de Graaff accelerator was shaken and released from the shell clamps that were severely deformed. A beamline pipe was broken at the ceramic insulator nipple, and some bellows connecting beamlines and chambers were also damaged. Two magnetic levitation-type turbo-molecular pumps, both of which had been installed horizontally, became inoperable. It should be noted, however, that all other turbo molecular pumps including those installed vertically survived the megaquake, even though some were in operation at the time of the incident. Latching hardware on two swinging shielding doors was completely broken. Because one of the broken doors could not be closed manually and so was left partially open to the outside, a radioactive plume, which arrived from the damaged Fukushima Dai-ichi Nuclear Power Plant on March 15, contaminated the floor and wall inside the radiation-controlled area. Additionally, because the anchoring bolts could not bear the seismic shock, several components shifted slightly eastward. According to the GPS analysis of Geospatial Information Authority of Japan, the crust around Tokai-mura also shifted 1 m eastward [2], which is consistent with the shift direction of components.

To resume the accelerator operation as quickly as possible with limited availability of funds, it was necessary to consider what kind of irradiation environment is most required for the research

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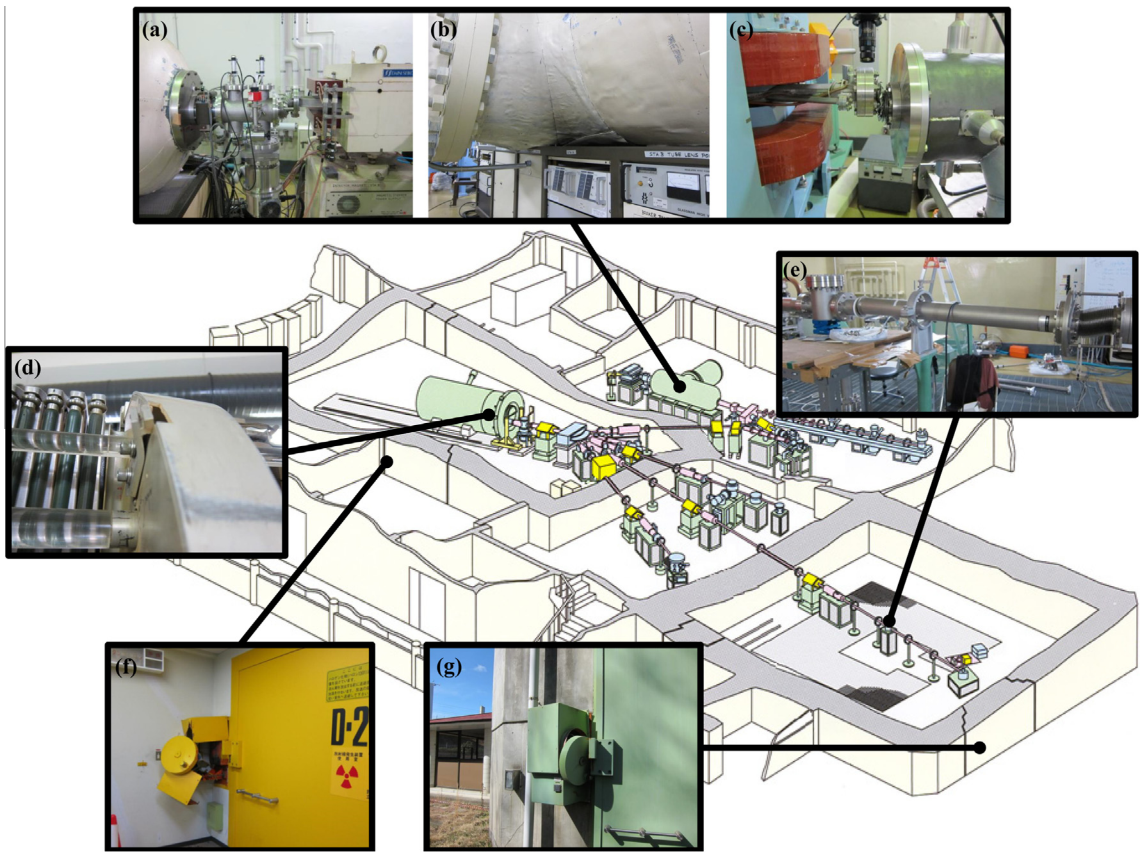

Fig. 1. Summary of the seismic damage in HIT facility. (a) Low energy end, (b) tank, (c) high energy end of the 1 MeV tandem Cockcroft-Walton accelerator. (d) Bended shell clamp of the 3.75 MV single-ended Van de Graaff accelerator. (e) Fractured insulator and bellows of a beamline. (f, g) Broken latching hardware of swinging shielding doors. Fission product from Fukushima Daiichi NPP flew in through the partially open door at (g).

communities, instead of fully repairing the seismic damage. This paper describes the reconstruction of the HIT facility in keeping with recent research trends on the effect of radiation on metals. In addition to restoring the dual-beam irradiation capabilities, which have been present at the HIT facility since it has been in operation, a new beamline for in-situ observation was constructed.

2. Replacement of tandem accelerator

A 1.7 MV tandem Cockcroft-Walton accelerator made by High Voltage Engineering Europe (HVEE) replaced the original tandem accelerator, which was destroyed in the earthquake. The replacement accelerator was previously used at the RAPID facility at the Asano campus of the University of Tokyo [3], where it was scheduled for decommissioning in a few years. Dual ion sources also manufactured by HVEE: a 360 lithium canal, and a 860 cesium sputter, were also relocated to HIT. The ion species and the beam current measured at beamlines of 10° from the accelerator's axis are shown in Fig. 2. When Fe^{2+} ions are accelerated by 1 MV of terminal voltage, 10^{16} ions/m^{2}s of ion flux can be obtained at the irradiation chamber with magnetic lenses on the beamline, with the maximum flux approximately corresponding to 10^{-3}dpa/s in iron-based materials.

In order to replace the accelerator, related beamlines had to be relocated and reassigned. Fig. 3 shows the reallocation of beamlines. No significant changes were made to BL0, BL1, BL2 and BL3. BL0 is the straight beamline from the Van de Graaff accelerating tube and is used for microparticle acceleration experiments focused on cosmic dust detector development [4]. BL1 is for a pulsed ion beam whose full-width half-maximum (FWHM) is

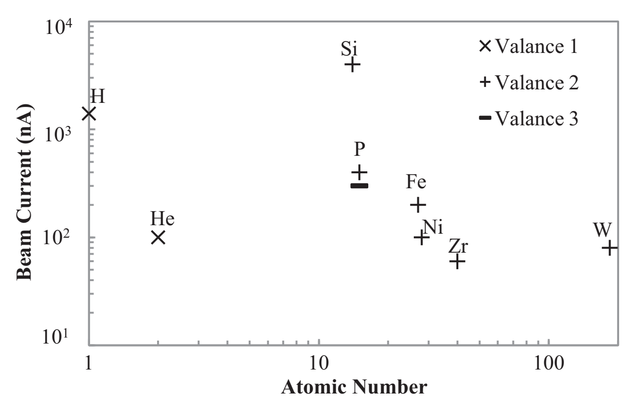

Fig. 2. Ion species and the beam current at the BL5 or BL6 of 1.7 MV tandem Cockcroft-Walton accelerator at the HIT facility.

1.8 ns [5]. The terminal chamber is designed for conducting tests on proton beam extraction into air environments, and for steam corrosion tests under proton irradiation [6]. BL2 was originally for neutron generation [7] but a terminal chamber connected to a 30 kV slow positron beamline with a 740 MBq Na-22 radiation source was later added. Additionally, in-situ Doppler broadening measurement is available [8]. The control of the sample temperature in the chamber from 12 K to 773 K, as well as isochronal annealing after low temperature is also possible [9]. BL3 is a beamline featuring a wide variety of applications including particle-induced X-ray emission analysis, ion-beam induced luminescence experiments, and high temperature (approximately

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