In-Situ Resources Production of Hydrogen Peroxide and Hydrogen Using Nano-enabled Optical Fibers

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Introduction: In-situ resource production holds promise for providing essential materials for life support, construction, energy, and propelltant for space exploration. This approach presents a promising and cost-effective strategy for reducing the mass and cost of space exploration architectures, considering the expensive nature of transporting materials from Earth (e.g., > $10,000 per kilogram to the moon). Resource production via light-driven photocatalytic (PC) and photoelectrochemical (PEC) processes holds significant promise. However, traditional resource generation system designs are hindered by inefficient light delivery and utilization, high equipment costs, and large physical footprints. Therefore, developing efficient and innovative system designs that allow for the inclusion of a wide range of emerging advanced materials plus efficient light delivery is critical for unlocking the full potential of sustainable light-driven resource production technologies.

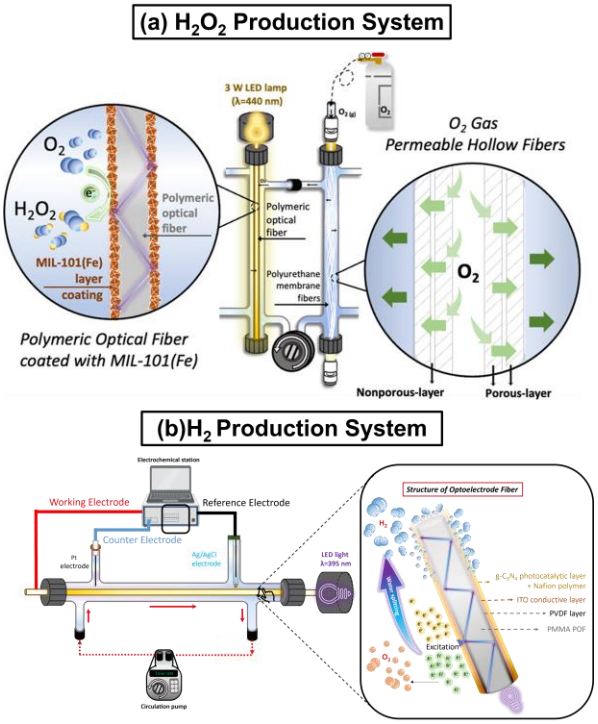

Fig 1. Schematic illustration of (a) H_2O_2 production in a dual-fiber system. (a) H_2 production in a POF incorporated-PEC system.

Results and Discussion: We introduce two optical fiber integrated systems (**Fig.1**), offering superior in-situ H_2O_2 and H_2 resource production, physical flexibility, low-cost operation, and a small physical footprint, all advantageous for in-situ space resource utilization. Our dual-fiber system for H_2O_2 genreation (**Fig. 1a**) comprises a photocatalyst-coated polymeric optical fiber (POF) and an O_2-permeable membrane fiber bundle. A light-emitting diode (LED) source (λ = 440 nm, 3.0 W) was supplied on the top of a POF to provide durable light illuminatton while the POF surface is coated with a Fe-based metal-organic framework (MIL-101(Fe)). The POF emits light laterally, activating the embedded MIL-101(Fe) and facilitating effective H_2O_2 generation**. The H_2O_2 generation system can achieve a remarkable H_2O_2 yield (308 mM h^{-1} catalyst-g^{-1} in ultrapure water), which is 1.5 to 50 fold larger than most slurry-based system design** [1]. Also, atmospheric water-generated condensate water can serve as a promising alternative feedstock for light-driven in-situ H_2O_2 production (H_2O_2 yield 288 mM $h^{-1}g^{-1}$) [2].

H_2 production system (**Fig. 1b**) introduces a modified POF in a PEC steup, with indium tin oxide (ITO) and graphite carbon nitride (g-C_3N_4) nanomaterials coated onto the POF, serving as both optoelectrode and light delivery source. A monochromatic UV-light LED (λ = 395 nm, 2.18 W) and a bias potential of 1.2 V vs Ag/AgCl is applied in a 0.2 M Na_2SO_4 electrolyte at pH 6.8. The side-emitting light activates water splting via the g-C_3N_4 layer for H_2 gneration, while the ITO layer enhances side emission and provides hole/electron separation to enhance H_2 production. **Our optoelectrode system achieves a rapid hydrogen production rate of 344 μmol h^{-1} catalyst-g^{-1}, up to 135 times higher than most existing PEC designs** [3]. Furthermore, our optoelectrode system also offers a geometric space capacity (defined as the catalytic surface area m^2 per unit volume m^3) of 2,670 m^2 m^{-3}, >25 times larger than conventional flat-electrode PEC designs, indicating the competitive space efficiency for space exploration [3].

Future Perspective: Future investigations will focus on examining the performance of POF bundles, exploring alternative photocatalyst materials, and assessing the impact of water quality.

References: [1] Wang, T.-H et.al, *ACS Sustainable Chem. Eng.* **2023**, 11, 6465-6473. [2] Jing Wang et al., *Water Res.* under review. [3] Fu, H. et al., *ACS mater. lett.* under review.