Hydrogen generation by water splitting using TiO_2 and 3C-SiC in tandem structure

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Hydrogen generation by water splitting using semiconductor photoelectrodes is attracting attention as a next generation energy technology utilizing sunlight. The tandem structure is a structure in which a plurality of semiconductors is stacked in series. This allows light energy that cannot be absorbed by the first few layers of semiconductor to be absorbed by the next few layers. This research is being conducted to utilize this tandem structure with TiO_2 and 3C-SiC for hydrogen generation. Figure 1 shows the schematic diagram of tandem structure.

As samples of this experiment, a Nb-doped rutile TiO_2 (band gap: 3.2 eV) with concentration of 0.01 wt%, and a p^+-type 4H-SiC substrate having an off angle of 0.7° with p-type 3C-SiC (band gap: 2.2 eV) epitaxially grown on was used (Film thickness: 30 μm, acceptor concentration: $N_A < 1 \times 10^{15}$ cm^{-3}). Both the two samples were fabricated by fixing the material on a polycarbonate plate by wax with only the surface exposed.

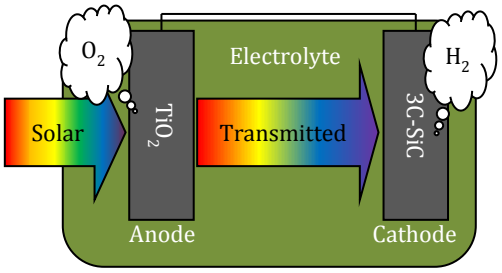

Fig. 1 Schematic of tandem structure

The TiO_2 and 3C-SiC samples were tested by photoelectrochemical (PEC) analysis with a three-electrode system respectively before they were used in tandem structure. For the PEC measurement, the aqueous solution was 1 mol/L of H_2SO_4, the TiO_2 or 3C-SiC sample was used as the working electrode, a Pt plate was used as the counter electrode, and an Ag/AgCl was used as the reference electrode. Exposed part of the sample is irradiated with light by a solar simulator with an irradiation intensity of 100 mW/cm^2. We scanned the potential at 5 mV/s while irradiating light at 10 second intervals. Figure 2 shows the results of PEC analysis for TiO_2 and 3C-SiC with red and blue lines, respectively.

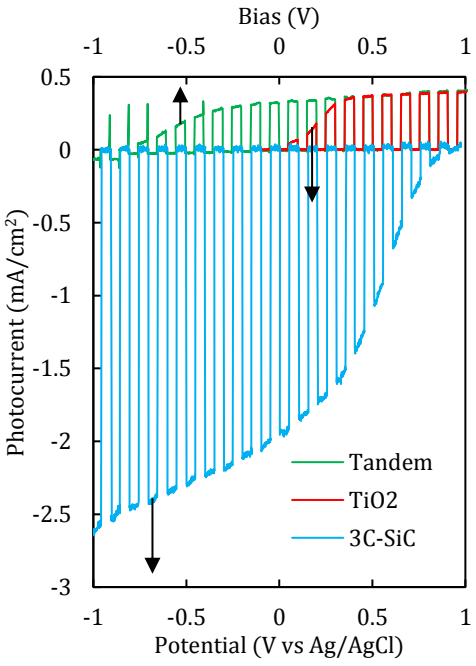

Fig. 2 Chopped light I–V curve of the tandem structure and PEC analysis of the TiO_2 and 3C-SiC samples.

The characteristics of the tandem structure were measured by photocurrent-voltage (I-V) in a two-electrode type cell. The aqueous solution and the lighting conditions are the same as that used in the PEC analysis. TiO_2 was used as the anode while 3C-SiC was used as the cathode. The two samples were placed one in front of the other, TiO_2 was first irradiated, and the transmitted light was absorbed by 3C-SiC. The I–V curve obtained is shown in Figure 2 with green line. As shown, when the bias is 0, the photocurrent is about 0.31 mA. From the photocurrent, we estimated a solar-to-hydrogen conversion efficiency of 0.38% for the tandem structure.

This work is supported by the Hibi Science Foundation.

[1] Naoto Ichikawa et al., International Journal of Hydrogen Energy, 42, 22698 - 22703 (2017)