Electrochemical Concentration of O_2 and CO_2 from the Air Using an Anion Exchange Membrane

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Oxygen and carbon dioxide were concentrated from an air feed with the use of an electrochemical cell[1]. Oxygen was concentrated from 20% in the air feed to 85% in the product stream. Carbon dioxide was concentrated from 1% in the air feed to 15% in the product stream.

An electrochemical cell was constructed with the use of an anion exchange membrane and Pt and Ni electrocatalysts for the purpose of concentrating both oxygen and carbon dioxide from the air. Oxygen present in the air is reduced at a Pt/C cathode to hydroxide ions. Carbon dioxide present in the air homogenously reacts with these hydroxide ions to form a carbonated electrolyte. These anions travel across an anion exchange membrane, Neosepta, under the influence of an electric field. At a Ni anode, the reverse reactions occur producing both oxygen and carbon dioxide gas. An example of the relevant reactions is shown in equation 1.

$$\begin{aligned} &\text{Cathode:} \\ &O_2 + 2H_2O + 4e^- \rightarrow 4OH^- \\ &4CO_2 + 4OH^- \rightarrow 4HCO_3^- \\ &\text{Anode:} \\ &4HCO_3^- \rightarrow 4CO_2 + 4OH^- \\ &4OH^- \rightarrow O_2 + 2H_2O + 4e^- \end{aligned} \qquad (1)$$

A maximum of 4 carbon dioxide molecules could be separated for every oxygen molecule according this reaction scheme.

Platinum supported on carbon black obtained from ETEK was used as the electrocatalyst for the cathode. Nickel created through a polyol process was utilized as the electrocatalyst for the anode[2]. Cell potentials and current density readings were taken using a NUV10 potentiostat supplied by Nuvant Systems, Inc. Gas evolution from the anode was monitored using a mass spectrometer from Hiden Analytical. A humidified air flow feed of 50 cm^3/min was used for all experiments. Humidified nitrogen or argon gas served as the sweep gas across the anode to monitor gas evolution. Cell potentials for all experiments were kept below 1.23 V. All experiments were conducted at room temperature and pressure.

Air separation was initially examined using a cell potential range of 0.4 V to 1.2 V. The current density of the cell and the corresponding mass spectrometer reading taken at the anode is shown in Figure 1.

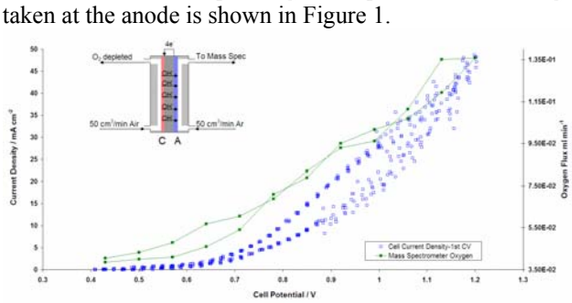

Figure 1. Current density and oxygen readings taken at the anode confirm oxygen separation from the air at potentials lower than 1.0 V.

From Figure 1, it is shown that oxygen is electrochemically separated from nitrogen in the air at potentials lower than 1.0 V. Current density reaches a maximum of 50 mA/cm^2 at a cell potential of 1.2 V.

Over time, the low concentration of carbon dioxide in the air carbonates the electrolyte to form carbonate or bicarbonate anions. Figure 2 shows the concentration of oxygen and carbon dioxide evolving from the anode after the 1st and 6th cycle between 0.4 V and 1.2 V.

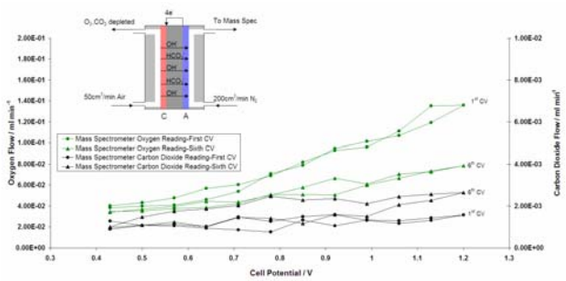

Figure 2. Oxygen evolution decreased as the cycles increased. Carbonation of the electrolyte occurred which resulted in the separation of both oxygen and carbon dioxide from the air.

As is evident from Figure 2, the carbonation of the electrolyte decreases the cell activity. Carbon dioxide separation from the air becomes apparent after the 6th cycle.

A longer term air separation experiment was constructed to determine the steady state gas evolution rates of oxygen and carbon dioxide. Cell potential was set to 1.2 V, and the separation ran for over 24 hours.

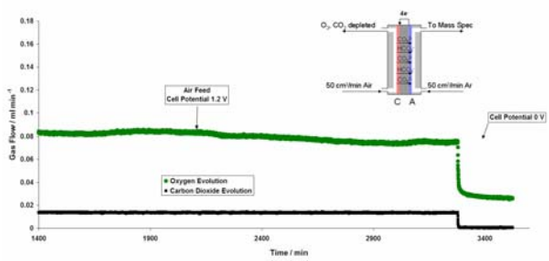

Figure 3. Long term air separation shows the extensive concentration of carbon dioxide from the air that is possible. The resulting gas stream is 15% CO_2.

Extensive concentration of both oxygen and carbon dioxide was possible from the air. Carbon dioxide was concentrated from less than 1% to 15%.

Oxygen and carbon dioxide gas were selectively separated from the air using an anion exchange membrane and cell potentials below 1.23 V. This technology could be used to produce a gas feed for oxy-fired coal plants which burn coal in the presence of oxygen and carbon dioxide. Catalyst innovation could lower the cell potentials necessary to conduct this separation.

References

1. Tomter, S. S., Oxygen Concentrator. *Chemical Engineering Progress* **1965,** 62, (66).
2. Li, D.; Ni, X.; Zheng, H.; Qi, B., A simple Ethylene Glycol Reduction Route to the Fabrication of Metallic Nickel Nanoplatelets with Hexagonal and Triangular Shapes. *Chemistry Letters* **2008,** 37, (2), 148-149.