Towards a Sustainable Energy System

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Renewable energy resources are the backbone of any sustainable future

Solar energy is by far the largest energy resource on earth

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[Bar charts showing energy production by year and type, with notes on renewable energy dominance over time.]
Exploiting the Power of the Sun

- Highly efficient low cost solar energy conversion
- Batteries for short-term balancing
- Fuel-based concepts are needed for longer-term storage

From: B. Burger, Fraunhofer ISE (2014)

He's not much fun in the evening
He uses solar cells
Common Challenges for PV & Solar Fuels

R&D needs for PV Technology \(^{(1)}\)
- Low-cost production processes
- **Increased efficiencies**
- Development and innovation by e.g. new materials
- Intelligent systems solutions

Research needs for Solar Fuels
- Earth-abundant catalysts
- **Stable and efficient light absorbers**
- Smart cell design by e.g. light management

**Approach:**
Electricity for fuel generation by high-voltage multi-junction cells including novel wide-bandgap absorbers

**Multijunction hybrid cells:** going beyond 10% solar-to-H\(_2\) efficiency and >25% photovoltaic efficiency, *at a price we can afford*
Today’s Unique Opportunity (1) Overcoming Limits of Today's Technology

Perovskite/Si tandem cell opens up a path to efficiencies > 30%

Evolution of halide perovskite solar cells
Today’s Unique Opportunity (2) & Challenges
Halide Perovskite Semiconductors

**Organos- Cs,**

Metallic-
M = Pb, Sn

**Perovskites**

Halide-
H = Cl, Br, I

- Low T processing
- High quality semiconductor
- Chemical variability
  - Critical Stability
  - Best performance with Pb
  - Interface control?

**Solution requires:**
In-depth understanding and control of materials – interfaces – devices!
Today’s Unique Opportunity (3) & Challenges
Solar Fuel Devices

Next-Generation Solar Fuel Devices Require:

- Discovery and optimization of new semiconductors
- Understanding of semiconductor / catalyst interfaces
- Strategies for managing photons, electrons, and ions

Example: BiVO₄
A new oxide semiconductor that now shows efficiencies close to 90% of theoretical value
Goals & Key Questions

How we design novel, more efficient and stable halide perovskite & metal oxide light absorbers?

Can we reduce efficiency losses by understanding of physical and chemical processes at interfaces?

Can new large-bandgap light absorbers reach the required solar-to-fuel efficiencies and chemical stabilities needed for practical applications?
We already achieved…

- Voltage of 1.5V for single perovskite solar cell
- Efficiency of more than 20%
- Stable perovskites for high light intensity
Seizing the chance: Tackle the challenge towards highly efficient Solar Fuels

**Breakthroughs** with halide perovskites finally offer paths towards high-voltage, highly efficient, and affordable solar electricity and fuels

**Scientific Challenge:** Generation of electricity for fuels by high-voltage multi-junction cells that include novel wide-bandgap absorbers ⇒ key enablers for a sustainable energy future

Perovskites for Photovoltaics in the Spotlight: Photoinduced Physical Changes and Their Implications

Vapor and healing treatment for $\text{CH}_3\text{NH}_3\text{PbI}_3-x\text{Cl}_x$ films toward large-area perovskite solar cells
...Zaban et al. Nanoscale. 2016

Perovskites roll forward
Hodes, Cahen, Nat. Photon. 2016

Hybrid organic-inorganic perovskites
...Kronik, Hodes, Cahen, Nat. Mat. Rev. 2016
Omer Yaffe, WIS

High voltage and high efficiency two dimensional perovskite

Inorganic and hybrid organo-metal perovskite nanostructures: synthesis, properties and applications,
...Etgar. Et al. Advanced Functional Materials, 2016,

Electrocatalysis (Menny Shalom, BGU),

Degradation of perovskites

Etgar Lioz
Thank you

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