Building a Rechargeable Zn-Cu Battery Through Employing a Monovalent Selective Cation Exchange Membrane

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ABSTRACT
The Zn-Cu battery is plagued with both the problems of Cu$^{2+}$ migration into the anodic chamber as well as the problem of shape change of zinc electrodes, where both of these processes together have historically prevented this type of battery technology from being rechargeable. We herein propose using a monovalent selective cation exchange membrane (CIEM) that through X-ray diffraction experiments was shown to be effective in preventing any substantial Cu$^{2+}$ crossover on the charge process. By using Na$^+$ based supporting electrolytes, Na$^+$ can pass through this membrane and maintain electroneutrality in the battery, greatly alleviating the Cu$^{2+}$ crossover process. For our electrolyte composition we compared sulphate, chloride, and nitrate based zinc and copper salts. We saw that overall for the zinc half-cell sulphate based electrolytes require a larger overpotential than analogous chloride ones due to their differing dissociation constants, whereas nitrate ions lead to complete passivation of the zinc electrode due to the formation of insoluble ZnO. As for the copper half-cells, the chloride-based electrolytes required the largest overpotential for copper electrodeposition since chloride ions are able to stabilize the cupric (Cu$^+$) state of copper, and sulphate and nitrate based copper electrolytes required near identical overpotentials for electrodeposition. In the presence of 0.5 M background electrolyte, mass-transfer limitations are alleviated in all electrolyte compositions when the concentration of active species is increased over 0.1 M, where the electrochemical process is then dominated by the kinetics of the electrochemical process.
Zeta Potential of Poly(methyl methacrylate) (PMMA) in Contact with Aqueous Electrolyte–Surfactant Solutions

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ABSTRACT
The addition of surfactants can considerably impact the electrical characteristics of an interface, and the zeta potential measurement is the standard method for its characterization. In this article, a comprehensive study of the zeta potential of poly(methyl methacrylate) (PMMA) in contact with aqueous solutions containing an anionic, a cationic, or a zwitterionic surfactant at different pH and ionic strength values is conducted. Electrophoretic mobilities are inferred from electrophoretic light scattering measurements of the particulate PMMA. These values can be converted into zeta potentials using permittivity and viscosity measurements of the continuous phase. Different behaviors are observed for each surfactant type, which can be explained with the various adsorption mechanisms on PMMA. For the anionic surfactant, the absolute zeta potential value below the critical micelle concentration (CMC) increases with the concentration, while it becomes rather constant around the CMC. At concentrations above the CMC, the absolute zeta potential increases again. We propose that hydrophobic-based adsorption and, at higher concentrations, the competing micellization process drive this behavior. For the cationic surfactant results, the absolute zeta potential increases below the CMC where the negative surface charge is neutralized by a layer of adsorbed cationic surfactant. At concentrations near the CMC, the positive zeta potential is rather constant. In this case, we propose that electrostatic interactions combined with hydrophobic adsorption are responsible for the observed behavior. The zeta potential in the presence of zwitterionic surfactant is influenced by the adsorption, because of hydrophobic interactions between the surfactant tail and the PMMA surface. However, there is less influence, compared to the ionic surfactants. For all three surfactant types, the zeta potential changes to more-negative or less-positive values for alkaline pH values, because of hydroxide adsorption. An increase of the ionic strength decreases the absolute value of the zeta potential, because of the shielding effects.
ABSTRACT
In the present work, we report on the microfabrication of metal hydride thin-film electrodes which can be utilized for rechargeable microbatteries or sensor applications. A multi-layer deposition technique is developed based on physical vapor deposition to fabricate the thin-film electrodes on a glass substrate. The morphology and the structure of the thin-film electrodes are studied by using Field Emission Scanning Electron Microscopy coupled with an Energy Dispersive Spectroscopy module. The surface composition of the metal hydride films is inferred using X-ray Photoelectron Spectroscopy. Cyclic Voltammetry and galvanostatic charge-discharge measurements are performed to obtain insights into the electrochemical performance of the electrodes. Finally, a semi-empirical model is derived which allows for the determination of the equilibrium potential of the electrode as a function of its hydrogen content.

Keywords: Metal Hydrides, Thin-Film Electrode, DC Magnetron
ABSTRACT
To study the sintering process, three novel layer-by-layer inkjet printing schemes are presented with a sintering protocol for silver nanoparticle (AgNP) layers. The sintering process of the AgNP layers are studied by changing temperature, time and number of the layers. A two level – three factors (sintering parameters) central composite design is employed to find the optimal conditions of thickness and resistivity for the sintering protocols, where the resistivity of the sintered samples is measured using the van der Pauw method. A semi-empirical model to study the surface and grain boundary diffusion of the layers is developed for the first time. The model developed in this study is in good agreement with the experimental values. The explicit change in the resistivity observed with temperature is due to the variation in morphology of the sample, grain size and pore volume.
ABSTRACT
We propose a novel nano-plasmonic sensor based on crossed surface relief gratings (CSRGs) with gradually varying pitch generated on top an azobenzene thin films using a 532 nm laser and a modified Lloyd mirror setup. A cylindrical lens was placed in front of half of the beam’s path; thus, scattering the light horizontally, which results the varying pitch linear gratings. The crossed gratings were created by writing a varying pitch grating on top of an orthogonally placed constant linear grating; therefore, producing a chirped-pitch cross grating. CSRGs have already created a unique surface plasmon resonance (SPR) sensors, since no light passes through them except a narrow bandwidth where SPR conversion occurs. With the chirped grating, the narrow bandwidth shifts along the chirped grating creating a new kind of sensors. The sensors has potential as a new generation of biosensor, with the ability to obtain an accurate signal using multiple wavelengths of light. Alternatively, the sensor can be divided up to different sections, where each section could be used as a device by itself, with specific photonic characteristics.
ABSTRACT
Gasoline blending is a common process in oil refineries. The optimization of gasoline blending operation has attracted a lot of attention over the last 10 years, and discretization based global optimization has been recognized as an efficient optimization approach to gasoline blend planning. We proposed a $R^+$ formulation and prove its continuous relaxation is the convex hull relaxation of the bilinear term. This suggests the irrelavance of base selection with the tightness of relaxation. Furthermore we proposed a $H$ formulation that employs a hybrid-based discretization framework which is more efficient in discretization. Then we propose an iterative global optimization method that iteratively pre-determine the best increment for discretization in next MILP. In this method, the lower bounding problem is a mixed-integer linear program (MILP) resulting from the discretization. The number of binary variables involved in the MILP is adaptively increased over the solution procedure. The upper bounding problem is a nonconvex nonlinear program (NLP) that results from fixing the binary variables in the original problem. The simulation study of a set of literature problems demonstrates the computational advantage of the proposed method over state-of-the-art global optimization solvers.
Decentralized Extremum Seeking Control for Heating, Ventilation and Air Conditioning (HVAC) Systems

Judith Ebegbulem

ABSTRACT
This paper considers the application of decentralized extremum seeking control to heating, ventilation and air conditioning (HVAC) systems in residential, commercial and industrial buildings. The HVAC system considered comprises two rooftop units that each provide cool air to two zones. The compressor, fan and expansion valve of each rooftop unit are controlled by three inner loop proportional-integral (PI) controllers to meet specified control requirements. The objective is to determine the optimal supply air temperature setpoint for each rooftop unit that minimizes the overall power consumption of the units. In addition, each setpoint must satisfy the control objectives of the three inner loop PI controllers. To tackle this problem, a decentralized proportional-integral extremum seeking control technique that avoids the need for communication between the units is employed. A simulation result is included to show the effectiveness of this technique.

Keywords: Decentralized extremum seeking control, HVAC systems, Rooftop units, Proportional-integral control, Real-time optimization