Towards Implantable Bio-Supercapacitors: Pseudocapacitance of Ruthenium Oxide Nanoparticles and Nanosheets in Acids, Buffered Solutions, and Bioelectrolytes

Since the early 1990s when ruthenium oxide-based electrode materials were found to have pseudocapacitive properties, they have been extensively investigated as promising supercapacitor electrodes. A best benchmark example is $RuO_2 \cdot nH_2O$ in combination with H_2SO_4 as the electrolyte, being able to operate with high voltage window, high capacitance and long cycle life. As the research continues in this area, researchers at the Shinshu University of Japan recently explored the pseudocapacitive behavior of ruthenium oxide nanoparticles and nanosheets in environmentally benign electrolytes near neutral pH, and reported their findings in the JES Focus Issue on Electrochemical Capacitors: Fundamentals to Applications. In acetic acid-lithium acetate (AcOH-AcOLi) buffered solutions (pH = 5.4, 5 M solution), the authors found that highly-crystalline RuO_2 nanosheets could achieve a capacitance value as high as 1038 F/g, which is over 40% higher than in the widely quoted benchmark value of 720 F/g in H_2SO_4 electrolyte. The authors also studied the effects of ionic strength and pH, as well as the role of weak acid in Li_2SO_4 electrolyte. These different electrolyte conditions affected the surface redox behavior of RuO_2 nanomaterials, resulting in different pseudocapacitive behaviors. Furthermore, comparable performance was obtained with RuO_2 nanosheets in phosphate-buffered saline (837 F/g) and fetal bovine serum (772 F/g) electrolytes. The results demonstrated possible future applications of these materials toward implantable bio-supercapacitors.

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Influence of the Altered Surface Layer on the Corrosion of AA5083

Aluminum alloys are increasingly replacing heavier materials in transportation, military and other applications, oftentimes in environments demanding of exceptional corrosion performance. In this regard, AA5083 has served as one of the alloys of choice for marine applications. This alloy, and some others in the 5xxx series, contains greater than 3 wt% Mg, making it inherently vulnerable to in-service sensitization involving precipitation of β-phase (Mg_2Al_3) at grain boundaries. Preferential intergranular corrosion (IGC) of β and, relatedly, stress corrosion cracking can severely compromise mechanical integrity. Despite the in-service occurrence of IGC, its initiation has typically not been observed under freely corroding conditions in laboratory studies. Researchers at Ohio State University have provided explanation for this discrepancy. Through electrochemical and microstructural characterization, they demonstrated that heat generated by grinding and polishing of sensitized AA5083 samples is capable of creating a recrystallized surface layer deficient in precipitated β. This surface layer blocks environmental access to the underlying sensitized microstructure, leading to corrosion behavior similar to that of the solutionized microstructure in certain cases. The authors demonstrated an etching method for removal of this altered surface layer. These findings will aid in future efforts to understand IGC initiation of 5083 and, potentially, other sensitization-prone 5xxx alloys.

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Advances in 3D Printing of Functional Nanomaterials

The intense and widespread interest in additive manufacturing techniques, including 3D printing, has resulted in an approximately $5 billion industry today with projections for growth to $15-20 billion by 2018. The commercial availability of 3D printing equipment, and the development of flexible additive manufacturing platforms in R&D laboratories, has provided a foundation for researchers to perform fundamental research in the materials science and engineering of polymers, organic materials, ceramics, inks, pastes, and other materials. Further, this fundamental understanding has been followed by technology maturation efforts to produce applications for 3D printing in biotechnology, electronics, photonics, photovoltaics, sensors, automotive, aerospace, chemical sensing, and numerous other fields. In the JSS Focus Issue on Printable Functional Materials for Electronics and Energy Applications, authors from Arizona State University, Freescale Semiconductor, Korea Institute of Science and Technology, and the University of Nevada-Reno published a review article on 3D printing and roll-to-roll manufacturing. The article cites exciting applications in bone tissue engineering, bone regeneration, radio frequency identification tags, chemical and biological sensors, flexible electronics (e.g., for wearable devices), and other fields. The incorporation of nanomaterials (carbon nanotubes, metals, dielectrics, etc.) in 3D-printed parts is also an active area of research, as these nanofillers can be tailored to improve materials performance for additively manufactured devices.

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A Critical Assessment of $X_{H_2O_2}$ as a Figure of Merit for Oxygen Reduction Electrocatalysts in Aqueous Electrolytes

In the assessment of electrocatalysts for the oxygen reduction reaction (ORR), the $X_{H_2O_2}$ figure of merit is commonly determined. This $X_{H_2O_2}$ parameter is the fraction of disk current in a rotating ring-disk electrode (RRDE) experiment attributable to hydrogen peroxide generated and subsequently lost to solution. The $X_{H_2O_2}$ parameter is commonly calculated by an equation that is based on the assumption that the disk electrode material is inactive toward peroxide reduction. In this paper, scientists from Case Western Reserve University provide a rigorous assessment of the reaction schemes and assumptions used in deriving expressions for currents and ultimately the $X_{H_2O_2}$ parameter. The authors base their examination on the 1966 work of Damjanovic et al., wherein the ratio of disk to ring currents for ORR exhibits a linear relationship to the reciprocal square root of rotation rate. The y-intercept may be used to extract the $X_{H_2O_2}$ parameter, and the slope to obtain the rate constant for the reduction of peroxide in solution at the disk. The authors used data from the literature and their lab to illustrate how use of a single rotation rate without satisfying the underlying assumptions of the expression leads to unreliable values of $X_{H_2O_2}$.

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Self-Aligned Fin-On-Oxide FinFETs on Si Substrates

Bulk-silicon (Si) FinFETs have become recognized as one of the most promising device architectures for advanced CMOS integration circuits. FinFETs are well known to have a controlled electrostatic integrity even with short channel lengths, and can be multi-gated. When fabricated on Si, punch-through stopper (PTS) doping is needed to suppress sub-channel leakage current. This doping also causes carrier mobility degradation and threshold voltage variability in transistors. FinFET formation on SOI substrates can provide a channel at the buried oxide, but integration costs are prohibitive using such substrates. Researchers at the Institute of Microelectronics at the Chinese Academy of Sciences in Beijing propose a new way to form Fin-On-Oxide (FOO) FinFETs on Si, and in this Letter they describe how they made this possible with just a few modifications to typical bulk-Si FinFET integration processing. Based on conventional bulk-Si FinFET integration flow, the team introduced fin notch etching with liner oxidation and isolation-oxide filling, isolating the fin from the substrate. When applied to 14 nm devices, they achieved a sub-threshold swing of 86 mV/dec and drain-induced barrier lowering of 106 mV/V, better than bulk-silicon FinFETs. The researchers suggest that the method provides a promising approach for ultra-low power circuits using scalable FinFETs on Si substrates without complicated process technologies.

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