Gas-Hydrate Research Laboratory

Laboratory Coordinator: Dr. M. K. Das

Associated Faculty Members (if any): P. K. Panigrahi

List of Major Equipment:

- High-pressure, Optically Accessible, Gas Hydrate Diagnostic System
- High Performance Computing System

Brief description of the laboratory:

The research work in lab intends to enhance the gas hydrate formation rate for gas storage and transportation application. A high-pressure pilot-scale reactor to simulate the field scale hydrate formation morphology is developed in the lab. The reactor is made of stainless steel (SS 316) with a maximum design pressure of 180 bar. The cylindrical reactor has an internal diameter of 232 mm and a height of 622 mm with a total volumetric capacity of 25 L. There are four circular optical windows (made of sapphire) with a diameter of 50 mm and a thickness of 25 mm for visual observation of hydrate growth inside the reactor. It is the largest reactor in India dedicated to gas hydrates. Since the hydrate formation is a very slow process and gas storage capacity is also very low. So, a chemical promotor to enhance the hydrate formation rate for a possible industrial application is developed. Doing an experiment in such a large reactor is very difficult because it consumes a lot of time and cost. So, for doing cost effective experiment and shorting the experimental time, a new setup is also developed.

Laboratory research keywords:

Gas hydrate formation, gas storage and transportation, CO_2 sequestration, THF hydrate formation, nanofluid synthesis, sea water desalination, cyclopentane hydrate formation.

Major Research and Development Contribution of the Laboratory

Year	Major research and development activity
2020-2021	▪ Study focuses on the synthesis of a hybrid nanofluid (Cu-Al LDH) and the investigation of its effectiveness as a promoter for CO_2 hydrate formation. ▪ The hydrate formation experiments are conducted in a pilot-scale reactor of 25 L volume with a design pressure of 180 bar. The wall temperature of the reactor is set at 2 ◦ C. The charging of the reactor is carried out in both single and dual stage at the maximum pressure of 30 bar. ▪ The presence of LDH nanofluid significantly enhances hydrate kinetics and maximum 176.19% increase in gas consumption compared to pure water.
2019-2020	▪ Study investigates the influence of surfactant crowding on hydrate growth and detachment of hydrate crystal from the interface in a droplet-based configuration. ▪ Experiments are conducted under a constant subcooling of 5 °C

	using a cyclopentane droplet of volume 5 μL immersed in the water pool. ▪ Hydrate growth without surfactant involves lateral growth followed by radial growth and the present of surfactant crowding encourages the radial hydrate growth and impedes lateral hydrate growth.
2018-2019	▪ Carbon dioxide hydrate formation is carried out to understand the kinetics of CO_2 hydrate formation in porous media for the application of CO_2 sequestration. ▪ CO_2 hydrate is formed in silica sand with particle size of 90-500 μm having porosity 38%. The operating temperature and pressure are set at 275.35K and 3.5MPa respectively. ▪ The results shows that the final water to hydrate conversion and hydrate saturation are 25.03% and 27.53% respectively at the end of the hydrate formation experiment.
2017-2018	▪ The objective of this work is to investigate the Tetrahydrofuran(THF) hydrate formation in a cylindrical reactor. ▪ THF hydrate experiments are done at two different THF concentrations 19.06% and 30%. ▪ The hydrate growth rate is mostly controlled by heat transfer phenomena at 19.06% THF concentration and mass transfer effect is eliminated at that concentration.

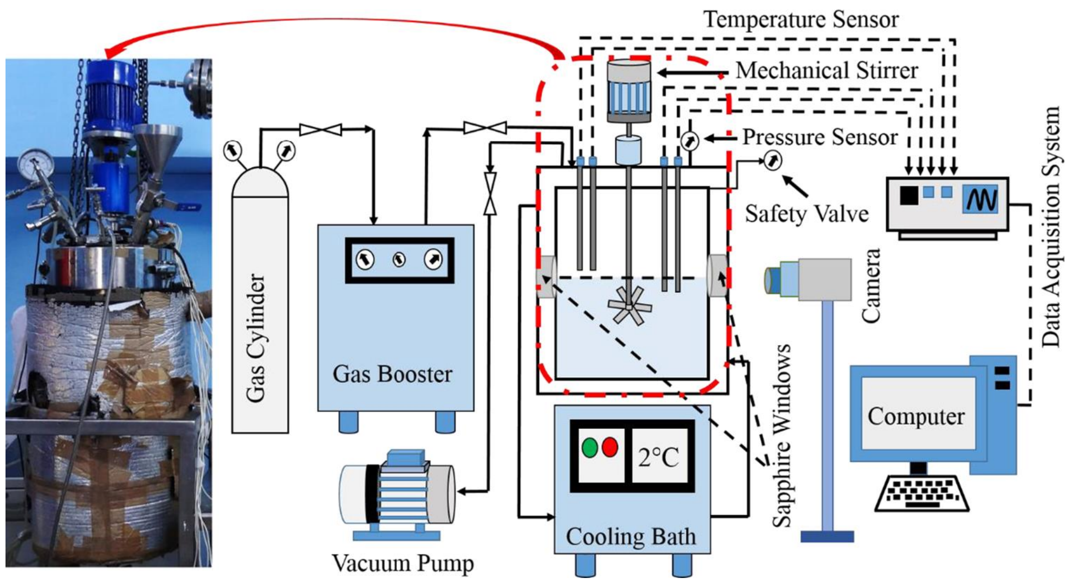


Figure #1. Schematic of the experimental setup for the study of the CO_2 hydrate formation process

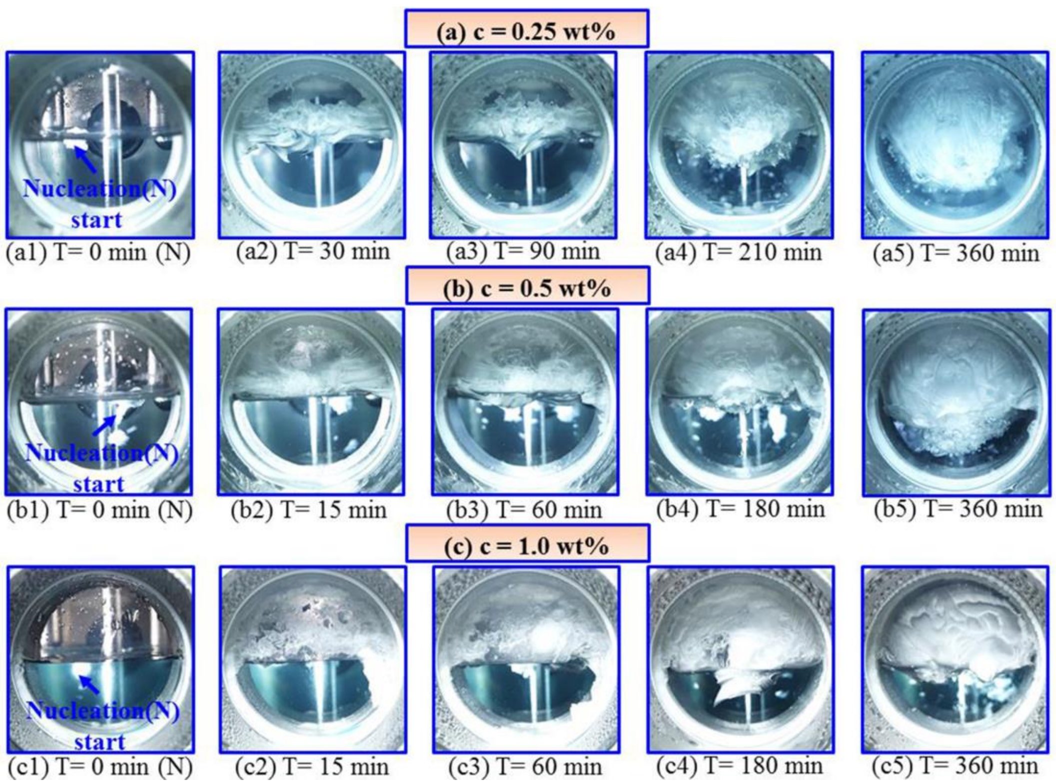
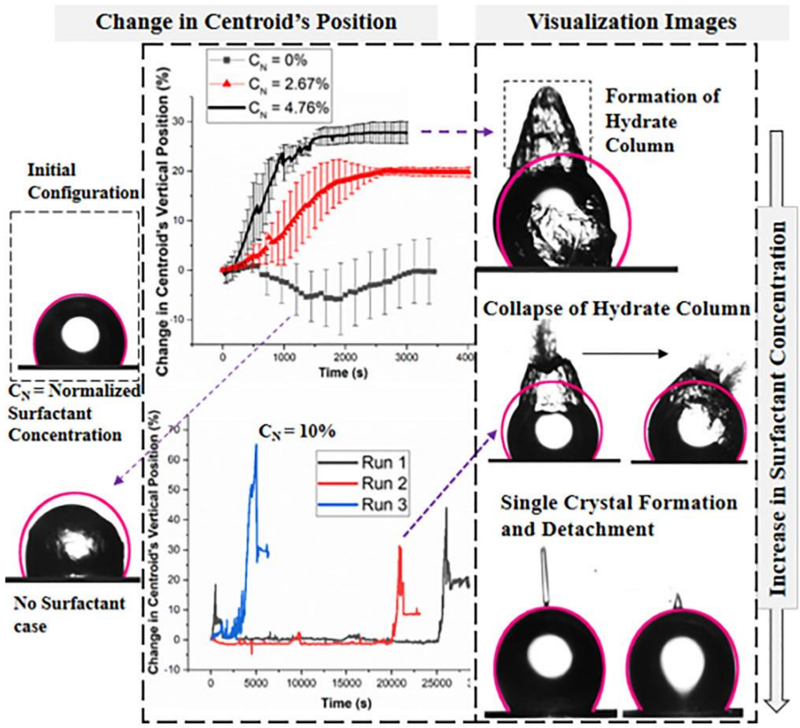


Figure #2: Visualization of CO2 hydrate growth process at different Cu-Al LDH nanofluid concentrations (c = 0.25, 0.5, and 1.0 wt %) for (Cu2+:Al3+: Na+ = 4:1:4) molar ratio.



Figure#3: Sequence of hydrate formation images at different surfactant concentration

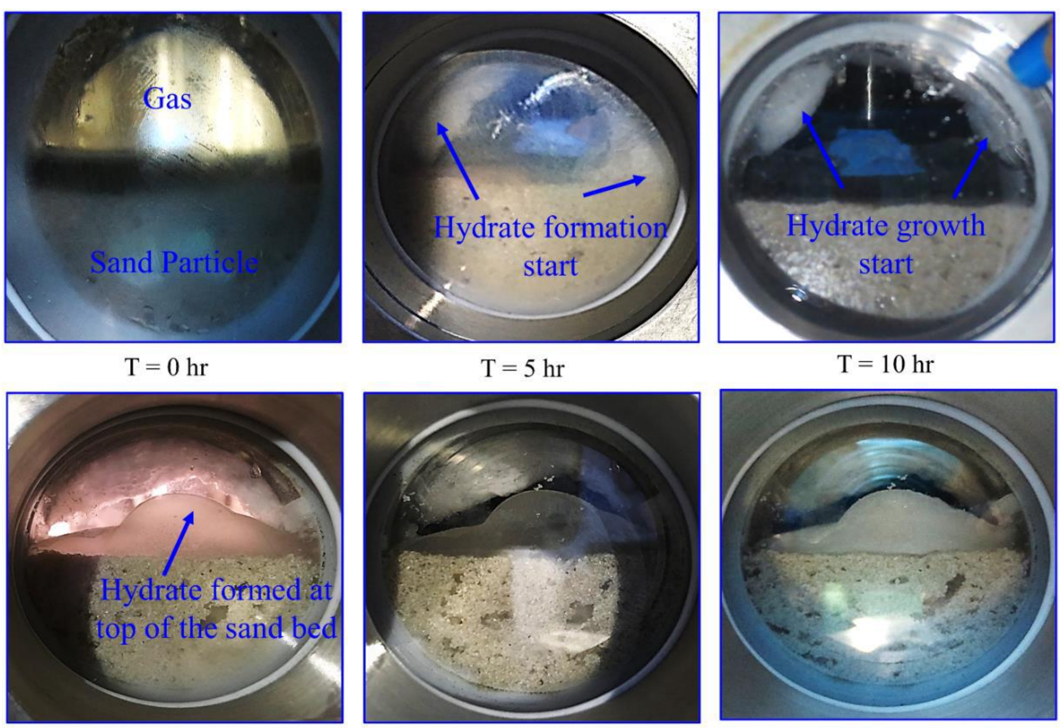


Figure #4: CO_2 hydrate growth visualization during the hydrate formation process

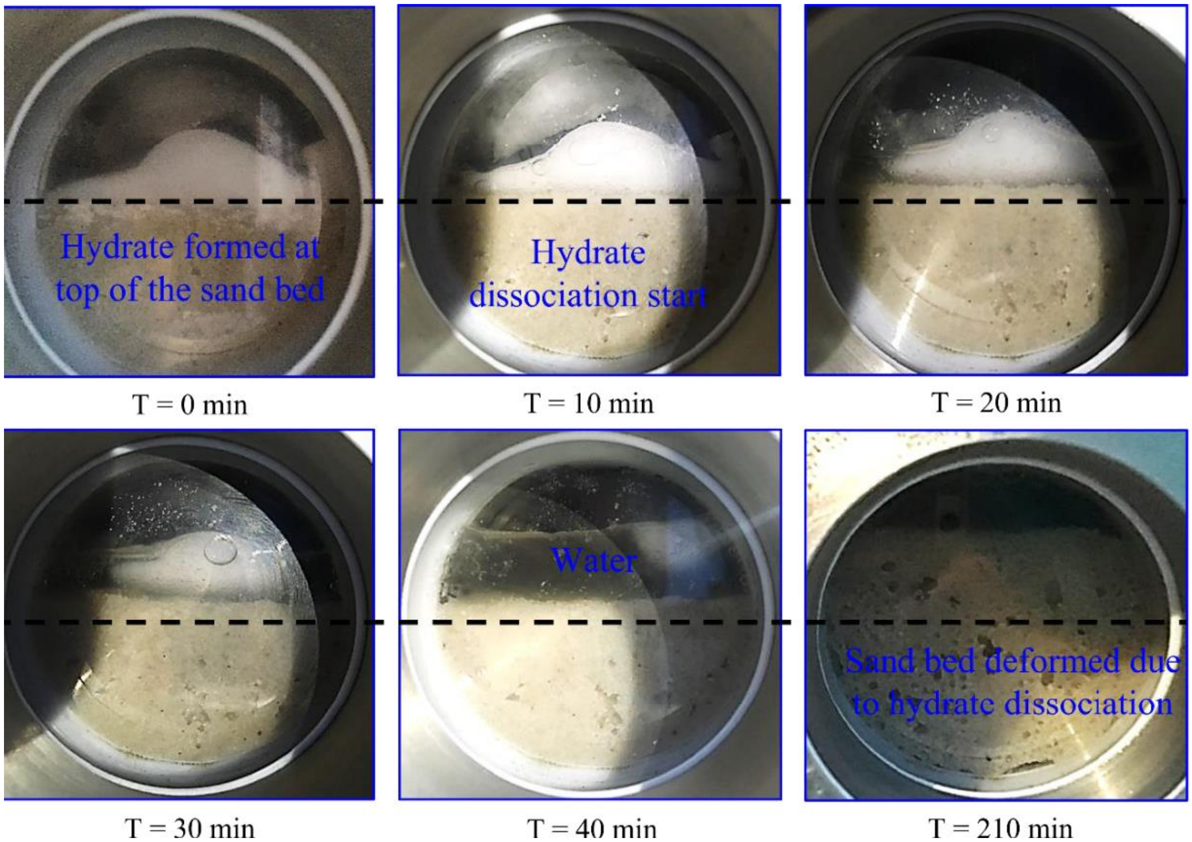


Figure #5: CO_2 hydrate dissociation visualization with time during the hydrate dissociation process