

Novel Lithium Intercalation Cathode Materials

The development of secondary lithium batteries requires high performance electrode materials. Although crystalline metal oxides prepared by conventional solid-state reactions show reasonable specific capacities, electrode kinetics and the reversibility of their insertion reactions can still be improved. One of the strategies that has been employed to enhance cathode performance is decreasing the preparation temperature. These low temperature cathode materials are generally less crystalline, with more open structures and higher specific areas compared to the corresponding high temperature materials. As a further extension in this direction, researchers at the University of Oklahoma have investigated mesoporous materials based on an aluminum-phosphorous-oxygen framework containing both manganese and vanadium. The mesoporous structures are formed by the crystallization of gels organized by a surfactant templating agent. Electrochemical evaluation of these matrices as host cathode materials for lithium intercalation indicates that the materials exhibit very good rate capacity and reversibility under cycling. The results show that the mesoporous framework structures are robust with respect to lithium insertion and are thus viable candidates for development as high rate lithium battery cathode materials.

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A Novel, High CO Tolerance Fuel Cell Electrocatalyst

Considerable effort has been expended at various research institutes to develop electrocatalysts for methanol fuel cells that are inexpensive and not prone to poisoning by carbon monoxide. Large-scale application of methanol polymer electrolyte membrane (PEM) fuel cells has been retarded by the lack of a suitable electrocatalyst. Researchers at Brookhaven National Laboratory in New York recently demonstrated a new fabrication method for Pt-Ru and other bimetallic electrocatalysts that results in lower Pt loading and increased resistance to CO poisoning compared to commercial Pt-Ru alloy electrocatalysts. Brankovic, Wang, and Adzic showed that Pt clusters could be spontaneously deposited on Ru nanoparticles via electroless deposition from a solution of hexachloroplatinic acid. Electrodes made using this technique were more than 3 times as active as a commercially available Pt-Ru electrocatalyst, as determined by comparison of their respective Pt-mass-specific oxidation currents. The authors believe that their deposition technique uses Pt more effectively by placing it only on the surface of Ru nanoparticles rather than throughout the bulk.

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Decoration of Defects in Monocrystalline Silicon

Defects in device areas of silicon integrated circuits can be an important limiting factor in fabrication yields and device performance. As device feature sizes decrease in new generations of microelectronics, the demand on the quality of the silicon substrate becomes more stringent. Microdefects in state-of-the-art silicon are primarily self-interstitials (silicon atoms displaced from normal positions in the lattice) and vacancies (formed by missing atoms in the lattice). Researchers at MEMC Electronic Materials in Missouri have reported a detailed analysis of microdefect decoration techniques. They describe a multi-step procedure whereby they saturate the wafer with copper at 800°C, rapidly cool the wafer to nucleate copper on the microdefects and facilitate subsequent growth of precipitates, and then decorate the defects by chemical surface polishing and decoration etching (e.g., with the well-known Secco or Wright etchants). The authors developed

theoretical descriptions and phenomenological models that accurately describe the kinetics and thermodynamics of etch pit formation resulting from differences in etching rates of the precipitate-influenced region around a microdefect and the surrounding, defect-free silicon.

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Colossal Reversible Volume Changes in Li Alloys

Intercalation of atoms or ions into solid lattices is fundamental to the behavior of many of the electrode materials used in advanced batteries. Some examples include hydrogen in metal hydrides and lithium in carbon, metal oxides, and lithium alloys. Researchers from Dalhousie University and the 3M Company have studied volume changes in lithium alloys, using *in situ* optical and atomic force microscopy, during electrochemical intercalation of lithium into sputtered films. The films expand perpendicular to the substrate when lithium is first intercalated; upon Li removal, they shrink in both parallel and perpendicular directions resulting in the formation of large (on the order of 100 μm) cracks. Subsequent intercalation results in the cracks seemingly disappear as the lattice expands. Further cycles reveal that these large volume changes occur reversibly. Optical and AFM images, taken at various points during a large number of charge and discharge cycles, revealed this interesting behavior, which the authors compare qualitatively to the desiccation of mud in a lake bed. Time-lapsed movies, posted at www.physics.dal.ca/~dahn/ECS_Letters.html, provide a window to the usefulness of this *in situ* technique. The ability to understand and control lithium intercalation provides a controlled framework for studying the effects of strains, volume changes, and fractures on the performance of these important alloys.

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High Performance Anodes for Solid Oxide Fuel Cells

Solid oxide fuel cells (SOFCs) provide one option for meeting society's ever-increasing energy needs. To further their general utility in this regard, as well as to increase efficiencies and reduce costs, there has been a significant level of research focused on lowering the operating temperature of these devices. Researchers at Nagoya University and the National Institute of Advanced Industrial Science and Technology in Japan have reported a study on high performance anodes for SOFCs operating in methane-air mixtures at reduced temperatures. The anodes were NiO-samarium cermet doped with various levels of PtO₂, PdO, Rh₂O₃, or RuO₂, with the best performance being observed with the PdO doped material. In fact, very little if any enhancement was observed with any of the other dopants. A range of PdO concentrations were evaluated, and the highest activity was observed at a concentration of 7 wt %, corresponding to a catalyst loading of 0.145 mg/cm². Using the optimum anode formulation, a Ce_{0.8}Sm_{0.2}O_{1.9} electrolyte thickness of 0.15 mm, and methane-air mixtures, the highest power observed for this SOFC was 644 mW/cm² at 550°C, with an open circuit voltage of approximately 900 mV. The authors do point out that various issues still need to be addressed, such as the low fuel utilization which is only 9.4% at the highest power levels observed.

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