

Electroreduction of Carbon Dioxide using Tin-Lead Alloy Catalyst

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Extended Abstract

Electrochemical conversion of CO₂ has promise to help overcome several of the challenges facing the implementation of carbon-neutral energy sources because it provides a means of storing renewable electricity in a convenient, high energy-density form (Whipple et al., 2010). In particular, electrochemical reduction of CO₂ at heterogeneous metal surface in aqueous solution is a promising technique for making useful end products, because the system is simple and the product can be selectively controlled by changing the electroreduction conditions, such as electrode and electrolyte (Ikeda et al., 1987). Conversion to formic acid/formate appears to have the best chance for the practical development of technically and economically viable processes, because formic acid can be obtained with high selectivity in aqueous electrolyte (Olomal et al., 2008). In the present work, electrochemical reduction of CO₂ to formate in aqueous solution was studied using Sn, Pb and Sn-Pb alloy as electrocatalyst. Electrodes were obtained by electrochemical deposition of Sn, Pb and Sn-Pb alloy on a carbon paper at potentiostatic condition of -0.55 V (vs. Ag/AgCl). The prepared electrodes were characterized by morphology and structure. The electrochemical behaviours of the electrodes were measured by cyclic voltammetry analysis. In addition, Faradaic efficiency and partial current density of formate production on the Sn-Pb alloy were investigated and compared with those on pure Sn and Pb.

The morphology of the electrodes prepared by electrodeposition was investigated by scanning electron microscopy (SEM), which confirmed that tin, lead and tin-lead alloy were deposited successfully on a carbon paper. The structure of the deposits were investigated by X-ray diffraction (XRD) patterns of the Sn, Pb, and Sn-Pb alloy, obtained in a 2 Θ range from 30 to 80 degree. Reflections for both tin and lead were observed in the X-ray diffractogram of Sn-Pb alloy with a little excursion of peak approaching, indicating that tin and lead were electrodeposited side by side on the surface as a solid solution phase of Sn-Pb alloy. Cyclic voltammetry (CV) analysis was carried out using prepared electrodes as a working electrode at 298 K in three-electrode cell. The electrolyte used for CV measurement was 0.5 M KHCO₃ aqueous solution. Cyclic voltammograms were recorded from -2.2 V to 0.2 V (vs. Ag/AgCl) with scan rate of 50 mV·s⁻¹. The voltammetric results indicate that the Sn, Pb, and Sn-Pb alloy facilitate selective reduction of CO₂. Electroreduction experiments were performed at ambient temperature and pressure in a H-type two compartment cell, which designed to be separated into the two compartments of cathode and anode chambers by an ion exchange membrane (Nafion® 115). The cathode potential was controlled by -2.0 V against the Ag/AgCl using potentiostat/galvanostat. An aqueous solution 0.5 M KHCO₃ was used as catholyte, while 0.5 M KOH was used as anolyte. The catholyte was saturated with CO₂ by bubbling CO₂ gas for 5 h before experiment. Electrolysis was conducted during 30 min and the liquid samples were taken a 10 min intervals of operation time from the cathode chamber, and analysed using a HPLC to determine the amount of formate produced. As results, the Sn-Pb alloy electrode showed the highest Faradaic efficiency of 77.5 %, while the Sn and Pb electrodes exhibited efficiencies of 70.3 and 56.6 %, respectively. In addition, the highest formate production rate (7.6 mol m⁻² h⁻¹) was obtained from the Sn-Pb alloy electrode. Therefore, it can be concluded that the Sb-Pb alloy electrode is better for electroreduction of CO₂ into formate than single metal electrodes.

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