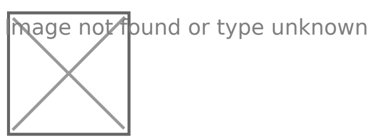
Docket #: S13-238

Efficient High-temperature Photoelectrochemical Cell

Stanford engineers have developed an efficient photoelectrochemical cell (PEC) that uses a mixed ion electron conductor (MIEC) heterojunction to enable high temperature (hundreds of ^{o}C) conversion of concentrated sunlight to chemical fuel (such as hydrogen). At the heart of the solid state PEC is a semiconductor light absorber coated with a thin MIEC layer for improved catalytic activity, electrochemical stability and ionic conduction. This provides a facile path for the ionic carriers to reach the solid electrolyte. This integrated photo-thermochemical device captures both thermal and photon energy to recover solar energy that would otherwise be lost. The single-device, isothermal design is potentially more scalable than more complex conventional thermochemical and hybrid photo-thermochemical water-splitting routes. This technology significantly enhances conversion of solar energy into chemical fuels to help overcome the inherently intermittent nature of solar radiation.



Schematic of elevated-temperature photocathode-based, oxygen-ion conducting PEC (a) with energy band diagram (b). (CB=conduction band and VB=valence band)

Stage of Research

- **Simulation** - predicted solar to hydrogen efficiency of 17% and 11% at 723 and 873^{o}K respectively (for an oxygen-ion-conducting photocathode in 1-D with a non-degenerate light absorber with 2.0 eV band-gap and uphill band offset of 0.3 eV)
- **Experimental** - experimental demonstration of this new type of PEC is ongoing

Applications

- **Photoelectrochemical cell (PEC):**
    - efficient conversion of solar energy to chemical fuel to enhance total solar energy utilization
    - low cost energy storage in solar power plants

Advantages

- **Extended operating temperature** - the MIEC layer allows this new class of PEC to operate at elevated temperature with concentrated solar flux
- **Increased efficiency:**
    - simulations show 17% and 11% at 723 and 873^{o}K respectively
    - free energy to dissociate water decreases by 16% from 1.23V at room temperature to 1.04V at 600^{o}C
    - good utilization of the solar spectrum
    - thermally enhanced carrier transport, electrocatalysis and fast removal of products in the gas phase decreases probability of carrier recombination
    - suppresses dark current
- **Single device:**
    - integrated photo-thermochemical device captures both thermal and photon energy from concentrated sunlight at temperatures between 673 and 973^{o}K
    - potentially more scalable than alternative water-splitting technology
- **Isothermal**
- **No additional energy supply** - energy for heating reactants is supplied by waste heat

Publications

- Issued US Patent 10,036,093
- Ye X, Melas-Kyriazi J, Feng ZA, Melosh NA, Chueh WC, "A semiconductor/mixed ion and electron conductor heterojunction for elevated-temperature water splitting.", *Phys Chem Chem Phys.* 2013 Oct 7;15(37):15459-69. doi: 10.1039/c3cp52536h.

Patents

- Published Application: 20150053568
- Issued: 10,036,093 (USA)

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