EFRC: ARGONNE-NORTHWESTERN SOLAR ENERGY RESEARCH CENTER (ANSER)

UPDATED: AUGUST 2016

AWARDS: $19.0M (August 2009 – July 2014); $15.2M (August 2014 – July 2018)	
WEBSITES: http://science.energy.gov/bes/efrc/centers/anser/; http://www.ansercenter.org	
TEAM: **Northwestern University (Lead):** Michael Wasielewski (Director), Michael Bedzyk, Robert Chang, Mark Hersam, Joseph Hupp, Mercouri Kanatzidis, Tobin Marks, Mark Ratner, George Schatz, Samuel Stupp, Emily Weiss; **Argonne National Laboratory**: Lin Chen, Alex Martinson, Michael Pellin, David Tiede; **Yale University**: Gary Brudvig, Robert Crabtree, Victor Batista, James Mayer; **University of Chicago**: Luping Yu; **University of Illinois, Urbana-Champaign**: Sharon Hammes-Schiffer	

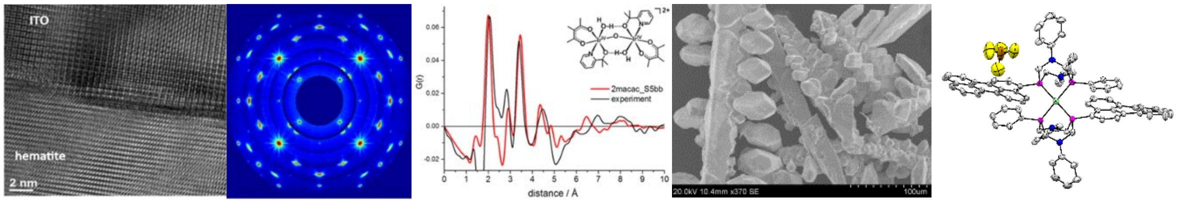
SCIENTIFIC MISSION AND APPROACH

The ANSER Center focuses on understanding how molecules, materials, and systems can use sunlight to generate charges that drive catalysts for solar fuels formation and directly power photovoltaic cells. The center addresses a common set of fundamental questions that must be answered in both contexts to successfully utilize sunlight as a renewable energy source for fuels and electricity. By attacking the common questions intrinsic to solar fuels and electricity in the same research center, ANSER provides opportunities for crosscutting solutions not possible by addressing only fuels or electricity alone. The long-term vision of the ANSER Center is to develop the fundamental understanding, materials and methods necessary to create dramatically more efficient technologies for solar fuels and electricity production. This vision is realized by understanding and characterizing the basic phenomena of solar energy conversion dynamics, by designing and synthesizing new nanoscale and mesoscale architectures with extraordinary functionality, and by linking basic solar energy conversion phenomena across time and space to create emergent energy conversion systems operating with exceptional performance. The center consists of two thrusts:

1) **Solar fuels**: A hierarchical approach to understanding catalyst and photocatalyst function is used to realize efficient solar fuel production (from water-splitting and CO_2 reduction) at acceptable rates and driving forces.
2) **Solar electricity**: Fabrication of photovoltaic cells from relatively simple, non-toxic, Earth-abundant, and low-cost materials affording large-scale solar electricity production in the future.

SELECTED SCIENTIFIC ACCOMPLISHMENTS

- First to demonstrate an all-solid-state dye-sensitized solar cell, based on perovskites, with a power conversion efficiency greater than 10%, launching a flurry of research on perovskite solar cells.
- Found that replacing the uniform self-assembled monolayer on the anode in an organic photovoltaic cell with a "supersaturated" heterogeneous monolayer increases the power conversion efficiency 54% due to superior charge selectivity and collection.
- Synthesized a rare form of iron oxide and showed it is one of only a few feasible water oxidation photoanodes. ANSER also discovered that a common form of iron oxide, functionalized with iridium water-oxidation catalysts, can use the sun to split water into hydrogen and oxygen in acidic solutions.
- Discovered that nickel-sulfide catalysts deposited within metal organic framework (MOF) films exhibit enhanced hydrogen production compared to MOF-free versions due to the local MOF environment.
- Used theory to discover an amphiphilic organic molecule, used in solar fuel cells, with the optimal structure to facilitate the electron-transfer processes that occur during hydrogen production.
- Demonstrated that ternary organic components, which expand the spectral range of light absorption, improved the power conversion efficiency of bulk heterojunction solar cells by 20%.



ANSER research, from left: epitaxial relationships between indium tin oxide substrate and iron oxide (hematite); structural features of crystalline films elucidated at the Advanced Photon Source (Argonne National Lab); measured and calculated pair distribution functions for an active iridium water oxidation catalyst; crystals of a hybrid perovskite material; X-ray crystal structure of a molecular catalyst for proton reduction

IMPACT

- ANSER hosts an annual symposium with the main theme alternating yearly between the two thrusts of the Center (solar electricity and fuels). Each year a roster of six outstanding young and established scientists from the field are invited to discuss their work in a forum open to the community. The symposium is attended by 160+ registered participants from around the Midwest, and is highlighted by a public keynote address from one selected invitee.
- ANSER and the Northwestern University Office for STEM Education Partnership co-host an annual teacher workshop series for middle and high school teachers from the greater Chicago area. The Climate Change and Sustainability Professional Development Series includes workshops, research symposia, lab activities and curriculum development.
- **Catalytic Innovations LLC**, a spin-off company from Yale University founded in 2015 to commercialize molecular materials for catalysis and corrosion resistance. This technology demonstrates an application of research done at ANSER, where Catalytic Innovations' implementation of molecular iridium electrocatalyst technology is the first demonstration of industrial use of a heterogenized molecular catalyst. Catalytic Innovations wastewater systems using this technology are also pioneering solar fuel generation, as an early demonstration of an economically viable solar fuels system. http://cat.aly.st/

PUBLICATIONS AND INTELLECTUAL PROPERTY

As of May 2016, ANSER had published 341 peer-reviewed publications cited over 16,000 times and filed 30 disclosures, 20 US patent applications, and 1 foreign patent applications. One patent has been issued. The following is a selection of impactful papers:

- Stoumpos, C. C., Malliakas, C. D., Kanatzidis, M. G. Semiconducting Tin and Lead Iodide Perovskites with Organic Cations: Phase Transitions, High Mobilities, and Near-Infrared Photoluminescent Properties. *Inorganic Chemistry* **52**, 9019-9038, doi:10.1021/ic401215x (2013). [**851 citations**]
- Chung, I., Lee, B., He, J. Q., Chang, R. P. H., Kanatzidis, M. G. All-solid-state dye-sensitized solar cells with high efficiency. *Nature* **485**, 486-U94, doi:10.1038/nature11067 (2012). [**630 citations**]
- Loser, S. *et al*. A Naphthodithiophene-Diketopyrrolopyrrole Donor Molecule for Efficient Solution-Processed Solar Cells. *Journal of the American Chemical Society* **133**, 8142-8145, doi:10.1021/ja202791n (2011). [**370 citations**]
- Weingarten, A. S. *et al.* Self-assembling hydrogel scaffolds for photocatalytic hydrogen production. *Nature Chemistry* **6**, 964-970, doi:10.1038/NCHEM.2075 (2014). [**65 citations**]
- Zhou, N. J. *et al*. Metal-Free Tetrathienoacene Sensitizers for High-Performance Dye-Sensitized Solar Cells. *Journal of the American Chemical Society* **137**, 4414-4423, doi:10.1021/ja513254z (2015). [**62 citations**]
- Sheehan, S. W., Thomsen, J. M., Hintermair, U., Crabtree, R. H., Brudvig, G. W., Schmuttenmaer, C. A. A molecular catalyst for water oxidation that binds to metal oxide surfaces. *Nature Communications* **6**, 6469, doi:10.1038/ncomms7469 (2015). [**48 citations**]