

TECH HIGHLIGHTS

A Non-Flooding Hybrid Polymer Electrolyte Fuel Cell

During the operation of a proton exchange membrane (PEM) fuel cell, enough water (from the cell reaction product and from the humidified reactants) is needed to keep the membrane hydrated. Yet the build up of excess water can cause electrode flooding. Balancing the two conflicting requirements remains a major issue for PEM fuel cells. Researchers from the University of Delaware recently reported a hybrid polymer fuel cell that prevents flooding. In their approach, a PEM and an anion exchange membrane (AEM) are placed on the anode and cathode sides, respectively, of a thin, porous, hydrophilic membrane soaked with water. The protons (H^+) conducted through the PEM and the hydroxide ions (OH^-) conducted through the AEM react within the water in the pores of this membrane. The water produced in the porous membrane is then shunted out to the exterior of the fuel cell. Testing results indicated that flooding was avoided even when the cell was discharged at 50 mV at 30 °C and with 100% humidified gas streams. However, the cell's maximum power output was not as good as comparable PEM and AEM fuel cells. Maintaining hydration at higher temperatures remained a challenge.

From: Electrochim. Solid-State Lett. 14, B121 (2011).

GILDES Model Simulations of the Atmospheric Corrosion of Copper Induced by Low Concentrations of Carboxylic Acids

In this work, a computer simulation of the atmospheric corrosion of copper when exposed to varying concentrations of formic, acetic, and propionic acids was performed. The simulation utilized the COMSOL multiphysics software and was based upon the GILDES chemical/physical model of the corroding system. The GILDES model expresses the metal/atmospheric interface as five discrete regions – the **Gas Interface**, the **Liquid** layer, the **Deposition** layer, the **Electrode** layer, and the metal **Surface**. A set of 114 reactions (and their associated kinetic parameters) taken from the literature were considered in the model, encompassing surface absorption, chemical, and electrochemical interactions. The specific model results differed quantitatively from experimental observations, suggesting that the kinetic parameters used to construct the model had inaccuracies associated with them. In many cases, the measurement technique utilized to acquire various kinetic parameters influences the reported value, and as such a wide distribution is reported in the literature. In such cases, the model was exercised for a range of values in order to understand why the model results differed from experimental observations. While the exact reaction kinetics were not well described by the model, qualitatively, the simulation was demonstrated

to be consistent with experimental results in terms of the relative aggressiveness of the three acids, and the proportions of the various corrosion products present.

From: J. Electrochim. Soc., 158, C429 (2011).

Comparison of Withstand Voltage and Durability of Alkylated Cyclic Carbonates for Electric Double Layer Capacitors

Electric double-layer capacitors (EDLCs) demonstrate high power density and cycle life relative to other electrochemical energy storage devices; however, market demand for EDLCs has been low due to their relatively low energy density. The energy of an EDLC is a function of the voltage squared; therefore, the electrolyte solvent systems exhibiting a large voltage stability window, *i.e.*, solvent systems that display both oxidative and reductive stability, can significantly improve the energy density of EDLCs. Researchers from Japan evaluated and compared the physicochemical properties and oxidative stability of cyclic carbonates with methyl, ethyl, or propyl substituents at the 4th and/or 5th positions of the five-membered carbonate ring. The researchers reported that EDLCs with electrolyte systems incorporating 2,3-butylene carbonate (2,3BC) maintained capacitance to a higher voltage and exhibited less degradation compared to the other EDLC solvents. The withstand voltage for the 2,3BC solvent system was 30% greater than the withstand voltage for the propylene carbonate solvent system. The researchers attributed the greater withstand voltage and durability of 2,3BC solvent system to the oxidative protection provided by the methyl substituents at both the 4th and 5th positions of the carbonate ring compared to a substituent at just one of these positions for the other solvents.

From: J. Electrochim. Soc., 158, A1320 (2011).

Analysis of the Temperature Dependence of Trap-Assisted Tunneling in Ge pFET Junctions

For the most recent CMOS technology, the implementation of high-k gate dielectrics, which can reduce low-field mobility due to remote phonon and Coulomb scattering, has led to a search for new channel materials other than Si to give significant carrier mobility enhancement and higher drive currents. Ge pMOS devices are being investigated as a candidate on the technology roadmap below the 22 nm node. With bulk hole mobility 4.4 times that of Si, circuit speeds can be enhanced by developing process technology that can increase transistor drive current. When integrating Ge using Si process tools, Ge transistors processed in thin layers on Si handles have extended defects at the Ge/Si hetero-interface. Researchers from imec in Belgium investigated the temperature-dependent behavior of trap-assisted tunneling

in Ge pFET junctions selectively grown in shallow trench isolation (STI) substrates. They show that the electric field and threading dislocation densities (TDD) cause a 14-fold reduction in carrier lifetime suggesting the influence of locally enhanced electric fields by the agglomeration of such defects. Promisingly, samples annealed at 850 °C for 3 min in a N₂ ambient have a factor of 40 lower TDD. The work points to a better understanding of the field-assisted leakage current mechanisms occurring in the Ge drain-substrate junctions.

From: J. Electrochim. Soc. 158, H955 (2011).

Electrochemical Characterization of Electrically Induced Adhesive Debonding

Adhesively bonded structures that can be disassembled using electrical energy are being explored for applications in aerospace, defense, automotive, and shipbuilding applications. These assemblies typically consist of conductive (metallic) substrates held together by ionically-conducting epoxy adhesives. Upon application of electrical energy, electrochemical reactions at one of the metal-epoxy interfaces produce adhesive failure and concurrent debonding. Recently, researchers at the KTH Royal Institute of Technology and the Karlstad Research Center, both in Sweden, published results of an electrochemical investigation of the mechanism of a debonding reaction for an aluminum-adhesive-aluminum assembly prepared with an amide-cured epoxy. They used electrochemical impedance spectroscopy, galvanostatic measurements, and scanning electron microscopy to probe the reactions, and determined that the debonding mechanism consisted of oxidation of aluminum (at the anodically biased conductor) to form aluminum ions. These ions subsequently reacted with ethyl sulfate (an ingredient in the adhesive) and with hydroxides and oxides (from absorbed water) to form complexes that penetrated the adhesive bondline region. This in turn produced a volume increase in the adhesive that resulted in stress-induced debonding. The methodology developed by the authors can be extended to the study of other electrically induced debonding systems, including those where debonding occurs at the cathodically biased metal-epoxy interface.

From: J. Electrochim. Soc., 158, P109 (2011).

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