Solar Thermal Laboratory

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Research Interests:
• Solar thermal and thermochemical systems
• Heat driven systems and waste heat utilization
• Thermal energy storage
• Heat and mass transfer
• Reacting flows
Prospective Research Topics

• Development of Solar Receiver Material subjected to High Intensity Radiation

• Solar Methane Reforming in Micro-Reactors for Hydrogen Production

• Microchannel based Adsorption Dehumidifier driven by Data Center Waste Heat

• Sustainable Direct Capture of CO₂ from Air

• Compact and Efficient Energy Storage Systems

• Circulating Fluidized Bed Adsorption Dehumidifier
Solar Thermal and Thermochemical Systems

Solar Thermal and Thermochemical Systems
• India (especially north-western regions) are blessed with high solar influx
• Concentrated solar power production via. thermal route
• Utilization of concentrated solar radiation for driving endothermic gasification and reforming processes

How can Solar Thermal / Thermochemical Systems make a difference?
• With thermal energy storage, solar thermal power plants have potential for sustainable electrical power source
• Upgrading the energy content of chemicals or producing useful chemicals / fuels through thermochemical routes
• Production of hydrogen (or syngas) via splitting of water or hydrocarbon fuels
High Flux Solar Simulator (HFSS)

- To be installed at SEE-IITK
- Radiation intensity >500 suns
- Controlled and repeatable experiments

Material Testing

- Effect of high intensity radiation, high temperature gradients and cyclic / abrupt thermal cycles on material properties
- Development of advanced materials to withstand the harsh operating conditions

Methane Reforming (endothermic process)

- \( CH_4 + 2H_2O \leftrightarrow CO_2 + 4H_2 \quad \Delta H = 165 \text{ kJ/mol} \)
- The driving heat input from solar radiation (from high flux solar simulator – upto 500 suns)

Construction

- Additive manufacturing to build micro-reactor

Model Development

- Evaluate various micro-reactor configurations

Heat Driven Systems and Waste Heat Utilization

Heat Driven Systems and Waste Heat Utilization
• Absorption / Adsorption chillers and heat pumps $\rightarrow$ eliminate electrically driven compressor used in vapor compression systems
• Desiccant based air dehumidifiers $\rightarrow$ eliminate high energy intensive process of cooling air below the dew point temperature to remove moisture

How can Heat Driven Systems make a difference?
• Use heat as prime mover – reduce burden on electrical infrastructure
• Potential to utilize waste heat from automobile / power plant exhaust, industrial processes, data centers and solar collectors
• Use benign fluids – e.g. water
Microchannel based Adsorbent Coated Heat Exchanger

Silica Gel Coated-Microchannels
• Extremely fast heat and mass transfer
• Very low thermal mass
• Compact and lightweight
• Use of high-performance adsorbent materials

Operation
• Heating (desorption) by low grade heat from solar thermal or waste heat

Beneficial Feature
• Heating time less than 10% of the cooling time

Prospective Research Topics Based on Microchannel based Heat Exchangers

• Microchannel based Adsorption Dehumidifier driven by Data Center Waste Heat

• Sustainable Direct Capture of CO$_2$ from Air

• Compact and Efficient Energy Storage Systems
Circulating Fluidized Bed Adsorption Dehumidifier

Operation

- Silica Gel balls in fluidized beds can circulate automatically between regeneration and dehumidification columns

Beneficial Features

- Elimination of mechanical energy driven rotary wheels to switch regeneration / dehumidification
- Avoid cyclic operation
- Increase adsorption/desorption rates by 20% and lower the pressure drop by 30% as compared to packed bed

Design Improvement

- Improve the design for effective use and efficient transport of the desiccant material