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Photoelectrochemical CO_2 reduction on 3C-SiC photo-anode

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1. Introduction Many investigations have been attempted for establishing the CO_2 conversion system, because CO_2 is considered as greenhouse gas and an energy resource for useful chemical energy such as formic acid (HCOOH) and methanol (CH_3OH) [1]. Since TiO_2 photo-electrode for water-splitting was demonstrated, electrochemical CO_2 reduction with inorganic photo-electrode has been regarded as a promising method. For this system, the material of photo-electrode must have band-structure for CO_2 reduction potential. As one of candidates, 3C (Cubic) type SiC has an appropriate band-gap, 2.2 eV for significant solar-light absorption and the sufficient band-edge level for CO_2 reduction [2]. Despite of its potential, most researches for SiC photo-electrode has been focused on water-splitting. Herein, we demonstrated the electrochemical CO_2 reduction system with n-type 3C-SiC photo-electrode.

2. Experiments n-type 3C-SiC (N doping density: 1.0×10^{16} cm^{-3}) grown by low pressure vapor deposition (LPCVD) was used as a photo-anode. An aluminum (Al) layer 200 nm in thickness was deposited on backside for ohmic contact. Photoelectrochemcal (PEC) cell contains 0.1 M NaOH (pH = 13.6) and 0.1 M $KHCO_3$ (pH = 8.5) electrolytes in anode and cathode sides separately with ion exchange membrane. As a counter electrode, a Pt wire was utilized. A 500 W Xe lamp which has characteristic of solar-light spectrum was implemented for light illumination. As a process of the gas analysis, N_2 gas was injected first for 10 min to purge the inside and CO_2 gas was bubbled to only cathode part for 30 min. Then, PEC cell was sealed immediately after finishing the CO_2 bubbling. After the PEC reaction at the applied bias of -0.8 V (vs. counter electrode) for designated time, collected gases were analyzed by real-time monitoring gas-chromatography that we have established.

3. Results and discussion

CH_4 and CO gases are successfully generated as the products of CO_2 reduction with 3C-SiC photo-anode. The products were analyzed with different flowed charge amounts, 0.04, 0.09, 0.11, and 0.26 C. In Fig. 1, it is shown that H_2 production increases linearly with regards to charge amount. Figure 2 shows the CO and CH_4 gases are produced after PEC reaction. CO and CH_4 gases increase to ~ 0.003 and ~ 0.001 μmol at 0.09 C. However, the amount of products diminishes to ~ 0.002 and ~ 0.0008 μmol for CO and CH_4, respectively at 0.26 C. It means that no CO_2 reduction occurs after ~ 0.1 C. Although CO_2 reduction proceeds in the early phase of the reaction (< 0.1 C), it is suppressed after 0.1 C due to high adsorption property of hydrogen ion on Pt electrode [3]. In conclusion, these results demonstrate possibility of CO_2 reduction with 3C-SiC, but it is necessary to reduce H_2 generation and improve the CO_2 conversion rate with different counter electrode.

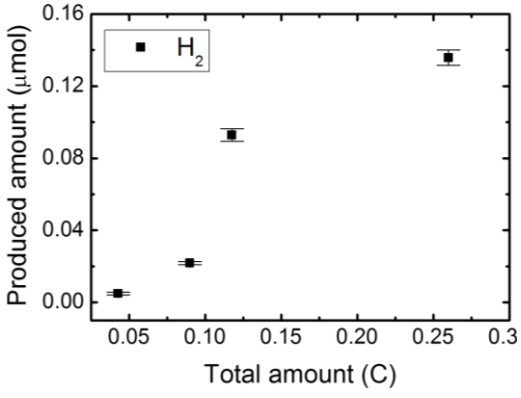

Figure 1. H_2 gas generation with total charge.

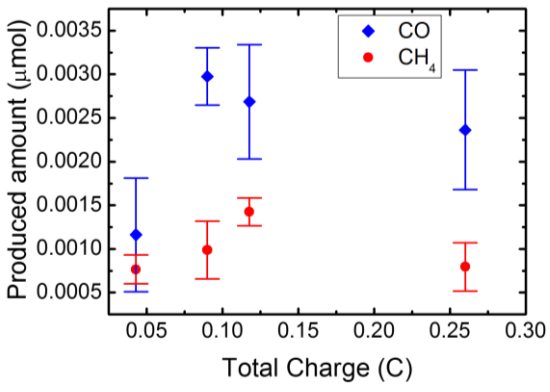

Figure 2. Gas production by CO_2 reduction.

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References

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