TECH HIGHLIGHTS

Bonding Organics to H-Terminated Silicon

Researchers at the University of Minnesota, 3M Company, and Physical Electronics, Inc. used X-ray photoelectron spectroscopy (XPS), multiple internal reflection infrared (MIR-IR), and time-of-flight secondary ion mass spectrometry (TOF-SIMS) to probe the Pt-catalyzed hydrosilation reaction between 3,4,-dichlorobutene and hydrogen-terminated (100) Si surfaces. This team found that, by contacting hydrided silicon surfaces with carbon tetrachloride containing Pt complexed with divinyltetramethyldisiloxane (DVTMDS) and 3,4, dichlorobutene, a monolayer of 3,4,-dichlorobutane would covalently bond to the Si. They also found that this hydrosilation reaction was favored over the competing hydrolysis of the Si surface hydride groups (which is also catalyzed by Pt) by minimizing trace amounts of water in the system and by using high concentrations of the 3,4,-dichlorobutene. The main conclusion of this work is that organic molecules can be selectively bonded to hydrogen-terminated silicon via Si-C bonds and these molecules can be patterned using standard microelectronic techniques by exploiting the fact that reaction only occurs on the hydrogen-terminated Si surface

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Plasma Treatment to Improve Adhesion

Plasma-enhanced chemical vapor deposited (PECVD) fluorinated silica glass (FSG) films are attractive for both intermetal dielectric and passivation applications due to their lower dielectric constant and improved step coverage over undoped tetraethylorthosilicate oxide films. Both of these properties can be further improved by increasing the fluorine content of the film. At high fluorine levels, however, the films absorb moisture, which increases the dielectric constant. Unfortunately, barrier layers typically used to block the diffusion of moisture are poorly adhered to the high-fluorine films. R. Swope, et al., from Novellus Systems in San Jose, report that a nitrous oxide plasma treatment improves the adhesion properties of the FSG film. Based on thermal desorption spectroscopy and other experiments, a mechanism for the improved adhesion postulated is that nitrogen from the plasma getters hydrogen at the FSG surface. With untreated FSG, the subsequent silicon nitride (SiN) films blister as the hydrogen present in the silicon nitride reacts with silanol and fluorine from the FSG to form water and HF, which are thermally desorbed during the SiN deposition. By gettering the hydrogen with either the nitrogen-containing plasma or a silicon-rich oxide film, the blistering was prevented.

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Electrodeposited Superlattices

Alper, Schwarzacher, and Lane, at the University of Bristol, developed a method for preparing superlattices of Cu/Co-Ni-Cu by electrodeposition from aqueous solutions. The method used maintains the electrode voltage at a negative enough voltage to deposit the Cu, and then periodically steps the voltage beyond the reduction potential of the Co-Ni-Cu alloy. In this way, a layered Cu/Co-Ni-Cu supperlattice of variable thicknesses can be prepared. The details of the technique used to prepare these superlattices are described, along with a thorough study of the effect of pH on the magnetic and magnetotransport properties of the material. It was found that the pH of the solution from which the superlattices were deposited can significantly affect these characteristics. Giant magnetoresistance of over 15% was measured from deposits obtained at low pH, and either anisotropic magnetoresistance or much smaller giant mangetoresistance was obtained from superlattices prepared at a higher pH of 3.3.

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Numerical Modeling of Lead-Acid Batteries

Lead acid batteries are widely perceived as a near-term, low cost and versatile power source for electric vehicles. W.B. Gu, C.Y. Wang and B.Y. Liaw at the University of Hawaii at Manoa have developed mathematical models to predict discharge and charge behavior, as well as the effects of cycling to complement the empirical method of improving performance and cycle life of lead-acid batteries. A computational fluid dynamics technique is employed to solve the large set of coupled, non-linear differential equations arising from their battery model. The model is a lead acid cell consisting of a lead dioxide electrode, an electrolyte reservoir, a porous separator and a pure lead electrode. The two basic assumptions of the model are that the sulfuric acid is a binary electrolyte, dissociating completely into H^+ and HSO^{4-}, and the system is isothermal. The numerical model fully integrates electrochemical kinetics, mass transport, fluid flow and multidimensional aspects of a battery system. The authors benchmark three different cases that correspond to three different cells and four simulations. In the first case, most of the input parameters were experimental data. The second case was one-dimensional discharge and charge simulations, with results reported to be in good agreement with experimental data. The third case corresponded to experimental work in which the electrolyte velocity and concentration in the reservoir region were measured. In addition to predicting charge and discharge performance in lead-acid batteries, the authors have used the modeling to identify various mechanisms that limit battery performance by addressing free convection and acid stratification phenomena.

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Rechargeable MH/MnO_2 Cells

Scientists at Xinjiang University in China have been studying the metal hydride/manganese dioxide (MH/MnO_2) rechargeable cell. Their work focuses on the study of the MnO_2 cathode material and methods to improve its rechargeability. The MnO_2 was formed and doped with Bi_2O_3 electrochemically. The material was studied using cyclic voltammetry, X-ray diffraction and potentiostatic techniques, as well as cycling in 3.5 Ah cells. The test cells were assembled "half charged," as the MnO_2 cathode is in its charged state and the metal hydride anode is in its discharged state. The initial problem of charging the cell was overcome by adding $Ni(OH)_2$ and some recombination catalyst to the MnO_2 cathode. The optimum MnO_2/$Ni(OH)_2$ ratio was found to be between 5:1 to 7:1. The cells were cycled using one-fifth capacity (C/5) discharge rate and a 100% depth-of-discharge down to 0.7 V. One cell showed that over 78% of its initial capacity still remained after 208 cycles. The addition of $Ni(OH)_2$ raised the average discharge voltage of the cell from about 0.9 V to nearly 1.2 V, while maintaining a relatively flat voltage profile. The researchers found that the addition of $Ni(OH)_2$ to the cathode improves the rechargeability of the MnO_2 by preventing both overcharge and the formation of non-rechargeable Mn_3O_4.

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