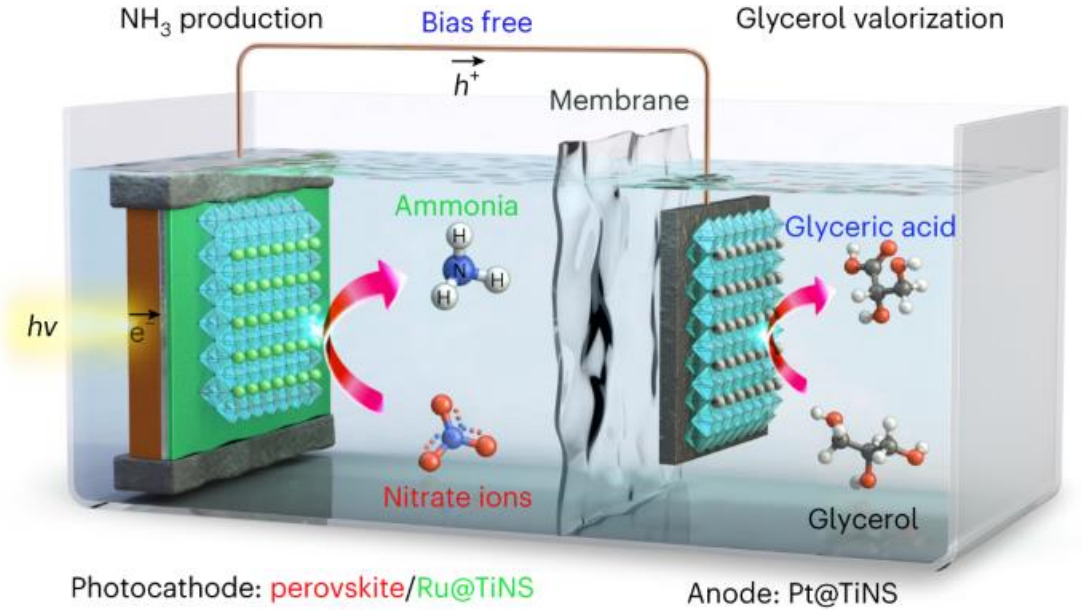
Photoelectrochemical Ammonia Production

NH_3 is a key source for producing fertilizer, food, pharmaceuticals, and other essential chemicals. Most of the NH_3 is produced through the energy-intensive Haber-Bosch Process which requires high temperature (400 ~ 450 °C), and pressure (150 ~ 250 atm). This single process not only utilizes 1% of the world's total energy but also emits 1.6 % of global CO_2. Photoelectrochemical (PEC) NH_3 production technology got much attention as a less-energy-requiring and eco-friendly technique because it is performed at ambient pressure and temperature without emitting CO_2. For the practical application of PEC NH_3 production technology, NH_3 production rates should be at least more than 1,000 μg_{NH3} cm^{-2} h^{-1}.

Photoelectrochemical production of ammonia (NH_3) offers a sustainable alternative to traditional ammonia synthesis, yet current systems are limited by low solar-to-ammonia productivity (SAP) and the need for significant external bias to drive the coupled reactions of nitrate reduction and water oxidation. In this work, several PEC strategies for improving nitrate-to-ammonia conversion are explored . These include patterned catalysts integrated on silicon-based photocathodes to enhance reaction selectivity, the use of Ru-based selective electrocatalysts paired with perovskite photocathodes enabling bias-free nitrate reduction when coupled with glycerol oxidation, and the incorporation of low-cost Ni foil catalysts to further reduce overall system expense. Collectively, these approaches aim to advance efficient, scalable, and economically viable PEC ammonia production.



1. Tayyebi et. al. Nature Catalysis, 7, 510–521, 2024.
2. Tayyebi et. al. EES Catalysis, 2025, **3**, 446-458.
3. W. Jin, …, Tayyebi, et. al. Advanced Materials, 2025, 37, 2506567.