Development of a zinc/air fuel cell

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Funded by: BMBF
Period: 01.10.2007 – 30.09.2011

Introduction

The recent advances in micro electro-mechanical systems and in downsizing of electronic compounds lead to the development of a new generation of sensors and actuators. These systems often require an autonomous energy supply that has to be miniaturized as well. Because of its high theoretical energy density, low toxic properties and attractive price, the zinc/air fuel cell is an interesting candidate. However, large scale commercialisation of this system is hindered by inherent drawbacks of the zinc electrode, such as poor reversibility, low energy efficiency, shape change and dendrite formation during the charging process. Moreover, the activity of bifunctional catalysts for oxygen reactions and the resistance of gas diffusion electrodes (GDE) towards carbonate poisoning have to be improved.

Electrode reactions

The electrode reactions for the zinc/oxygen system in high concentrated alkaline solution (pH 14) are listed below followed by calculation of the theoretical maximal capacity of 1g zinc:

- Discharging process
  
  Cathode: 0.5 O₂ + H₂O + 2e⁻ → 2 OH⁻ (+ 0.4 V)
  
  Anode: Zn + 4 OH⁻ → Zn(OH)₄²⁻ + 2 e⁻ (-1.25 V)

  Overall reactions: Zn + 0.5 O₂ → ZnO (+1.65 V)

- Charging process
  
  Cathode: ZnO + 2 OH⁻ → Zn(OH)₂ + 2 e⁻

  Anode: Zn + 2 OH⁻ → ZnO + 2 e⁻

  Overall reaction: Zn + 0.5 O₂ → ZnO + 0.5 O₂

Specific capacity: Q = (m/M) + z + F = 819 mAh g⁻¹

Objectives

Five research institutes and five companies are involved in this project that aims at the development of a new type of zinc/air fuel cell (www.ziluzell.de). The last part of this project focused on the development of a electrically rechargeable zinc/air single cell. The development of a new generation of sensors and actuators. These systems often require an autonomous energy supply that has to be miniaturized as well. Because of its high theoretical energy density, low toxic properties and attractive price, the zinc/air fuel cell is an interesting candidate. However, large scale commercialisation of this system is hindered by inherent drawbacks of the zinc electrode, such as poor reversibility, low energy efficiency, shape change and dendrite formation during the charging process. Moreover, the activity of bifunctional catalysts for oxygen reactions and the resistance of gas diffusion electrodes (GDE) towards carbonate poisoning have to be improved.

Experimental

The main work of the KWI in this project deals with the electrochemical characterization of the electrode materials in a half-cell, the development of reaction layer for the air electrode and the test of the different compounds in a laboratory cell. The electrochemical characterization was carried out by using cyclic voltammetry and chronopotentiometry methods. The flow chart of the catalyst, ink and cell preparation and characterisation is shown in figure 2.

Results

Characterisation of the air electrode in the half-cell

Prior the test in fuel cell, the gas diffusion electrode was tested towards oxygen reduction reaction (ORR) in a flow cell. At 50 mA cm⁻², the potential difference between oxygen reduction (discharge) and oxygen evolution (charge) at La₀.₆Ca₀.₄CoO₃ is large and amounts about 925 mV (see Fig. 3).

Tests in the laboratory cell

One important challenge consisted on optimise the laboratory cell for long-term experiments in a way to prevent any electrolyte leak. The best results (17 cycles) were obtained with a paste containing 55% Zn, 4% KS75, 6% CMC and 35% 6M KOH, a Celgard separator and a perovskite-based bifunctional oxygen cathode.

Conclusion & outlook

The feasibility of a rechargeable zinc/air fuel cell composed of a zinc paste, a commercial separator and a bifunctional cathode was demonstrated in the laboratory cell. The corrosion resistance of the air electrode should be improved. Further experiments with a zinc foam and a PVA/TiO₂ membrane have to be carried out.

BMGF and project partners are thanked for financial support and excellent cooperation, respectively.