

Hydrogen Peroxide as an Oxidant for Microfluidic Fuel Cells

A microfluidic fuel cell is a device that confines all fundamental components of a fuel cell to a single microstructured manifold. Researchers at the University of Victoria in Canada recently developed a membraneless microfluidic fuel cell using hydrogen peroxide as the oxidant. The cell employed a design with a grooved channel geometry that utilized gas evolution and unsteady two-phase flow characteristics to enhance local transport rates and time-averaged current density. This design also restricted oxygen bubble growth and expulsion to the channel section directly above the cathode in order to enhance the rate of oxygen reduction and prevent detrimental fuel and oxidant crossover effects. This proof-of-concept microfluidic fuel cell demonstrated competitive power density and current density levels that were comparable to air-breathing designs and significantly higher than cells based on dissolved oxygen. The advantages of using hydrogen peroxide as the oxidant include its easy availability at high concentrations and its high standard reduction potential. In addition, it enables fuel cell operation where natural convection of air is limited or anaerobic conditions prevail, as in submersible and space applications.

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Enhancement of InGaN/GaN Flip-Chip ITO LEDs with Incline Sidewalls Coated with TiO₂/SiO₂ Omnidirectional Reflector

Gallium nitride (GaN) based materials have been widely employed in a variety of light emitting diode (LED) applications, such as backlighting in luminescent displays, due to their high brightness and high power capabilities. However, a strong interest to improve the output power and external quantum efficiency in packaged, flip-chip LEDs persists. One approach to improve these devices lies in the recovery of emitted photons that are directed laterally into the sidewalls or downward into the substrate of the device. Scientists from the Institute of Electro-optical Engineering, National Chiao Tung University and Epistar Corporation have developed a new architecture for the sidewalls of InGaN/GaN flip-chip LEDs that has markedly improved its effectiveness. By incorporating into the sidewalls omnidirectional, high reflectivity distributed Bragg reflectors (DBRs), comprised of alternating layers of silicon dioxide and titanium dioxide, they observed increases in the output power upwards of 90% compared with conventional LEDs. Further optimization of the design of the LEDs introduced inclined DBRs (50° slope) to the sidewall profile, which resulted in a 122% improvement of the output intensity compared to conventional diodes. Simulations of the propagation and reflection of light within these

architectures confirmed the significant light extraction efficiency that arises from the inclined sidewalls. These results provide evidence for GaN-based devices with substantially increased external luminescence efficiencies and output powers.

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Oxide Networks, Graph Theory, and the Passivity of Fe-Cr-Ni Ternary Alloys

Utilizing Mathematical Graph Theory, oxide films are considered to be a network of metal and oxygen atoms where individual atoms and bonds are represented by a two-dimensional collection of vertices and edges. In previous work, this technique was employed to evaluate the minimum chromium concentration required for passivity, defined here as the formation of a continuous network of the required material, of binary iron-chromium alloys by determining the chromium cation concentration required in the oxide to form a continuous network of -Cr-O-Cr-. The work presented in this paper extends the use of mathematical graph theory to iron-chromium-nickel ternary alloys. The technique was utilized to evaluate whether passivity in these ternary systems was generally due to the formation of a continuous network of -Ni-O-Ni- or -Cr-O-Cr-. The numerical treatment presented in this paper demonstrates that passivity would be achieved at a minimum chromium cation (Cr³⁺) fraction of 0.3 or a minimum nickel cation (Ni²⁺) fraction of 0.55. From the literature, passive oxides on ternary Fe-Cr-Ni alloys have been found to contain Cr cation fractions ranging from 0.33 to 0.67, while Ni cation fractions ranged from 0.03 to 0.18. Comparing the aforementioned literature results to the calculations presented in this paper, it is clear that passivity in these ternary systems is the result of the formation of a continuous -Cr-O-Cr- network, similar to that observed in the binary Fe-Cr alloys.

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Three-Dimensional Reconstruction of Porous LSCF Cathodes

Porous electrodes with interpenetrating ionic and electronic pathways are ubiquitous in electrochemical systems with applications in fuel cells, batteries, and industrial electrolysis. Often porous electrodes consist of multiple phases with distributions of these phases across the length of the electrode. Much of the behavior of the system is controlled by the fraction of these phases, and their variations across the electrode. Previously, it has been difficult to quantify this variation and therefore effective parameters, such as surface area or porosity, have been used to describe the electrode. Gostovic and coworkers from the University of Florida show a method to reconstruct the porous electrode by using a focused ion beam

(FIB) in combination with a scanning electron microscope (SEM). While the SEM is used to image the electrode, the FIB is used to physically sputter material away. Using this technique the authors perform a three-dimensional reconstruction of the porous La_{0.8}Sr_{0.2}Co_{0.2}Fe_{0.8}O_{3- δ} (LSCF) cathode used in solid oxide fuel cells to determine various microstructure properties including the overall porosity, graded porosity, surface area, pore size *etc.* The authors also perform impedance spectroscopy for cathodes prepared at various sintering temperatures and correlate the microstructure properties to the polarization and conclude that the increase in polarization with temperature is due to the decrease in surface area caused by the coarsening of the microstructure with sintering.

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Fully Infiltrated 3D Solid-State Interpenetrating Electrochemical Cell

Rate improvement in lithium-ion batteries has been achieved by minimizing Li⁺ diffusion path lengths and maximizing electrode/electrolyte interfacial area. Researchers at the University of Minnesota have continued their study of a three-dimensional (3D) interpenetrating electrochemical cell based on a photonic crystal architecture. The macroporous space in the three-dimensionally ordered carbon anode is coated with a nanometer-thick poly(phenyleneoxide) polymer electrolyte layer and filled with a vanadium pentoxide (V₂O₅) cathode material. The cathode infiltration method employed for their previous cell did not form an aerogel-like or ambigil structure. In the present report, the V₂O₅ gel shrinkage was controlled by addition of a water/acetone mixture. The added acetone prevents immediate shrinkage of the gel and aids in the extraction of water from the system. Their recent refinement yielded an increase in the reversible gravimetric discharge capacity of the cell from 0.7 $\mu\text{Ah g}^{-1}$ to 350 $\mu\text{Ah g}^{-1}$. The authors have identified several possible contributing factors leading to limited cell performance. Among these include the absence of a conductive additive in the cathode combined with the low electronic conductivity of V₂O₅, thereby making difficult the concurrent reduction of V⁵⁺ and insertion of Li⁺ in the material during discharge.

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