A novel machine learning model for copper electroplating process optimizing chemical additives

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Copper electroplating is essential in semiconductor interconnect technology, particularly in the dual damascene technique. This technique demands filling trenches and vias with copper seamlessly without any voids. To prevent void formation, additives are employed to regulate the electroplating rate, in conjunction with the application of an adequate current between a copper electrode and the wafer. Hence, optimizing the intensity and concentration of these additives is imperative to avoid void formation.

In this study, a machine learning model was developed based on simulation results to estimate an optimized concentration and intensity of the additives, and subsequently verified experimentally through electroplating wafers. Initially, simulations were conducted to acquire data used in a machine learning process. Machine learning techniques were then applied utilizing data from the simulations to construct a predictive model for void occurrence based on process parameters.

The machine learning methodology employed in this study is renowned for its prowess in addressing classification problems with nonlinear relationships, leveraging deep neural networks. The neural network's configuration was determined by comparing 128 structures using grid search, which outperformed support vector machines in accuracy. Finally, copper electroplating experiments in 12-inch wafers were conducted to validate the effectiveness of the developed machine learning model.

A Study on Manufacture of Hard-faced Forming Tools Using a DED Process

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Keywords: DED process, Deposited region design, Forming tool, Hard-facing, Substrate design

The wear phenomenon has been classified as a critical failure mode to determine the service life of forming tools and the quality of the fabricated part. Although the wear occurs in the localized region of the forming tool, the forming tool should be discarded when an excessive wear is taken place. Hard-facing technologies have widely used to improve the wear resistance and the functionality of the forming tool. Hard-facing technologies deposit dissimilar materials on the steel. The hard-facing technologies can reduce the material cost through the creation of the functional material on the cheap material. The goal of this presentation is the manufacture of the hard-faced forming tools using a directed energy deposition (DED) process. Inconel powders are deposited on AISI 1045 structural steel using a laser engineered net shaping (LENS) process. In order to obtain a proper design of the substrate and the deposited region, the effects of the substrate design on the deposited volume and residual stress characteristics are investigated. The deposition strategy is proposed to deposit appropriately on edges and corners of the substrate. An amount of the offset for the post-processing of the deposited tool is estimated via thermo-mechanical analyses. Several types of hard-faced forming tools are created by the proposed hard-facing method. Finally, characteristics of fabricated forming tools are discussed.

Enhancing Drone Flight Time using SOFC with ALD Thin Film Coating

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Keywords: atomic layer deposition, deep reactive ion etching, micro-SOFC, thin film process

This presentation introduces the latest advancements in micro solid oxide fuel cells (micro-SOFCs) that utilize silicon-based micromachining technology. Our objective is to significantly extend the operational flight time of drones by expanding the lateral dimension of these electrochemical energy conversion devices. Historically, the lateral dimension of the ultra-thin film electrolyte membrane, which has a thickness of only tens of nanometers, was constrained to a few hundred micrometers due to its delicate oxide membrane. Leveraging a unique mechanical design, we have reduced the membrane's stress level. Coupled with a streamlined combinatorial etching process, we have successfully expanded the lateral dimension of the micro-SOFCs' electrolyte membrane to several millimeters. This technological leap could propel such devices closer to commercial production, particularly benefiting areas like unmanned aerial vehicles (UAVs) and military drones that require extended flight times for broader applications.

Fabrication and characterization of porous perovskite thin film cathode for low temperature solid oxide fuel cells

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Keywords: LSC, LT-SOFCs, cathode, perovskite, thin film

Solid oxide fuel cells (SOFCs) are gaining attention as next-generation energy conversion devices because of numbers of strong points. However, SOFCs must operate at high temperatures to ensure the performance of SOFCs. This high operation temperature caused critical issues such as thermal stability and requirements of expensive materials. Therefore, research on low temperature SOFCs (LT-SOFCs) has recently conducted. In LT-SOFCs, platinum (Pt) is commonly used as the electrode material. However, Pt has drawbacks such as low stability at high temperatures and cost. Therefore, in this study, the perovskite material LSC (La0.6Sr0.4Cr1O3-x) was used to minimize Pt loading on LT-SOFCs. In order to fabricate porous LSC thin film cathode for LT-SOFCs, porous GDC (Gd-doped ceria, Gd0.9Ce0.1) cathode functional layer was used. The porous Ni thin film anode was adopted for fuel cells, and SCSZ electrolyte substrates were employed. The performance of the fabricated fuel cells was systematically analyzed. Also, X-ray Diffraction (XRD) and Scanning Electron Microscope (SEM) analysis were conducted to evaluate properties of :LSC and GDC thin films.

Fabrication of GDC/YSZ Bilayer Electrolyte by Reactive Sputtering for Thin-Film Metal-Supported Solid Oxide Fuel Cells

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Keywords: electrolyte, metal-supported solid oxide fuel cell, physical vapor deposition, reactive sputtering

Solid oxide fuel cells (SOFCs) represent a promising technology for future clean energy systems due to their high efficiency and low emissions. Metal-supported solid oxide fuel cells (MSCs) offer several advantages over conventional ceramic-supported SOFCs, including fast start-up capability, mechanical robustness, cost-effectiveness, and excellent thermal cyclability. However, the fabrication of MSCs presents challenges, particularly regarding the use of ferritic steels for metal supports, which cannot withstand the high temperatures required for conventional slurry-based methods due to issues such as counter-diffusion of elements and metal oxidation. Physical vapor deposition emerges as a promising method for manufacturing MSCs, as it enables the deposition of thin film electrolytes without the need for high sintering temperatures. Thin film electrolytes, with thicknesses of a few micrometers or less, offer the advantage of reducing the operating temperature by minimizing ohmic resistance. In this study, we propose a reactive sputtering method to deposit pinhole-free thin film electrolytes for thin-film MSCs (TF-MSCs). By controlling the substrate temperature during sputtering, we were able to manipulate the grain size and grain boundary density of the Yttria-stabilized Zirconia (YSZ) electrolyte. A substrate temperature of 500°C resulted in significantly reduced grain boundaries, leading to improved ionic conductivity and overall performance, as grain boundaries typically impede ionic conduction. Subsequently, an optimized YSZ film was deposited onto a sputtered Gadolinium-doped Ceria (GDC10) electrolyte to form a 1 μm-thick GDC-YSZ bilayer. This bilayer configuration prevented electronic leakage and resulted in a TF-MSC with exceptional peak power density of 699 mW/cm^2 at 500°C.

Hydrogen Energy – Electrochemical/Thermochemical Clean Hydrogen Production Technology

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Keywords: Dry Reforming, Hydrogen Production, Methane Pyrolysis, Water Splitting

Electrochemical water splitting and thermochemical methane pyrolysis & dry reforming of methane are promising technologies for producing clean hydrogen. However, developing earth-abundant and efficient energy conversion materials and systems such as catalysts operated under relatively low overpotential for the electrochemical method and low temperatures for the thermochemical method is still challenging. Herein, I will first present two scalable electrochemical methods to activate the basal plane of molybdenum disulfide (MoS_2) for hydrogen evolution reaction (HER) in acid condition, i.e., the electrochemical desulfurization and addition of cobalt clusters. Secondly, I will discuss the thermochemical method, i.e., the thermal oxidation and its mechanism, to easily create and control active edge sites of MoS_2 for HER. Lastly, I will introduce recent research progress of methane pyrolysis by a molten metal-based thermochemical system and the progress of dry reforming of methane by a solid catalysts-based vertical furnace reactor system in the Clean Energy & Nanoheat (CLEAN) Lab at Seoul National University.

Transient Strain-Induced Electronic Structure Modulation in a Semiconducting Polymer Imaged by Scanning Ultrafast Electron Microscopy

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Keywords: photo-elastic effect, secondary electron emission, semiconducting polymer, strain effect, ultrafast electron microscopy

Understanding the opto-electronic properties of semiconducting polymers under external strain is essential for their applications in flexible devices. While prior studies have highlighted the impact of static and macroscopic strains, assessing the effect of a local transient deformation before structural relaxation occurs remains challenging. Here, we employ scanning ultrafast electron microscopy (SUEM) to image the dynamics of a photo-induced transient strain in the semiconducting polymer poly(3-hexylthiophene) (P3HT). We observe that the photo-induced SUEM contrast, corresponding to the local change of secondary electron emission, exhibits an unusual ring-shaped profile. We attribute the observation to the electronic structure modulation of P3HT caused by a photo-induced strain field owing to its low modulus and strong electron-lattice coupling, supported by a finite-element analysis. Our work provides insights into tailoring opto-electronic properties using transient mechanical deformation in semiconducting polymers, and demonstrates the versatility of SUEM to study photo-physical processes in diverse materials.