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Hydroponics gel as a new electrolyte gelling agent for alkaline zinc–air cells

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Abstract

The viability of hydroponics gel as a new alkaline electrolyte gelling agent is investigated. Zinc–air cells are fabricated employing 12 wt.% KOH electrolyte immobilised with hydroponics gel. The cells are discharged at constant currents of 5, 50 and 100 mA. XRD and SEM analysis of the anode plates after discharge show that the failure mode is due to the formation of zinc oxide insulating layers and not due to any side reactions between the gel and the plate or the electrolyte.

Introduction

In this work, zinc–air primary cells are prepared with a low concentration (12 wt.%) of aqueous potassium hydroxide (KOH) electrolyte and a new material, i.e. a hydroponics gel, as an electrolyte gelling agent. Hydroponics gel is a medium used to store water and soluble nutrients in hydroponics technology where plants are grown in nutrient-rich water rather than in soil. Hydroponics gel is attractive due to its capability to store solution from 20 to 100 times by weight. This minimises the weight of the cell. Upon mixture with solution, the gel expands into a loosely bound gel medicine and thus reduces the amount of electrolyte that is required to occupy a particular cell volume. Compared with other polymer-type gelling agents, e.g. cellulose or cellulose derivatives such as CMC [1], [2] and vinyl polymers such as PVA [3], [4], hydroponics gel is much cheaper. Further, there is a certain limit where polymer-type material tend to shield and reduce the capacity of cells [4], whereas hydroponics gel merely absorbs and stores electrolyte.

A zinc–air cell has been selected to examine the efficacy of hydroponics gel because this cell system possesses the highest specific energy compared with other zinc-based alkaline batteries. This is mainly due to the unlimited and free supply of oxygen from the ambient air which is not incorporated within the cell. Other advantages of the zinc–air system include [5] a flat discharge voltage, a capacity which is independent of load and temperature within the operating range, long dry storage, use of an environmentally benign and low cost metal.

Section snippets

Zinc–air cell chemistry

The zinc–air cell has a theoretical specific energy of 1085 Wh kg^{-1}, based on the molecular weight of ZnO (658 Wh kg^{-1}) and the theoretical cell voltage 1.65 V. The overall cell discharge reactions can be summarised as follows [5], [6]:

$$\text{at the positive (cathode) electrode: } O_2 + 2H_2O + 4e^- \rightarrow 4OH^-, E^0 = 0.40\,V$$

$$\text{at the negative (anode) electrode: } 2Zn \rightarrow 2Zn^{2+} + 4e^-$$

$$2Zn^{2+} + 4OH^- \rightarrow 2Zn(OH)_2, E^0 = 1.25\,V \quad 2Zn(OH)_2 \rightarrow 2ZnO + 2H_2O$$

$\mathrm{overall\,cell\,discharge: 2Zn + O_2 \rightarrow 2ZnO, E^0 = 1.65\,V}$The oxygen reduction process is complex and involves a rate-limiting stage which…

Cell components and fabrication

The zinc–air cell comprised a zinc anode, a caustic alkali electrolyte, and a carbon-based electrode that was sufficiently porous and gas-permeable to 'breathe air' but resisted electrolyte penetration. All components were enclosed in a cylindrical plastic casing of dimensions: 28 mm (height), 45 mm (diameter). Both ends were attached with screwed, L-shaped, plastic rings. The container and both rings weighed 12.8 g.

A 0.4 mm thick zinc foil of 99.98% purity was cut into a circular anode plate of 45…

Cell characterisation

The OCV values of the cells were around 1.45 V. The OCV remained stable, without any significant drop, during 24 h of storage (see Fig. 3). The operating voltage and the power density delivered by the cell as a function of current drain from 10 μA to 100 mA are given in Fig. 4. The measurements were conducted after 24 h of storage. The cell voltage at each particular current drain was monitored for 10 s and the average value was recorded. The power of the cell was calculated from the measured…

Discussion

Zinc–air cells have been fabricated employing a comparatively low concentration (12 wt.%) aqueous potassium hydroxide and hydroponics gel as the electrolyte gelling agent. OCV measurements over a period of 24 h does not show any sign of fast self-discharge. The cell close-circuit operating voltage in the 10 μA to 100 mA current range is in agreement with reported data [6], [7]. The cells are capable of delivering 5, 50 and 100 mA constant current drains with resulting capacities of 229, 165 and 115…

Conclusions

Hydroponics gel is a promising alternative electrolyte gelling agent for zinc batteries and very likely for other alkaline electrolyte batteries such as nickel–metal-hydride. Primary, monopolar, zinc–air cells which use a hydroponics gel as the electrolyte immobilising agent have been fabricated and found to be capable of sustaining discharge loads of 5, 50 and 100 mA with corresponding capacities of 229, 165 and 115 mAh. The discharge capability of the cells and XRD analysis show that the…

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> …This indicates that no Mn or Ag oxidation occurred in the Zn-air mode. As for the Zn anode, a significant deposition of flower-like ZnO was observed in Fig. 3c, which was originated from the continuous oxidation of Zn [41]. Also, the semi-solid surface of the paper-based gel electrolyte might also prevent the generated ZnO from dissolution into the electrolyte, leading to its continuous accumulation on the Zn surface.…

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