Room-Temperature Direct Bonding Using Fluorine-Containing Plasma Activation

Conventional hydrophilic and hydrophobic wafer bonding processes are carried out at 700-1000 °C annealing temperatures. Recent development efforts have made improvements by employing dry plasma treatment to activate the surface prior to bonding, followed by either low-temperature annealing (200-400 °C) or wet chemistry treatment, an additional processing step needed to strengthen the bond. Alternatively, existing room-temperature processes employ high vacuum conditions not amenable for mass production. Researchers from the University of Tokyo report achieving strongly bonded Si/Si pairs employing a small addition of tetrafluoromethane (CF_4) into the oxygen plasma treatment. An X-ray photoelectron spectroscopy (XPS) peak for a Si surface treated in the CF_4-containing plasma mixture was identified as Si-F bonding. Fourier transform infrared (FT-IR) measurements revealed a decrease in the amount of O-H absorption bond at the interfaces for the CF_4-containing plasma, thereby suggesting a decreasing in hydrophilicity and yet still some adsorbed water. The authors speculate that too much adsorbed water plays a role in breaking polymerized silanol groups formed across the bonding interface. For an optimized fluorine-containing plasma treatment, the authors measured ~2.4 J/m^2 bond strength, comparable to the bulk-fracture strength of silicon. In contrast, the oxygen plasma-activated bonding yielded a weak bonding strength of ~0.6 J/m^2.

From: J. Electrochem. Soc., ***158****, H525 (2011).*

Cogeneration of Hydrogen and Electrical Power with Steam-Carbon Fuel Cell

Energy-efficient and geographically distributed production methods of carbon-free hydrogen must be developed if hydrogen is to be a viable energy storage medium. Common commercial processes for producing hydrogen, such as direct electrolysis or steam reforming, are either electrically inefficient or require expensive separation techniques to remove fuel cell catalyst-poisoning carbon by-products. Researchers from Stanford University have overcome both of these problems with a steam-carbon fuel cell that spontaneously produces carbon-free hydrogen while simultaneously generating electrical power. The overall reaction of their process is similar to the steam reforming reaction of carbon, but by having the reaction occur in an electrochemical cell, the hydrogen and carbon monoxide products at the cathode and anode, respectively, are kept physically and chemically separate by a solid yttrium stabilized zirconia (YSZ) electrolyte. An experimental cell operating at 850 °C produced a peak power density of 8 mW/cm^2 while concurrently producing carbon-free hydrogen at a rate of 354 g H_2/(m^2 day). The researchers predicted reaction activation losses by fitting electrochemical impedance spectroscopy (EIS) data to theoretical models. The carbon monoxide oxidation, oxygen reduction, and steam reduction reaction activation energies were estimated to be 132 kJ/mol, 80 kJ/mol, and 189 kJ/mol, respectively. The authors believe that the activation losses can be reduced by employing improved electrode materials.

From: J. Electrochem. Soc., ***158****, B505 (2011).*

Improved Performance of Near-Ultraviolet Light Emitting Diodes on Selectively Etched GaN Templates

GaN-based light-emitting diodes have been intensively developed because of their applications as outdoor full-color displays, back lighting in liquid-crystal displays, and solid-state lighting. However, GaN epitaxial layers contain a high threading dislocation (TD) density (10^9–10^{11} cm^{-2}) when grown on lattice-mismatched substrates. Those dislocations act as non-radiative centers, resulting in low internal quantum efficiency for III–V LEDs. Researchers from the National Chung Hsing University in Taiwan integrated selectively etched GaN (SE-GaN) with the recesses in a patterned sapphire substrate to fabricate a template. The NUV-LED contains less threading dislocations than conventional approaches when fabricated with the SE-GaN template. Threading dislocations formed within GaN were spatially concentrated due to the pyramidal patterning of the substrate, and continuous propagation of concentrated TDs in the subsequent epitaxial growth was blocked by SiO_2 filling at etched pits. The method is reported to effectively reduce the TD density of NUV-LEDs to about 10^5 cm^{-2} without any photolithography process. The technological approach was vetted when the researchers showed low leakage currents from fabricated devices, with a template approach that allowed better material crystallinity. The complex process is reported not to cause any performance deterioration and the electro-optical property of NUV-LEDs was dramatically improved.

From: Electrochem. Solid-State Lett. ***14****, H222 (2011).*

New Method to Evaluate the Oxygen Reduction Activity of Catalysts for Lithium-Air Batteries

Rechargeable Li-air batteries have the potential to provide energy densities 3-4 times that of conventional Li-ion batteries. Among the challenges that must be met to make Li-air batteries practical for key applications are increasing round-trip efficiency, rate capability, and cycle life. A number of research groups are researching new catalysts with improved activity for the oxygen reduction reaction (ORR) during discharge and the oxygen evolution reaction (OER) during charge. The conventional approach to evaluate the activity of these catalysts is to fabricate porous electrodes and measure discharge voltage profiles in a Li-O_2 single cell configuration. Researchers at the Massachusetts Institute of Technology (USA) and the Technische Universität München (Germany) recently reported a new rotating disk electrode (RDE) method to quantitatively determine the electrocatalytic activity of high-surface-area catalysts. Levich-Koutecky analysis of the RDE data showed that the mechanism for ORR in the presence of Li^+ ions on Vulcan carbon proceeds by a 1-electron reduction to LiO_2 as the rate-limiting step. Further, the authors showed that the difference in ORR activity (as measured by the RDE method) between Vulcan carbon and Au nanoparticle catalyst supported on Vulcan carbon is well correlated with discharge voltages of Li-O_2 cells, thereby demonstrating their new method as a convenient, quantitative tool for evaluating Li-air battery catalysts.

From: Electrochem. Solid-State Lett., ***14*** *A70 (2011).*

Electrochemical Energy Storage Device for Electric Vehicles

An ideal power source for electric vehicles should possess such features as high specific energy, high power density, and long life, along with competitive cost and safety. Traditional batteries have high specific energy but cannot meet the demands of rapid and deep charging/discharging cycles. Supercapacitors are able to store rapidly available energy with their high power density but suffer from low specific energy and high cost. Researchers at Xiamen University of China recently reported a new electrochemical energy storage device that combined the advantages of a battery and a supercapacitor. The device stores electrical energy using vanadium redox couples in sulfuric acid solutions. A basic module consists of two micro-porous carbon felt electrodes soaked in the vanadium couple solution and separated by an anion-exchange membrane. Taking advantage of the high mass transfer rate in the liquid phase, the stored chemical energy can be electrochemically converted into electrical energy at a high rate. Rapid charging and discharging can be realized within 10 seconds. At high current rate of 80 C for deep charge/discharge, a long cycle life (30,000) and excellent capacity retention have been achieved. The authors proposed that a practical application of this new device could be an on-board rechargeable power source for electric vehicles.

From: J. Electrochem. Soc., ***158****, A443 (2011).*

Tech Highlights was prepared by Zenghe Liu of Abbott Diabetes Care, Mike Kelly of Sandia National Laboratories, Colm O'Dwyer of University of Limerick, Craig Walker of Valence Technology, Inc., and Donald Pile of Dow Kokam LLC. Each article highlighted here is available free online. Go to the online version of Tech Highlights, in each issue of Interface*, and click on the article summary to take you to the full-text version of the article.*