

High-Peak-Power Fuel Cells

Polymer electrolyte membrane fuel cells (PEMFCs) may find use in a variety of applications because of their light weight and high power density. However, their low ratio of peak to continuous power and slow response to instantaneous loads limit their applications in devices requiring high-peak-power outputs. A solution to this requirement is to hybridize PEMFCs with supercapacitors but such hybrid systems result in increased complexity, weight, volume, and cost. Researchers at Texas A&M University recently described a new strategy to realize a simpler hybridization without these drawbacks. In their work, the authors fabricated a PEMFC with an amorphous hydrated ruthenium dioxide supercapacitive sublayer inserted between the electrocatalyst layer and the Nafion membrane. The approach resulted in a high-peak-power PEMFC that performs the same functions as those of a relatively complex supercapacitor/fuel cell hybrid system. The thin sublayer slightly decreased the steady-state power output of the PEMFC but doubled its pulse power output. The water retention properties of the sublayer also benefited anode performance. Moreover, the sublayer decreased methanol crossover from anode to cathode in direct methanol fuel cell applications, resulting in higher fuel efficiency and improved cathode operation.

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Electropolishing Copper Damascene Interconnects

Since the late 1990s, copper has replaced aluminum as the interconnect metal of choice for advanced integrated circuit architectures. Copper interconnects are fabricated by the damascene process via electrodeposition processes that typically leave a metal step on and between damascene features. This is typically remedied using chemical mechanical polishing (CMP) to planarize the interconnects. However, conventional CMP slurries contain abrasive materials that can scratch and damage polished surfaces. A group of researchers from four institutions in Taiwan has explored electropolishing as a planarization alternative. The authors found that that addition of various organic acid additives (*e.g.*, citric acid) to the phosphoric acid electrolyte results in significant improvement in the smoothing of the surface when compared to additive free electropolishing. They hypothesize that because of transport limitations, the enhanced conductivity resulting from these additives is more pronounced in the vicinity of peaks than of valleys. As a result, electrodisolution rates are enhanced at the peaks thereby contributing to improved planarization efficiency. Additionally, the authors determined that addition of polyethylene glycol to the electrolyte increased the overpotential of the oxygen formation reaction and produced fewer etch pits in the planarized surface.

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A High Moment CoFe Soft Magnetic Thin Film

Soft magnetic materials with high saturation magnetic flux densities (B_s) are being developed by many research groups for applications in high-density magnetic recording. Thin films with a B_s of approximately 24 kG, close to the limiting value obtainable with ferromagnetic alloys, have been prepared by dry sputtering processes. These include a NiFe/CoFe-N/NiFe trilayer film and CoFe-O and CoFe-Al-O granular films. Researchers at Waseda University in Japan now report the successful electrodeposition of high magnetic moment ($B_s = 24$ kG) CoFe thin films. The key to realizing these films is to prevent the oxidation of ferrous ion to ferric ion in the plating bath. This in turn prevents the incorporation of undesired ferric hydroxide in the film, which presumably contributes to degradation in B_s values. Addition of trimethyl-

amineborane (TMAB) reducing agent to the bath and separation of the anode and cathode compartments were both effective means to avoid ferrous ion oxidation. Further, annealing these high moment films in vacuum at 350-400°C resulted in a decrease in coercivity (H_c) to values as low as 8 Oe without degradation in the saturation magnetic flux density.

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Measuring Electrocatalytic Activity on a Local Scale

The inability of existing anode catalysts in polymer electrolyte membrane fuel cells (PEMFCs) to efficiently oxidize fuels other than hydrogen has restricted this technology to a limited set of applications. Combinatorial approaches for discovery of improved catalysts require development of *in situ*, chemically sensitive screening tools to ascertain reactivity parameters and spatially evaluate catalytic activity. Jambunathan and Hillier at the University of Virginia recently described the development of a new technique, scanning differential electrochemical mass spectrometry, and demonstrated its utility in several model catalytic reactions (hydrogen evolution, carbon monoxide oxidation, and methanol oxidation on Pt and Pt-Ru electrodes). In one experiment, they used a micropositioning system to precisely locate a 150- μ m diameter capillary (covered with a nanoporous, hydrophobic membrane) over a series of 8 band electrodes with Pt-Ru compositions ranging from 0/100 to 100/0. This capillary served as the differentially pumped inlet to a quadrupole mass spectrometer that allowed quantitative measurement of gaseous and volatile products resulting from the oxidation of methanol (in sulfuric acid) at the band electrodes. At 0.65 volts vs. RHE, the highest concentrations of CO₂ and methyl formate were obtained with the 94/6 Pt/Ru band electrode.

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Direct-Write Planar Microultracapacitors

Electrochemical supercapacitors are key components in large commercial energy storage systems because of their ability to deliver pulsed power and provide load leveling. High power pulsed energy is also a critical requirement for autonomous microelectronic, microsensor, and microelectromechanical systems, and these needs cannot be met in every instance by the current generation of microbatteries and microfuel cells. Microcapacitors can be used in combination with these energy sources to supply pulsed power for these microdevices. Researchers at the Naval Research Laboratory in Washington, DC have reported the fabrication of planar microelectrochemical capacitors by a three-step process consisting of (1) deposition of a hydrous ruthenium oxide film onto a glass substrate, (2) laser-induced transfer of this dielectric material onto gold-coated quartz, and (3) laser micromachining of the deposited material into a planar capacitor with a pair of gold electrodes. The measured specific capacitance of 720 F/g agrees well with reported values for RuO₂·0.5H₂O, indicating that the processing steps do not unfavorably affect the dielectric material. Further, a typical 80 μ g cell yielded a specific power of 1100 mW/g and a specific energy of 9 mW-hr/g. These microcapacitors can be added in series or parallel and discharged at currents as high as 50 mA without damage.

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