Photocatalytic Solar Fuel Production at Upstream Conditions

Adrian Sepulveda, Mariia Ferree, Damian San Roman Alerigi

Aramco

Abstract

In an hour the sun provides as much energy as humanity consumes annually, making it the renewable energy source with the greatest potential to fulfil humanity's energy needs. Yet, due to the intermittency of solar radiation, harvested energy must be stored in a way that is easy to transport and recover for use. The common solution is to store the energy in batteries that can be used as sources of electrical power. An alternative is to store the energy as a chemical fuel, such as hydrogen generated via some photochemical process. Oil and gas operations provide an excellent source of hydrogen precursors, ranging from hydrocarbons (H-C) to hydrogen sulphide (H_2S). The former requires a high energy input to achieve splitting; however, H_2S could be split using at a lower energy demand. The most common decomposition method is the well-established Claus process, which yield sulphur and water. However, the energy stored in H_2S is wasted on water production instead of H_2. The thermodynamics of H_2 evolution from H_2S splitting is less energy demanding in comparison to water splitting ($\Delta<G^{O}_{water}$ 273 kJ/mole vs. ΔG^{O}_{H2S} 33 kJ/mole). Despite its abundance in subsurface, H_2S has been seldom investigated as a hydrogen source due its high toxicity. Thus, conversion should ideally happen at the source to eliminate the risk of leaks or emissions to the environment. Our work shows the potential benefits, areas of opportunity, and remedial-strategies of in-situ H_2S photocatalysts, specifically helio-catalysis. The study considers the performance at higher pressures and temperatures. It also investigates strategies to circumvent oxide catalyst deactivation or corrosion, including pre-sulphidization, band engineering of photocatalysts, thin-film encapsulation using core-shell structures or directly using sulphide-based catalysts. These sulphide-based photocatalysts broaden the window of usable solar radiation into the near infrared, well beyond the oxides rage. We describe how sulphide catalysts could form S-vacancies during photonic activation, and how higher H_2S partial pressures could be beneficial to increase the lifetime of the photocatalysts. To conclude we will address potential schemes of photocatalyst regeneration as well as for sulfur management at the wellhead or below it. Photo-catalytic H_2 evolution combined with a renewable source of energy would have in theory an energetical advantage of almost an order of magnitude in comparison with other green hydrogen producing sources. H_2S is not a greenhouse gas and its hydrogen evolution could have a significant carbon offsetting potential if a commercially viable technology is developed.