Sandia National Laboratories

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SOLAR THERMOCHEMICAL HYDROGEN PRODUCTION

Sandia National Laboratories has a history of science-based engineering with respect to hydrogen isotopes that has led to work with hydrogen as an energy carrier. Water and ultra-high temperatures delivered by concentrating solar power can produce hydrogen thermochemically as a clean and sustainable energy source. Sandia provides a deep, quantitative understanding of the behavior of materials and engineered systems to enable technology development, particularly for systems subjected to the extreme environments found in solar thermochemical water splitting processes.

CLEAN SOLAR HYDROGEN

Clean, zero-carbon hydrogen is a potential fossil fuel alternative to enhance sustainability and reduce carbon dioxide emissions from energy intensive sectors, such as transportation and manufacturing. When produced by concentrating solar power (CSP), hydrogen provides a way to directly store solar energy for later use. As an energy carrier, hydrogen provides a domestic, sustainable resource to satisfy society's energy demands.

However, key technical challenges remain to unlock the potential of hydrogen and its related technologies. The foremost technical challenges are the cost, durability, reliability, and performance of hydrogen production technologies.

SOLAR THERMOCHEMICAL HYDROGEN PRODUCTION RESEARCH AT SANDIA

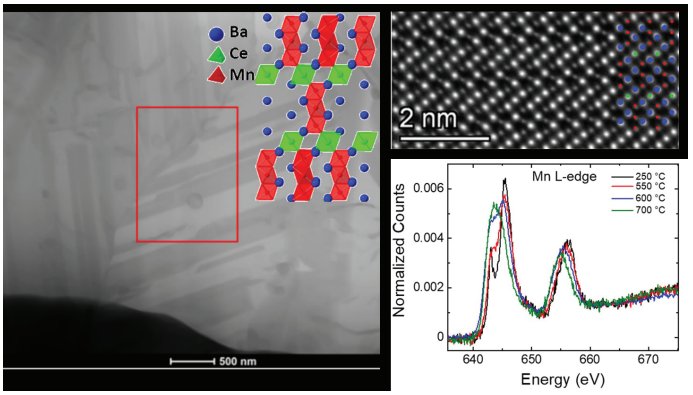
Sandia National Laboratories integrates our experience with concentrating solar power and materials science to advance solar thermochemical hydrogen (STCH) production technology. Sandia maintains the required equipment, technical expertise, and partnerships to develop advanced STCH water-splitting processes that couple CSP with two-step metal oxide cycles to produce hydrogen. Keys to the success of STCH technologies are optimally designed redox-active materials and developing robust solar receiver/reactor concepts for efficient CSP integration. 'Redox-active' refers to a material's ability to donate and regain electrons, a quality that facilitates the chemical reaction to "split" water molecules to produce hydrogen.

MATERIALS FOR HYDROGEN PRODUCTION

Several material systems have demonstrated water splitting functionality; however, they are challenged by stability issues or require high cycle temperatures. Next-generation redox active materials are key to commercializing a STCH water splitting technology that efficiently converts solar energy to hydrogen. Sandia is developing optimally designed materials that are stable and will efficiently operate at lower temperatures.

Complex Material Behavior

Sandia is conducting cutting-edge materials science research to understand the complex behavior of STCH materials at the level of atoms. A promising perovskite oxide with the potential to meet Department of Energy (DOE) performance targets[1] was codeveloped by Sandia, and we have since discovered many intriguing properties of this material that may inform the design of optimal redox-active oxides.



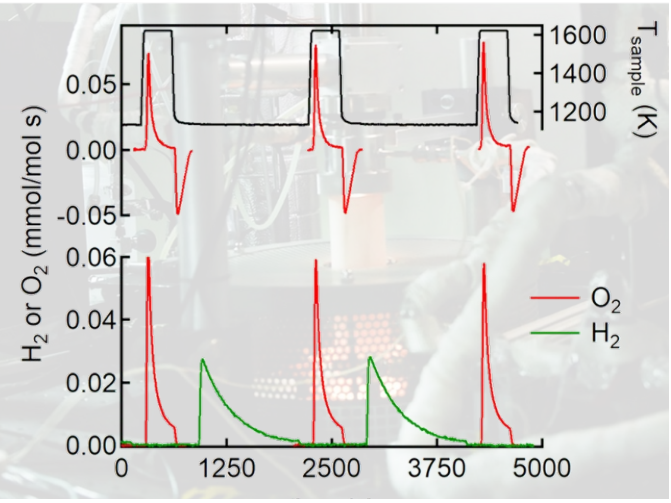
The micrograph of a high-performing perovskite STCH material called $Ba_4CeMn_3O_{12}$ (BCM) reveals the complex arrangement of atoms within the crystal that engenders structural stability under extreme conditions. Furthermore, Sandia has discovered that atom movement serves to maintain oxide stability as the manganese (Mn) cation reduces and oxygen (O) leaves the crystal lattice.

1 DOE Hydrogen and Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan

Material Discovery and Characterization

Sandia researches and develops methods to discover materials for hydrogen production, storage, and use—evaluating their properties and performance. Sandia has developed a high-throughput machine learning approach to rapidly screen for STCH-active materials from databases that warehouse tens of thousands of oxide crystal structures.

Alongside these efforts, Sandia contributes to the DOE HydroGEN Consortium, a collaboration that accelerates the research, development, and deployment of advanced water splitting materials for clean, sustainable hydrogen production. HydroGEN supports national laboratory research in photoelectrochemical, solar thermochemical, and low- and high-temperature electrolytic water splitting. HydroGEN makes these unique, world-class national lab capabilities more accessible to academia and industry.

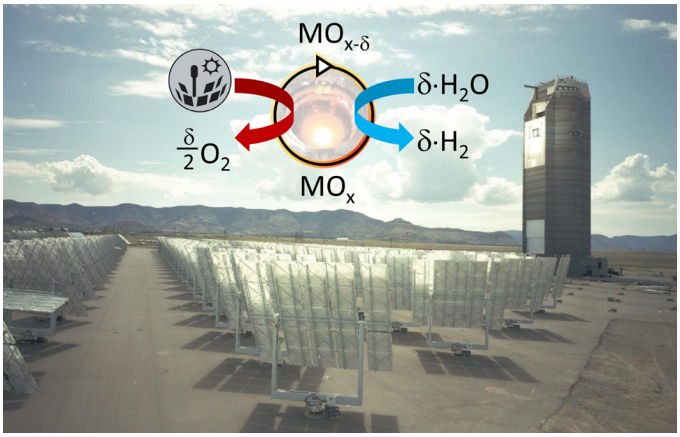


H_2 and O_2 production rates measured as a function of time during successive redox cycling of a STCH material. This information is needed to screen for and characterize the water splitting efficacy of STCH materials. This data is measured using laboratory facilities at Sandia that are customized to evaluate the water-splitting efficacy of potential oxides.

INTEGRATION WITH CONCENTRATING SOLAR POWER

STCH research at Sandia incorporates Sandia's experience developing and testing CSP technologies for DOE, industry, and the world for over 40 years. Capabilities and expertise at the National Solar Thermal Test Facility (NSTTF)—located at Sandia's Albuquerque, New Mexico site—advance CSP technologies for producing hydrogen as well as for other applications.

Sandia has established the key design principles to achieve DOE cost and efficiency targets through innovative particle flow reactor design concepts. These concepts maximize efficiency and optimize system performance. Sandia has established a pilot program at NSTTF to scale up Sandia's particle flow reactor technology.



Sandia operates the US DOE National Solar Thermal Test Facility (NSTTF) where concepts for integrating CSP into thermochemical processes can be field tested at flux levels greater than 250 W/cm² and total power in excess of 6 MW. The NSTTF is the only test facility of its type in the United States.

WORK WITH US

Sandia actively seeks opportunities to partner with private companies—large or small—and with state and local government agencies and universities. We offer a wide array of partnership opportunities and strive to cultivate the highest quality relationships with technology partners.

CONTACT:

hydrogen.sandia.gov

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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