Porous Ceramics for CSP Applications

June the 26th 2013
Department of Innovative Technologies
SUPSI – Lugano
Program: June the 26th 2013

08:45  **Arrival and registration**

09:00  **Welcoming remarks**  
(Prof. Ortona, Prof. Yoon, Dr. Fend)

09:15  **Aldo Steinfeld, Solar thermochemical H2O and CO2 splitting utilizing a reticulated porous ceria redox system**

Solar thermochemical cycles for the production of synthetic fuels make use of concentrated solar radiation as the source of high-temperature process heat. These processes inherently operate at high temperatures and utilize the entire solar spectrum, and as such provide thermodynamic favorable paths to efficient fuel production. Considered is the ceria-based redox cycle for splitting H2O and CO2. A 3kW solar cavity-receiver containing a reticulated porous ceramic (RPC) foam made of pure CeO2 has been experimentally investigated. The RPC was directly exposed to mean solar flux concentration ratios exceeding 3000 suns. The solar-to-fuel energy conversion efficiency, defined as the ratio of the calorific value of the fuel produced to the solar radiative energy input through the reactor’s aperture and the energy penalty for using inert gas, was 1.73% average and 3.53% peak. These are the highest solar-to-fuel energy conversion efficiency values reported to date for a solar-driven device converting CO2 to CO.

10:15  **Coffee break**

10:45  **Thomas Fend, Challenges in Lay-Out and Characterization of CSP- High-Temperature- Components**

Concentrated Solar Power (CSP) is a technology to generate electricity from high-temperature solar heat. To convert radiation into heat advanced components are necessary. For these components innovative functional materials are needed to fulfill the challenging technical and economical requirements. An overview is given on current and future material concepts as well as on experimental and numerical tools to characterize and assess candidate materials for their application at high temperatures. Special focus is put on porous materials and their efficiency heat transfer and permeability properties.

11:15  **Gianluca Ambrosetti, Achieving temperatures beyond 600°C on a parabolic trough**

Parabolic trough CSP systems with oil as a thermal fluid have since long demonstrated to be one of the most viable options for large-scale solar electricity production but have, in their current implementations, a limited maximum operating temperature below 450°C and expensive vacuum insulated receivers with exotic absorber coatings. A novel approach to linear receivers has been taken instead by Airlight Energy, with a crossflow design where heating is attained in a string of coiled tube cavities connected in parallel. The heat transfer fluid used by the system is air, which, besides being inexpensive and environmentally friendly, is optimally suited for high-temperature operation, above 650°C.

09:45  **Manuel Romero, Volumetric absorbers: closing the gap between ideal and real performance**

After more than three decades of research and engineering, the development of volumetric absorbers for central receiver systems has reached several milestones in terms of peak flux (> 1MW/m2) and temperatures of operation beyond 1,000°C. However thermal efficiencies remain modest and controllability of fluid dynamics is difficult. In addition, promising ceramic materials are still performing worse than more classical metallic wire mesh structures. Research in our group focuses on better understanding the experimental gas/solid temperature profiles for different materials and geometries; the design and fabrication of new geometrical configurations to improve volumetricity and penetration of photons and the analysis of integration into CSP systems.
11:45 Gerard Vignoles, An original Monte-Carlo method for the determination of effective heat diffusivity in radiative/conductive porous media
Numerous materials intended to work at high temperatures, like thermal protection system materials, heat exchangers, gas burners, etc … are porous and involve heat transfer both by conduction through the solid phase and radiation through the pores. Addressing simultaneously both types of heat transfer in numerical simulation is still an issue. We present a fully coupled numerical tool, based on a mixed random walk algorithm, intended to work on 3D images produced e.g. from CMT or image synthesis. It can also account for the heterogeneous and anisotropic nature of the solid phase. Validation on test cases and some preliminary results on X-ray CT images (woven composites, fiber bundles, foams) are shown.

12:15 Lunch

13:45 Maurizio Barbato, Si-SiC foams and lattices for high temperature volumetric receivers
Si-SiC foams and lattices are a new category of materials used in a concentrated solar power, thanks to their thermal and fluid-dynamics properties and their behavior at high temperature and harsh environments. Factors that contribute to these outstanding performance are their high specific surface area and material oxidation resistance. Three-dimensional thermo-fluid dynamics analysis were performed to evaluate heat transport properties of SiC based ceramic foams and lattices. The study aimed at evaluating the heat exchange performance of Si-SiC foams and at engineering the morphology of Si-SiC lattices structures looking at the customization of performance for the next generation of volumetric solar receivers.

14:15 Young-Wook Kim, Processing of Polymer-Derived Porous Silicon Carbide Ceramics
Interest in polymer-derived porous SiC ceramics has grown continually over the last 10 years because such materials are easier to process and seem to have superior mechanical properties than powder-processed porous SiC ceramics. Different processing routes for porous SiC ceramics have been developed for specific applications to satisfy the associated requirements of porosity, pore size, and degree of interconnectivity. These methods include replica, direct foaming, sacrificial template, reaction sintering, and partial sintering processes. However, all the methods require high temperatures. In this seminar, new processing strategies for producing porous SiC ceramics are presented including steam chest molding, expansion method, use of environmentally friendly templates and use of a bonding phase for lowering the processing temperature.

14:45 Sandro Gianella, New opportunities to increase solar absorber efficiency
Latest developments in ceramic engineering open new opportunities for the production of high performance solar absorbers. Innovative open cell silicon carbide structures will be presented and discussed.

15:15 Coffee break

15:45 Claudio D’angelo, Mechanical behavior of ceramic foams and lattices under compression
How finite element analysis can be used to study and optimize the morphological features of this reticulated ceramics in respect of their mechanical properties. Morphological data, obtained by X-ray computed tomography (XCT) on a commercially available Si-SiC foam produced by the replica method, have been linked to a set of computer generated lattices which properties were estimated in multiple directions. In parallel, Si-SiC lattices were produced via indirect rapid prototyping by 3D printing and replication in order to validate numerical domains designed during the simulation campaign. Both foams and lattices were then tested under compression.

16:15 Round table

19:00 Evening event
Aim
The workshop aims at exchanging information among scientists, engineers and end users involved in the field of CSP. It proposes a discussion on the sustainable development of CSP technology thanks to the recent developments in material science, materials characterization and new technological opportunities.

Objective
In the recent years Concentrated Solar Power (CSP) has become a small but increasing integral part of the electricity supply of many countries of the world. CSP technology uses high temperature solar heat to operate engines. CSP offers unique features such as the possibility of a sustainable base load electricity supply and the possible hybridization with a simultaneous use of the engine waste heat for secondary applications such as desalination. Therefore this technology can help in solving two of the main global problems especially occurring in countries belonging to the desert belt of the world: increasing water scarcity and electricity demand by a rapidly growing population. CSP offers both: a chance for economic growth in countries with access to areas with high direct solar radiation and a chance for the industrialized countries for a sustainable and competitive energy supply.

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The evening event is kindly sponsored by

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