Energy Materials Network
U.S. Department of Energy

HydroGEN
Advanced Water Splitting Materials

Demonstration of a Robust, Compact Photoelectrochemical (PEC) Hydrogen Generator

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Project Objectives

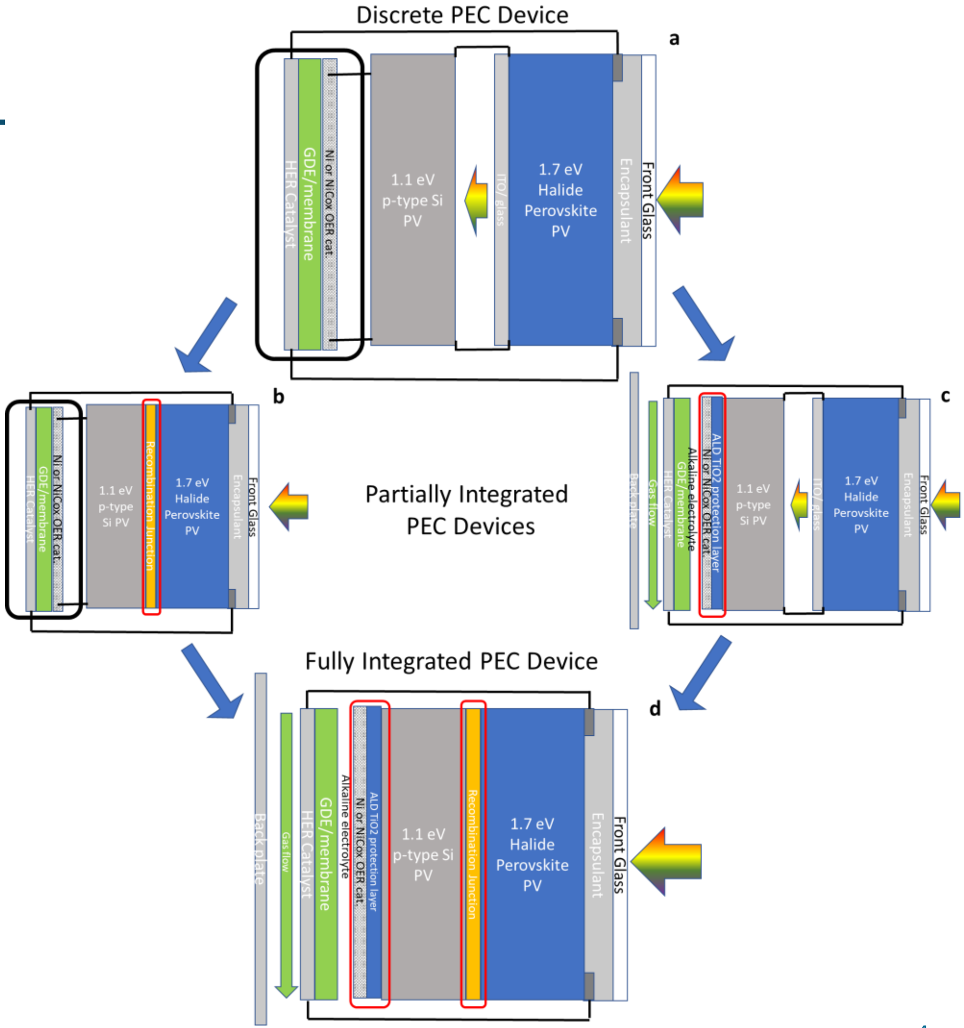
- End of Project Objectives
  - On ≥0.25 cm^2 area-matched devices demonstrate ≥15% STH efficiency for 1000 h under continuous AM1.5 illumination (FOA)
  - Demonstrate 0.1 g/h H_2 generation under diurnal cycle for 2 weeks at NREL PEC outdoor test facility (FOA)
- Additional Project Objectives
  - On ≥0.25 cm^2 area-matched devices demonstrate ≥25% STH efficiency for 0.5 h under continuous AM1.5 illumination
  - Area-match the electrochemical components to the light-absorbing components to demonstrate a tileable, deployable design

Our Approach—Performance

- Dual junction organo-halide perovskite (1.7 eV) and silicon heterojunction (SHJ) PV architectures
  - Collaborate with NREL's Hybrid Organic Inorganic Perovskite (HOIP) node (Kai Zhu) for the dual junction devices
  - Lowest cost dual junction capable of high efficiency and large-scale deployment
  - Concern about durability
- Portfolio of device integration levels to provide diagnostic insight into interface impacts on performance and degradation
  - Caltech-based PEC and pre- and post-mortem materials characterization
  - Collaborate with LBNL's (Photo)electrochemical-SPM node (Francesca Toma) for in situ and post-mortem nano-characterization of degradation and failure modes
  - Collaborate with LBNL's Multiphysics Modeling of PEC Devices node (Adam Weber) to incorporate experimental measurements with device modeling to understand degradation/improve durability

Degrees of Integration

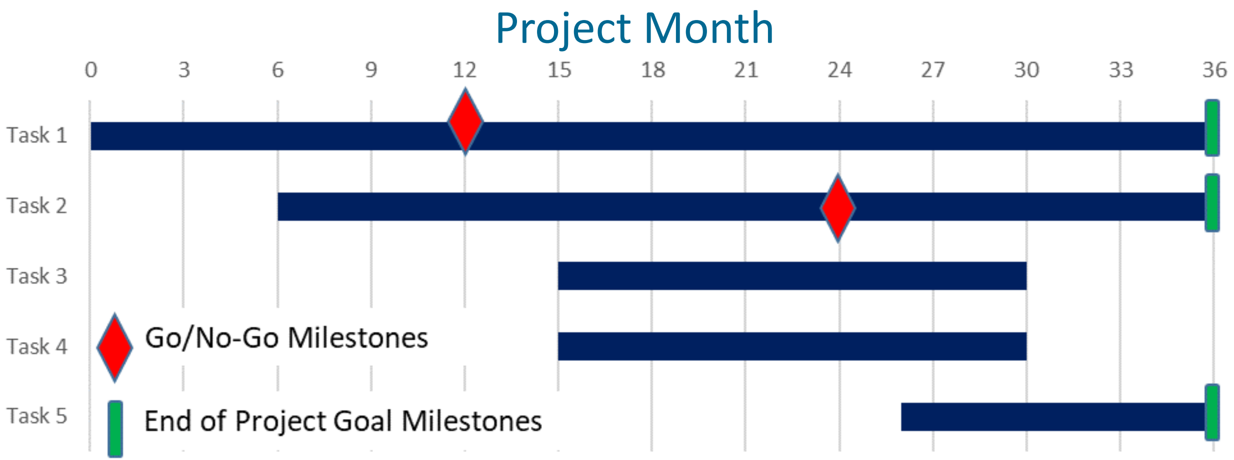
a. Minimum integration, maximum flexibility in water-splitting approach
b. 2-terminal monolithically integrated PVSK/Si PV—probe integration and durability
c. Ni activated ALD-TiO_2 protected Si PV for OER
d. Fully Integrated Device, minimum shadowing from contacts, minimum charge carrier and ionic transport distances—highest potential efficiency



Our Approach—Scale-up

- In Project Month 18 begin Scale-up tasks
- Using the most promising small-area architectures, scale-up device components to large-area while retaining high performance and compatibility
- Design large-area hydrogen generator device including reactant feeds and product collection using experimental measurements and multiphysics modeling
- Design module interconnecting multiple large area devices to produce 0.1 g/h H_2 during on-sun testing
  - Collaborate with the NREL On-Sun PEC Solar-to-Hydrogen node (Todd Deutsch) to devise reactant distribution and product collection and analysis capabilities

Project Schedule



Task 1: Maximize efficiency of ≥0.25 cm^2 devices via material and property characterization of differently integrated devices

Task 2: Evaluate degradation mechanisms and improve durability

Task 3: Scale-up subcomponents to ≥25 cm^2

Task 4: Design large-area PEC H_2 devices using experiments coupled with multi-physics modeling

Task 5: Tile multiple large-area devices into a module for on-sun production of 0.1 g/h H_2

CONTROL NUMBER: 2792-1536

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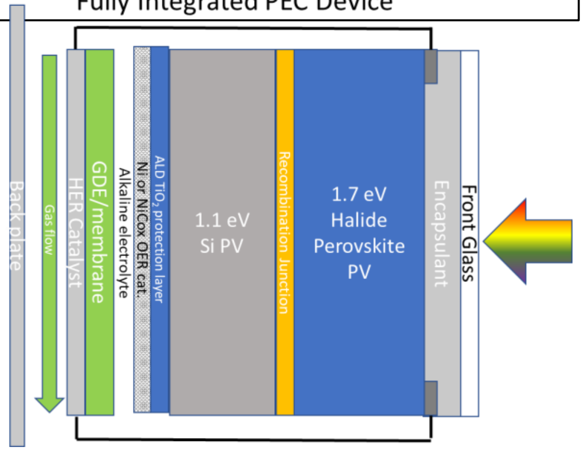
Joel A. Haber/California Institute of Technology

Technology Summary

In this project, we will utilize holistic photoelectrochemical device design to enable water-splitting electrolysis at potentials that maximize photocurrent from two-terminal, dual junction Si/organohalide Perovskite photovoltaics. Design of the electrolysis components will minimize electrocatalytic overpotentials, electrolyte polarization, membrane resistance, and flow inhomogeneities, enabling operation below 1.7 V photopotential. This approach will enable us to drive the device performance to 25% solar-to-hydrogen (STH) efficiency and extend durability to 15% STH for over 1000 hours.

Holistic Design of Efficient, Durable, Cost-effective H_2 Generation.

Fully Integrated PEC Device



Key Personnel

Prof. Harry A. **Atwater**; Res. Prof. John M. **Gregoire**; Res. Prof. Chengxiang **Xiang** (All at the California Institute of Technology)

Program Summary

Period of performance: 36 months

Federal funds: $1,000,000
Cost-share: $250,000
Total budget: $1,250,000

	Key Milestones and Deliverables
Year 1	on ≥0.25 cm^2 demonstrate device efficiency ≥15% under AM1.5
Year 2	on ≥0.25 cm^2 demonstrate device STH efficiency ≥15% for 100 h
Year 3	Demonstrate ≥15% STH unassisted efficiency in ≥25 cm^2 device Demonstrate device STH efficiency of ≥25% Demonstrate durability with STH efficiency ≥15% for ≥1000 h Demonstrate 0.1 g/h H_2 generation for 2 weeks diurnal cycling

Technology Impact

A viable Photoelectrochemical hydrogen generator technology will require five things: high STH efficiency, durability, low-cost materials and components, product separation, and a compact tileable design. This proposal addresses all of these requirements using a total system design, modeling, testing, diagnosis and improvement cycle.

Thanks!