§7. Radiation Induced Behaviors of Hydrogen Trapped in Oxide Ceramics for Fusion Reactor Blanket

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Radiation-induced changes in the electrical conductivity of oxide ceramics have been studied using electron and ion beams, gamma rays, and neutrons. [1, 2] 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). In addition, the charge states and mobilities of constituent ions and impurities such as hydrogen included in the ceramics of concern are also modified by the radiation; this is referred to as radiation-induced electrical degradation (RIED). RIED is a very interesting phenomenon from the point of view of fundamental studies on radiation effects in ceramics. However, the correlation between the hydrogen behavior and the radiation phenomena is not yet fully understood.

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)-doped proton-conducting oxide ceramic ($\mathrm{BaCe_{0.9}Y_{0.1}O_{3-\delta}}$), implanted in a zirconium electrode using 10-keV $\mathrm{H_2^+}$ ions at a fluence of 1.0 × 10^{22} $\mathrm{H^+}$ ions/m^2 were measured in situ during and after irradiation with a 1.8-MeV electron beam (ionization dose rates: 10 Gy/s). The dependence of RIC on the irradiation temperature and time were investigated.

Figs. 1(a), (b), and (c) show the effect of irradiation time on the RIC and base conductivity of H-doped $\mathrm{BaCe_{0.9}Y_{0.1}O_{3-\delta}}$ at 10 Gy/s and 298, 473, and 623 K, respectively. The dotted curves in Fig. 1 (a)–(c) represent base conductivity during irradiation, interpolated from the data recorded at the beginning and end of irradiation. At several temperatures, the RIC is considerably higher than the base conductivity. It can be seen from Fig. 1 that the RIC increases with the irradiation temperature and tends to stabilize just after irradiation begins. Furthermore, the RIC at 298 and 473 K is almost constant for irradiation times of approximately 300–400 min (dose: 1.8–2.4 X 10^5 Gy), while the RIC at 623 K gradually decreases as the base conductivity decreases. The difference between the RIC and base conductivity ΔRIC ($\sigma_{\mathrm{RIC}}-\sigma_{\mathrm{BC}}$) for H-doped $\mathrm{BaCe_{0.9}Y_{0.1}O_{3-\delta}}$ at 473 K is approximately one order of magnitude higher than that for $\mathrm{BaCe_{0.9}Y_{0.1}O_{3-\delta}}$ not doped with H; this is an effect of hydrogen doping. However, ΔRIC for H-doped $\mathrm{BaCe_{0.9}Y_{0.1}O_{3-\delta}}$ at 298 and 623 K is almost identical to that for $\mathrm{BaCe_{0.9}Y_{0.1}O_{3-\delta}}$ not doped with H. The values of ΔRIC at 298 and 473 K are also almost constant when the irradiation time is increased. The ΔRIC at 298 K is mainly caused by electronic excitations from valence bands to conduction bands, which in turn are caused by the slow diffusion of hydrogen atoms in $\mathrm{BaCe_{0.9}Y_{0.1}O_{3-\delta}}$ below 473 K. The difference between ΔRIC at 473 K for $\mathrm{BaCe_{0.9}Y_{0.1}O_{3-\delta}}$ doped and not doped with H indicates that the ionizing effects of radiation are modified by hydrogen diffusion as well as electronic excitations. Moreover, the ΔRIC at 623 K decreases slightly as the irradiation time increases; this is attributed to the change in base conductivity during irradiation. The effects of radiation on conductivity reveal the occurrence of RIED.

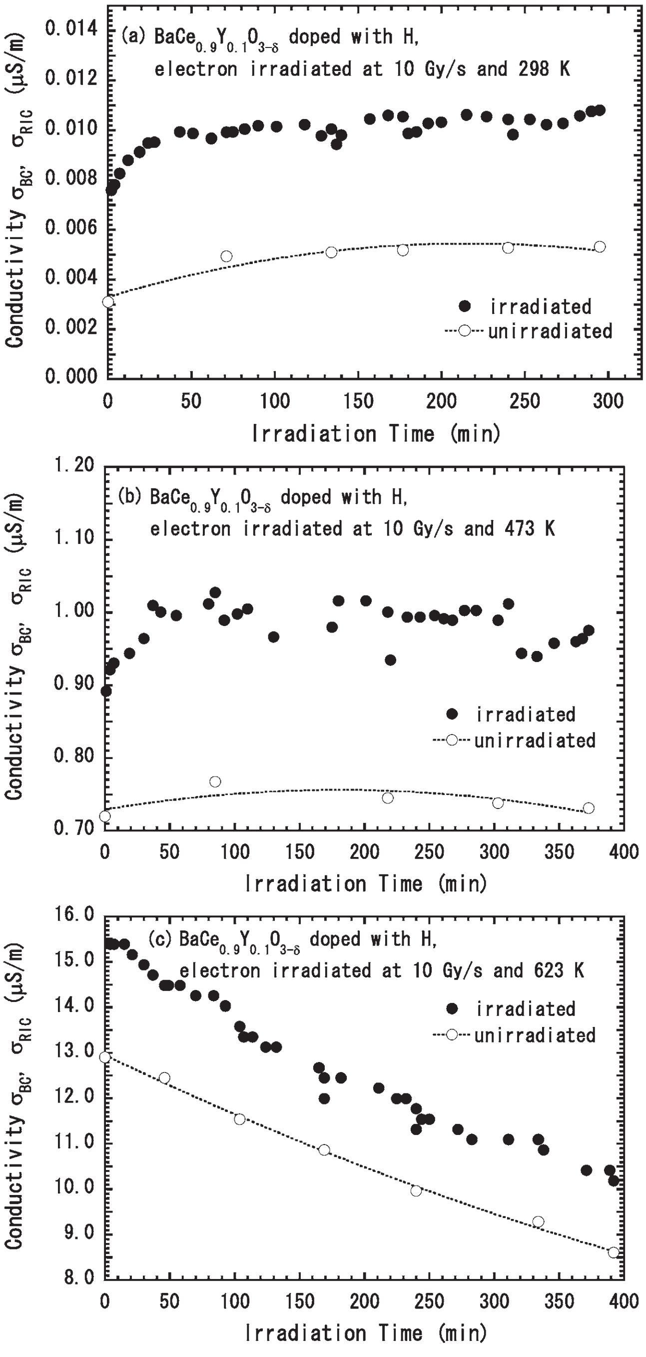

Fig. 1 RIC of H-doped $\mathrm{BaCe_{0.9}Y_{0.1}O_{3-\delta}}$ samples irradiated using 1.8-MeV electron beams at 10 Gy/s and (a) 298 K, (b) 473 K, and (c) 623 K..

1) Hodgson, E. R., Nucl. Instr. and Meth. in Phys. Res. B 191 (2002) 744.
2) Tsuchiya, B., Shikama, T., Nagata, S., Toh, K., Narui, M. and Yamazaki, M., J. Nucl. Mater. 367-370 (2007) 1073.