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§6. Radiation Induced Behavior of Hydrogen Isotopes Retained in Blanket Oxide Ceramics Materials for Fusion Reactors

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Rare-earth-doped proton-conducting perovskite-type oxide ceramics might be suitable as new functional materials for highly efficient energy converters that transform the energy released by chemical reactions, heat, optics, or radiation into electricity. Our group has studied the conversion of radiation energy into electricity using proton-conducting oxide ceramics. [1, 2] We have revealed that the electrical properties of insulators are modified dynamically by electrons that are excited from valence bands to conduction bands by ionizing radiation. The conductivity of such electrons is called radiation-induced conductivity (RIC). The charge states and mobilities of constituent ions and impurities such as hydrogen included in the ceramics are also modified by the radiation; this is referred to as radiation-induced electrical degradation (RIED). In particular, it is one of significantly assignments to understand the correlation between the hydrogen behavior and the radiation phenomena.

In the present study, the behavior of hydrogen ions trapped in proton conductors exposed to radiation environments was studied. For this purpose, the conductivities of a typical hydrogen (H or D)-doped $BaCe_{0.9}Y_{0.1}O_{3-\delta}$, implanted in a zirconium electrode using 10-keV H_2^+ (or D_2^+) ions at a fluence of 1.0×10^{22} H^+ (or D^+) ions/m^2, were measured in situ at an elevated temperature of 473 K during and after irradiation with a 1.8-MeV electron beam (ionization dose rates: 10–1000 Gy/s). The dependence of RIC on the irradiation dose was investigated, and the correlation among migrations of the doped-hydrogen and constituent ions, RIC, and RIED was determined by means of X-ray photoelectron spectroscopy (XPS) and ultraviolet and visible (UV-VIS) optical absorptions.

Figures 1(a), (b), and (c) show the effects of dose on RIC (●), σ_{RIC}, under irradiation and on the base conductivity (○), σ_{BC}, in the absence of radiation for $BaCe_{0.9}Y_{0.1}O_{3-\delta}$ samples doped with H, doped with D, and not doped, respectively, at 10–1000 Gy/s and 473 K. These relationships were determined from Ohm's law using the increment of the currents when applied from 0 to +10 V and the volume of the samples. The radiation-induced current was also proportional to the applied voltage under a constant irradiation intensity. The σ_{BC} value becomes higher because of ionizing effects just after irradiation begins; this is indicative of RIC. In addition, the σ_{BC} and the σ_{RIC} values of $BaCe_{0.9}Y_{0.1}O_{3-\delta}$ become approximately one and two orders of magnitude lower as the dose increases at approximately 8.0 MGy. These results indicate the occurrence of RIED.

The XPS spectra of the valence-band and Ce 3d regions and the optical absorption spectra of UV-VIS reveal the formation of Ba and Ce hydrides or hydroxides. This indicates that RIED is caused by a reduction in the concentration of defects created by doping Y^{3+} ions into the $BaCeO_3$ matrix and the suppression of protonic conductions by the reaction of activated protons with holes or activated oxygen ions.

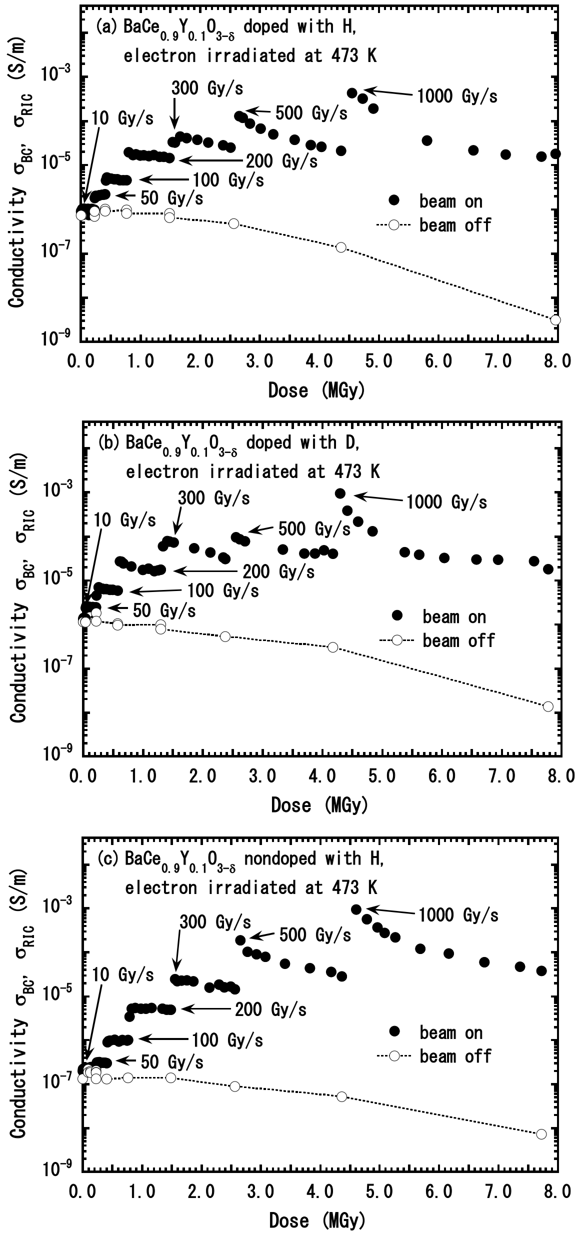

Fig. 1. Base conductivity, σ_{BC}, and RIC, σ_{RIC}, of $BaCe_{0.9}Y_{0.1}O_{3-\delta}$ samples (a) doped with H, (b) doped with D, and (c) not doped with H, where σ_{BC} and σ_{RIC} represent data on 1.8-MeV electron beam on at 10–1000 Gy/s and 473 K and off, respectively.

1) Tsuchiya, B., Moroño, A., Hodgson, E.R., Nagata, S., Toh, K., Shikama, T.: Physica Scripta **T118** (2005) 18.
2) Tsuchiya, B., Shikama, T., Nagata, S., Toh, K., Narui, M., Yamazaki, M.: J. Nucl. Mater. **367–370** (2007) 1073.