A Scalable Solar Electrolyzer for Distributed Hydrogen Generation

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Introduction

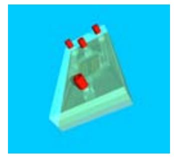
Problems

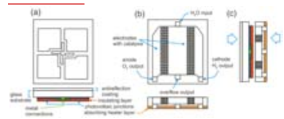
- ❑Worldwide 50 million metric tons of H_2 is generated per year from fossil fuel; 50% from natural gas, only 4% from electrolysis.
- ❑How to convert solar energy to chemical energy, thereby eliminating electrical storage and fuel transportation?
- ❑How to generate chemical on demand that has short storage life and is not easily transportable?

Technical Approach

- ❑Utilize photovoltaic cells to drive electrochemical reaction in a planar reactor

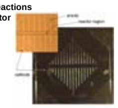
Device





(a) Multiple PV cells in series on glass substrate
(b) Microreactor for electrochemical reactions
(c) Bonding of PV cells and microreactor

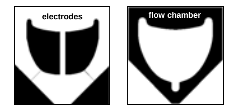
- ❑Reaction on demand, avoid contamination, transport and instability issues
- ❑Scalable architecture, safer production for hazardous chemistry



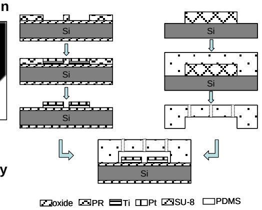
1st generation for H_2 microreactor

Design and Fabrication

Third generation reactor design



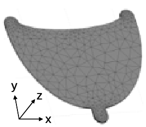
Design based on maximizing contact surface area and ability to separate oxygen and hydrogen

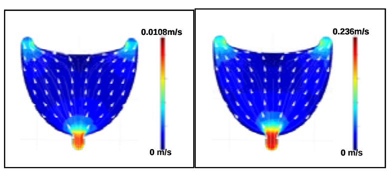


FEMLAB 3D Simulations

3D FEMLAB simulation to analyze flow dynamics

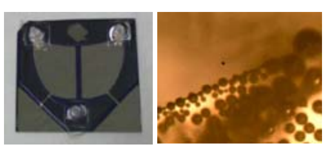
- ❑Total of 5411 elements for grid
- ❑Chamber thickness of 400 microns
- ❑Two streams separating O_2 and H_2 for flow rates of KOH solution up to 10ml/min





Bubble Formation and Extraction

- ❑28% wt KOH solution
- ❑Nucleation from supersaturation sites on electrodes
- ❑Gas bubble growth and departure with an average size ~100µm
- ❑Motion determined by flow convection, buoyancy, superficial tension, inertia and electrostatic forces
- ❑Suspension flow following liquid streams

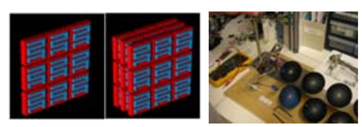


Experimental Setup

Reactor test

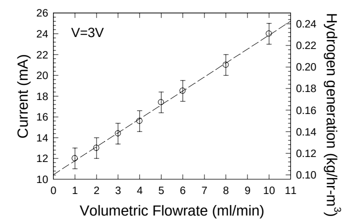
Microfluidic flow test

Integration with solar photovoltaic

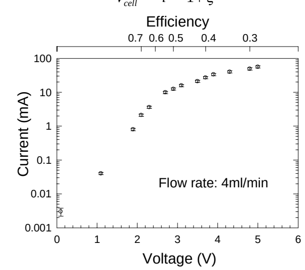


Characterization

$$V_{cell} = \frac{-\Delta A^0}{nF} + IR + \sum \eta$$



$$\eta_{EL} = \frac{1.47}{V_{cell}} \frac{i - i_{loss}}{i} \frac{\eta_{DC}}{1+\xi}$$



Conclusions

1. We present the design, fabrication and testing of a microfabricated planar reactor for the hydrogen evolution reaction (her) using thin film Pt electrodes and polydimethylsiloxane (PDMS) fluidic chamber.
2. The reactor is designed to separate gases by flow dynamics and reactor flow is analyzed by three dimensional finite element analysis. The planar geometry is scalable, compact and stackable.
3. Using 28 wt% KOH electrolyte we have achieved a hydrogen generation density of 0.23 $kghr^{-1}m^{-3}$ and an efficiency of 48% with a flow rate of 10 ml/min and cell voltage of 3V.
4. A direct PV cell to electrolyzer connection is inherently efficient since it does not require conversion to AC power to connect to the grid and then back to DC to power the electrolyzer.