

Photocatalysis – A New Approach to Processing Methane and Carbon Dioxide

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ARPA-E REMEDY Workshop



S Y Z Y G Y
P L A S M O N I C S

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Introduction/Background



▶ Personal Background

- PhD in Materials Science & Engineering. Rice University, 2014.
- 7 granted patents: Li-ion batteries, dissolvable structural materials, solid propellants, etc.

▶ Organization's background and area of expertise

Syzygy Plasmonics. Launched 2018. Team of 24.

- ▶ Photochemical reactors to electrify chemical manufacturing
- ▶ Product focus: Small-scale, onsite H₂ generation
- ▶ Technology: Photocatalytic steam methane reforming, dry methane reforming (CO₂ to value), ammonia decomposition
- ▶ Funding: Venture Capital, ARPA-E, NSF SBIR

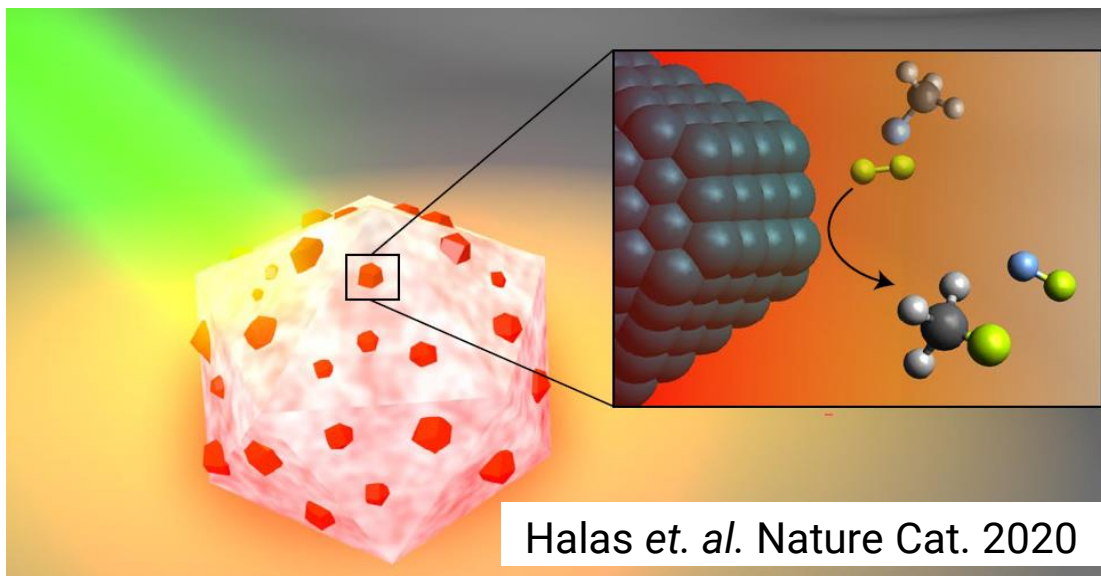


Artistic rendition of Syzygy's 500 kg/day of H₂ production system for fuel-cell applications

Syzygy's photocatalyst technology



WE USE LIGHT FROM LED TO POWER CHEMICAL REACTIONS



Syzygy's Antenna-Reactor photocatalyst at work

Syzygy's photocatalyst technology



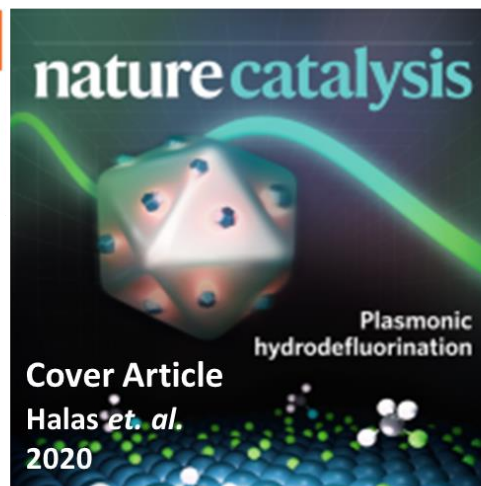
Light-driven methane dry reforming with single atomic site antenna-reactor plasmonic photocatalysts

Halas *et. al.* Jan 2020



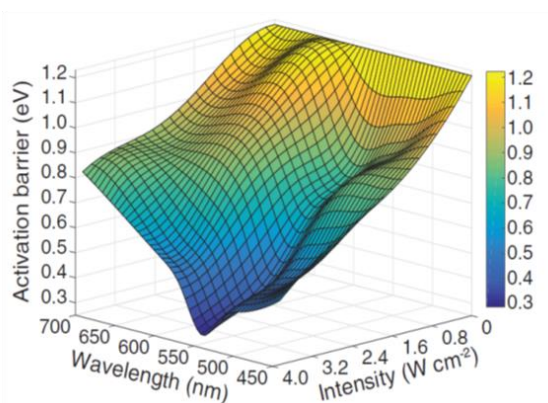
PLASMONIC CHEMISTRY

Quantifying hot carrier and thermal contributions in plasmonic photocatalysis Halas *et. al.* 2018

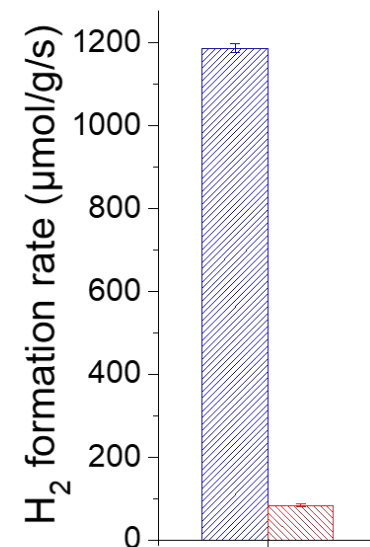
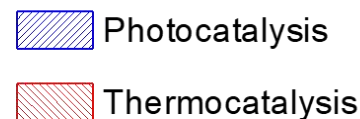


Published in World's Premier Scientific Journals

New science: Photocatalyst lowers thermal activation barrier



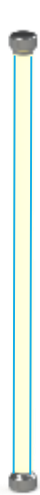
Unprecedented Performance



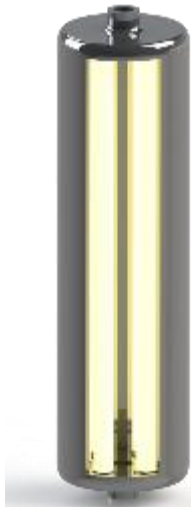
Syzygy's photo-chemical reactor technology



Cell based design leads to a modular, scalable product



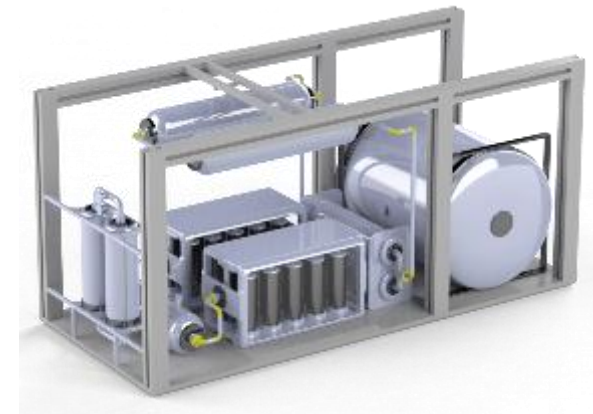
Cell – The smallest functional unit



Reactor – Multiple cells contained within an enclosure.



Reactor Bank – Multiple reactors combined together.



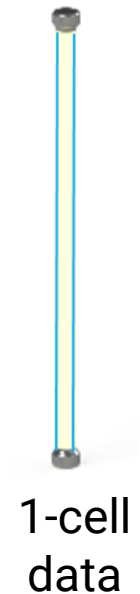
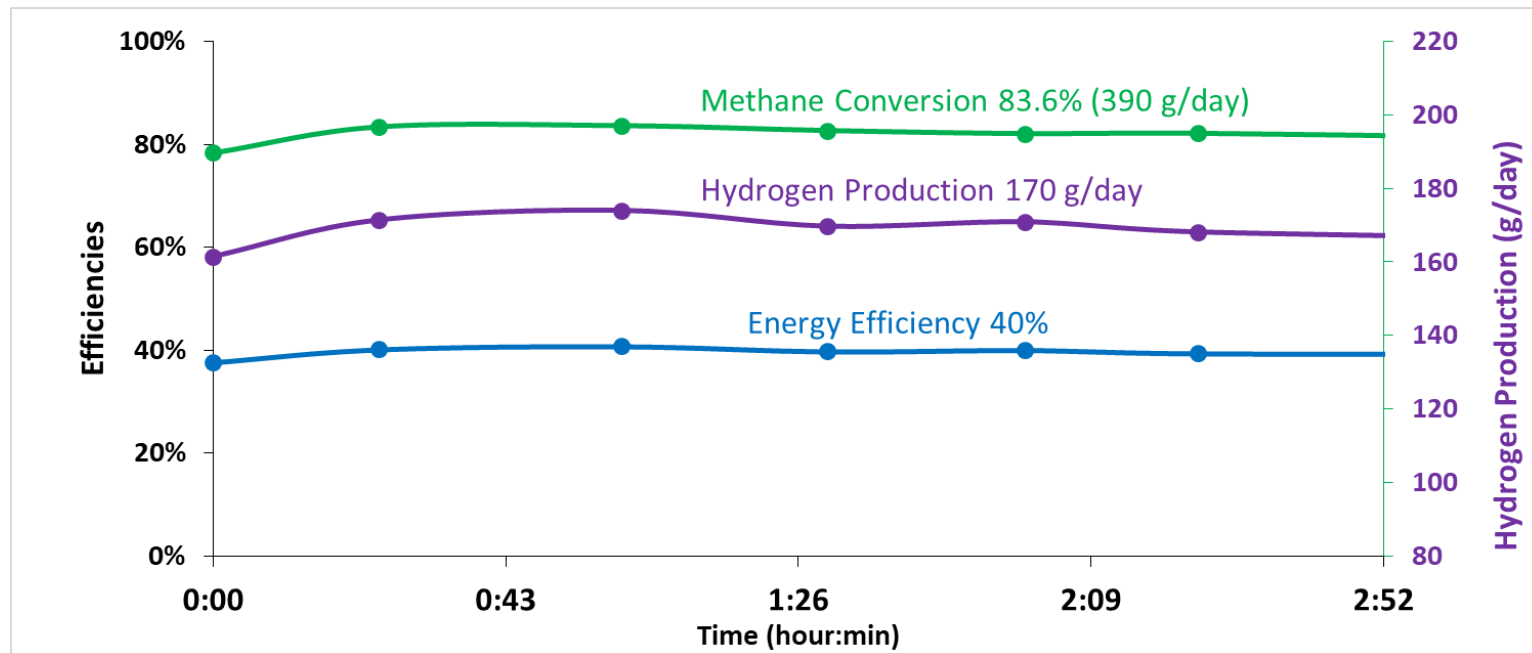
System – Our product. The reformer and other components.

- Primary Enabling Technologies:
1. Antenna-Reactor photocatalyst
 2. New LED technologies
 3. Innovative Cell and Reactor designs

Photo-chemical reactors to process CH₄ and CO₂



- ▶ Chemical Reaction #1: Photocatalytic Steam Methane Reforming (P-SMR)
 - ▶ $\text{CH}_4 + \text{H}_2\text{O} + \text{electricity} \rightarrow \text{CO} + 3\text{H}_2$

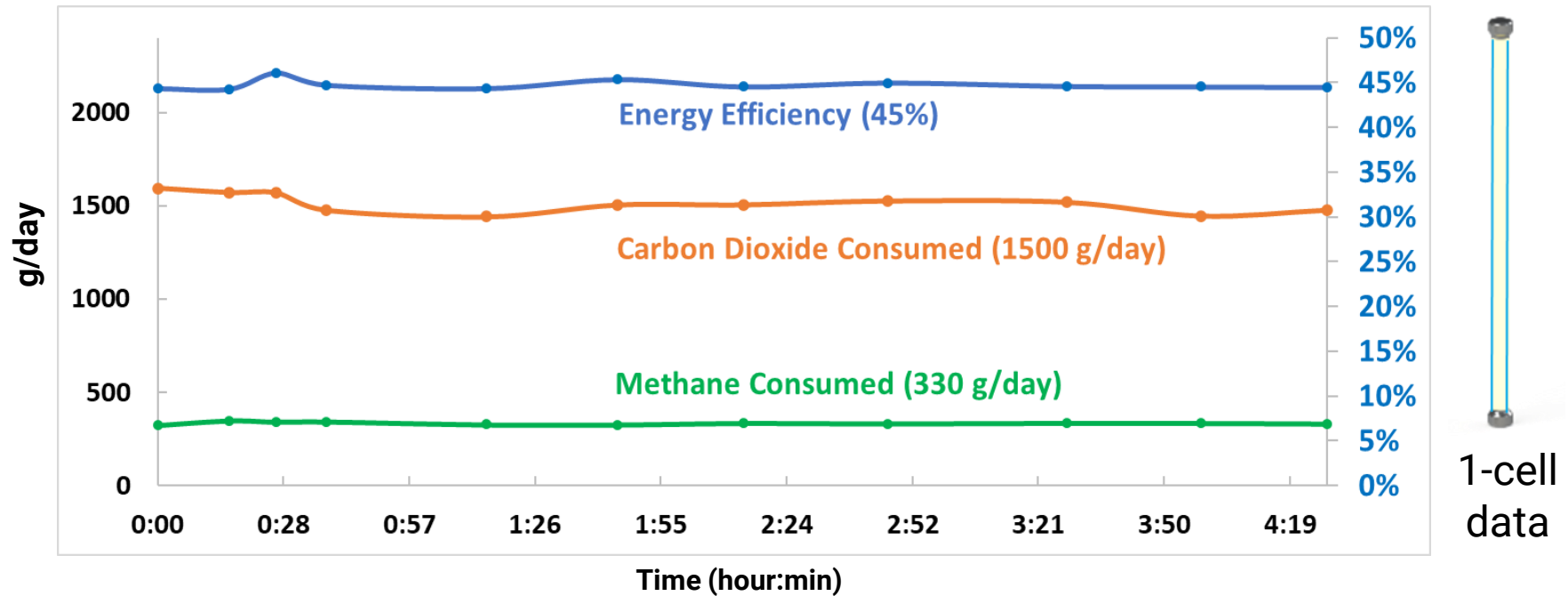


- ▶ Goal by Q1 2021: Multi-cell reactor producing 5 kg/day H₂ at 40% energy efficiency (buildout in progress)

Photo-chemical reactors to process CH₄ and CO₂



- ▶ Chemical Reaction #2: Photocatalytic Dry Methane Reforming (P-DMR)
 - ▶ CH₄ + CO₂ + electricity → 2CO + 2H₂ (syngas at C:H = 1)



- ▶ Goal by Q1 2021: Multi-cell reactor processing ~20 kg/day CO₂ at 40% energy efficiency (buildout in progress)

REMEDY program specific notes



- ▶ What's needed to apply Syzygy's technology developments to methane emissions?
 - Application-specific data
- ▶ What types of emission sources could the technology potentially address?
 - Ambient or high temperature methane streams; gas escaping from point sources, gas going to flare
 - Wide range of concentrations and flow rates
 - Mix-streams of methane and CO₂
- ▶ What's needed to make a system, and where are there gaps:
 - “Packaging” the system
- ▶ What would a team need to address gaps/succeed?
 - Application-specific
 - Commercial/Market insights

Contact Information



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