05 Renewable Energy and Thermal Science: Materials, Design, and Applications

Decentralized Renewable Off-grid Wastewater Treatment, DANIEL ANDRADE, KYLE MILLER, MOHAMMAD MASOUD MODABERNIA, THUAN JOHN NGUYEN, JUSTINE NGUYEN, and REZA BAGHAEI-LAKEH* (Mechanical Engineering Department, Calif. State Polytechnic Univ. at Pomona, Pomona, CA, 91768, rblakeh@cpp.edu)

The concerns of water availability has risen due to the stress from high water consumption and the effects of climate change. In the past, California has experienced extreme drought conditions where a series of executive orders have been issued to address concerns and conserve water. Even after the expiration of the exceptional drought condition, more than 10 million people still live in drought condition in California. In this presentation, a case study of a decentralized greywater treatment for non-potable use will be discussed. DROWT (Decentralized Renewable Off-grid Water Treatment) project is an innovative water recycling system which is expected to have a tremendous role in reclaiming a major proportion of water for non-potable purposes without having any carbon footprint. The research team at Cal Poly Pomona, with the support of Metropolitan Water District of Southern California, are developing an off-grid solar-powered greywater treatment system for single households and remote locations. The system consists of three stages of treatment, including a microfiltration, solar-driven reverse osmosis, and an ultraviolet disinfection unit. These treatments will remove particles of dirt and food, traces of organic chemicals and inorganic chemicals, etc. All electrical components of the system will be powered by the photovoltaic panels to make the system completely grid-independent. To further improve the power efficiency, the energy recovery device is also added to reduce the energy consumption of the system. The product of this project will be capable of reclaiming 90 gallons of water per day while recovering 63% of residential greywater. In this presentation the preliminary design of the system will be discussed and the energy consumption of the system will be compared with similar studies.

Discretized Enthalpy Method with Variable Heat Transfer Coefficient Capability Analysis for Shell and Tube Heat Exchangers, KEVIN R. ANDERSON and ANTHONY S. FLORES (Mechanical Engineering Department, California State Polytechnic University at Pomona, Pomona, CA, 91768; kranderson1@cpp.edu, asflores@cpp.edu).

Shell and tube heat exchangers (HXs) are the most common type of HXs used in industry. They are used to exchange thermal energy between two fluids of different temperatures without the use of mixing. They offer large flexibility in their design and a common method in analyzing their performance is through the widely accepted Number of Transfer Units (NTU) and the Log Mean Temperature Difference (LMTD) methods. These methods use the inlet and outlet properties of the fluids to predict the overall performance of the device. A severe limitation to these methods occurs from the neglect of the variability of thermal physical properties with respect to temperature of the fluids. The temperature of the working fluids change throughout the device due to phase change. A method for analyzing shell and tube heat exchangers which accounts for the variability in thermal physical properties of fluids is presented herein. The so-called discretized enthalpy approach is taken by splitting the shell and tube into a fixed number of elements where thermodynamic and fluid mechanic equations are applied locally. Moving from one element to the next, all elements are analyzed and an overall performance of the shell and tube HX can be determined. The MATLAB code developed will be demonstrated for the analysis of a high temperature, high pressure HX application for Venus space exploration. The use of the NIST REFPROP Thermophysical database interface to MATLAB will also be shown.

Effect of Porous Substrates as Novel Surface Treatments for Optimization of Single and Multi-Layer Microchannel Heat Sinks, ALI GHAHREMANNEZHAD* and KAMBIZ VAFAI (Mechanical Engineering Department, Bourns College of Engineering, University of California, Riverside, CA 92521, USA, agah001@ucr.edu).

In present study, porous substrates are utilized as surface treatments in single and multi-layer microchannel heat sinks (MCHSs) to optimize their thermal performance. Microchannel heat sinks with different solid fin thicknesses have been presented in three dimensional models and effect of adding porous substrates with various thicknesses is studied. Heat transfer and fluid flow through the microchannels are simulated using extended Darcy-Brinkman-Forchheimer method and different performance parameters are evaluated by performing parametric study on the porous-solid fin thicknesses for both single and multi-layer MCHSs. By comparing the results to the conventional heat sinks, it is found that for different geometrical parameter combinations, there exists a porous MCHS that improves the thermal performance. Moreover, a sensitivity analysis on the porous thickness of the new microchannel heat sinks shows that by a careful design, the hydraulic performance can also be improved simultaneously. The potential of utilizing porous substrate and their superior performance has been evaluated at various performance parameters, porosities, flow rates, and heat sink materials. Figure of merit for each MCHS is discussed in order to consider the change in thermal resistance and pumping power parameters at the same time.
Results indicate that by performing an optimization process on the microchannel heat sinks at different range of Reynolds numbers and utilizing porous substrates as surface treatments, optimized designs can be found which can provide a novel passive method to increase heat transfer capability of conventional MCHSs while decreasing the required power input.

**Thermal Nitridation of Stainless Steel Bipolar Plates for Proton Exchange Membrane Fuel Cells**, ADRIAN BARCIMO*, KEVIN DUONG and VILUPANUR RAVI (Department of Chemical and Materials Engineering, Cal Poly Pomona, 3801 W Temple Ave, Pomona, CA 91768; ambarcimo@cpp.edu).

Increasing concerns of climate change due to rising CO\textsubscript{2} emissions have prompted the development of alternative power generation systems. In response to this, proton exchange membrane fuel cells (PEMFCs) have gained steady interest in transportation and stationary applications due to their high efficiency and low emissions. Bipolar plates are a key component of fuel cells that function as electrical conduits between cells and distributors of reactant gases. Current materials used for bipolar plates are graphite due to its high corrosion resistance and electrical conductivity; however, the high cost of machining and poor mechanical properties of graphite limits its widespread use. To make these devices more commercially available, an alternative material that has better cost-effectiveness and mechanical properties is required. Metallic plates have been considered for this application, but notables issues involve their corrosion susceptibility and reduced electrical conductivity due to naturally-forming passive layers. To circumvent these problems, the metallic plates can be modified with a corrosion resistant and conductive coating. This project examines the corrosion behavior of uncoated and coated UNS S31600 and N08330 stainless steels nitrided at various temperatures and times. A thermal nitridation process was implemented using pure nitrogen (N\textsubscript{2}) gas. The test coupons were placed in a 0.01M H\textsubscript{2}SO\textsubscript{4} electrolyte solution at 70°C to simulate a PEMFC environment and characterized using DC electrochemical testing. The surfaces of the coated product were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), and optical microscopy. Electrical conductivity was measured before and after testing using a 4-point probe testing apparatus.

**Developing Fuel Cells for Transportation Application**, SHEHAB BASSIOUNI*, BROOKE SINGLETON, FIONA FOLLETT, SEAN VINIK, and VILUPANUR RAVI (Department of Chemical and Materials Engineering, California State Polytechnic University, Pomona, 3801 W. Temple Ave. Pomona, CA 91768; sbassiouni@cpp.edu).

The concentration of carbon dioxide in the atmosphere has steadily increased since the industrial revolution. Replacing fossil-fuel burning vehicles with electrochemically powered vehicles can greatly mitigate the greenhouse gas emissions in the atmosphere. The proton exchange membrane fuel cell (PEMFC) is an excellent solution due to its low operating temperatures, zero emissions and high efficiency. In this study, we aim to reduce fuel cell costs and improve their durability by substrate selection and surface modification of a crucial component – separator plates. Currently, graphite is used as the endplate material. While offering excellent corrosion resistance; its porosity makes it difficult to shape into thin sheets and its brittleness makes it unsuitable for transportation applications. In addition, the cost of manufacturing graphite separator plates is high, accounting for 60% of the fuel cell cost. Current targets goals for a bipolar plate require materials to have desirable mechanical properties, good corrosion resistance, high electrical conductivity, low cost and low density. In this study, UNS S41000 stainless steels were selected as possible candidate materials due to their high electrical conductivity, ductility and low cost. The surfaces of the selected material was surface modified by coating the coupon with graphene. As-received and surface modified test coupons were subjected to electrochemical tests that were conducted under simulated PEMFC environments, i.e., 70°C in 0.01 M H\textsubscript{2}SO\textsubscript{4} solution in a three-electrode flat cell. Scanning electron microscopy and X-ray diffraction were used to characterize the test coupons.

**Selection of Salts and Containment Materials for Solar Thermal Energy Storage**, CARINNE LUKIMAN*, STEVEN PIERCE, TOUBA SHAH and VILUPANUR RAVI (Department of Chemical and Materials Engineering, California State Polytechnic University, Pomona, Pomona, Pomona, CA, 91768; clukiman@cpp.edu).

Concentrated Solar Power (CSP) plants provide the twin advantages of energy generation and thermal energy storage. The latter provides CSPs the advantage of persistent power, a feature that is absent in photovoltaic plants. However, there is much to be done to make CSPs competitive with traditional coal-powered plants. Reduction of CSP costs relies on the selection and use of salts with high heat capacity, relatively low melting temperatures and good thermal stability. Chloride salts are viable candidates that fulfill the technical requirements and are relatively low-cost. However, the corrosivity of these salts needs to be addressed. This paper outlines the approach taken to select a promising salt (KCl - 44.5 wt% NaCl), and containment materials (UNS S31600 and UNS N08330 with G10180 as the control/baseline). An experimental approach involving electrochemical testing of candidate alloys (as-received and surface modified) is described. Microstructural characterization included optical and scanning electron microscopy. The selected salt was determined to be a viable candidate as a thermal energy storage medium based on thermodynamic considerations. The containment materials that are compatible with this salt in an argon atmosphere at 700°C are the as-received UNS S31600 and UNS N08330.

**Silicon-Carbon Anodes for Li-ion Batteries**, NICOLE J WAGNER1*, ALEJANDRO ALVAREZ BARRAGAN2, GIORGIO NAVA2, and LORENZO MANGOLINI1 (1Department of Industrial and Manufacturing Engineering, Cal Poly Pomona, 3801 West Temple Avenue, Pomona, CA 91768, njwagner@cpp.edu; 2Department of Mechanical Engineering, 900 University Avenue, Riverside, CA 92521, alejandro.jab@gmail.com, gionava@ucr.edu, lmangolini@engr.ucr.edu).

Core-shell silicon-carbon nanostructures have become a potential replacement for graphite in anodes for lithium ion batteries. However, it is difficult to directly compare the electrochemical performance of similar structures created from the
variety of fabrication methods available. Therefore, the current work is aimed to provide a direct comparison of core-shell silicon-carbon nanostructures created by two methods. The first approach used carbonization of common polymers to create the carbon shell surrounding silicon particles, while the second method was a chemical vapor deposition (CVD) process using acetylene as the carbon source. In both cases, the same type of silicon particles were used as the active material. This allowed for a direct comparison of battery performance for both approaches. The CVD process was superior to the polymer approach as it allowed for direct tuning of the silicon-carbon ratio, provided a conformal coating of the silicon particles, and eliminated a process step that exposed the particles to an oxidizing atmosphere. Anodes prepared with carbon-coated silicon particles from the CVD process showed improved performance over those created from the polymer carbonization approach.