A Method for Ink-Jet Printing Metal Oxide Materials For Water Splitting Using Solar Energy

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Abstract

Using commercially available ink-jet printers, we have developed a protocol to rapidly produce and test novel metal oxide materials for their ability to split water using solar energy as the energy input. Promising catalytic materials, which were unknown prior to this work, have been discovered and characterized.

Project Overview

Metal oxides have a multitude of demonstrated applications including superconductivity, magnetoresistance, luminescence, and catalysis. In almost all cases, it is necessary to incorporate multiple elements in order to optimize the special property of interest. For example, the highest transition temperature superconductor contains four metals ($HgBa_2CaCu_2O_{6+\delta}$). This suggests that each element plays a specific role in the overall functionality of special materials and that large compositional spaces must be searched in order to identify materials with special properties.

In order to meet mankind's energy demands, identification of a cost-competitive method to produce hydrogen, without the emission of greenhouse gases, is certainly a worthwhile pursuit. The direct splitting of water with visible light is perhaps the best long-term solution to this problem and it is widely believed that photocatalytic metal oxide semiconductors hold the most promise due to their potential low cost and stability in aqueous environments. Unfortunately, the metal oxides that have been promising to date are ineffective at utilizing all of the energy available from sunlight as their band gaps are typically too large.

We have constructed a simple and inexpensive, yet elegant protocol to rapidly and quantitatively produce mixed metal oxide libraries and screen them for photocatalytic activity. We have combined the speed and versatility of ink jet printing with photoelectrochemical screening to search for potentially promising metal oxide photocatalysts[1]. Gradient patterns of metal precursors are deposited onto conductive glass substrates with an ink-jet printer. Subsequent pyrolysis yields mixed binary through pentanary metal oxide compositions with varying stoichiometries, which are then screened for their ability to split water using visible light. Ink jet printing of these materials is a huge step forward in the quest to produce quality mixtures without the comparatively expensive and time-consuming techniques of electrodeposition or vapor deposition.

As we continue to add to our materials library, we have also made significant strides in the quality of the materials deposition, in quantifying the amount of material deposited and the stoichiometry of the as-produced mixtures, and in making the necessary transition from the small-scale printed materials found in our search to the production of large-scale thin films on transparent conducting substrates. The printing method can be adapted to a variety of material depositions. Results will also be shown which highlight how the same screening system, used for the identification of promising photocatalytic materials, can be also used a variety of other applications.

References

1. Woodhouse, M.; Herman, G.; Parkinson, B. A., A Combinatorial Approach to Identification of Catalysts for the Photoelectrolysis of Water. *Chem. Mater.* **2005,** *17*, 4318.

Acknowledgements

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Author Biography

Bruce Parkinson received his BS degree in chemistry at Iowa State University in 1972 and his PhD from Caltech in 1977 under the guidance of Professor Fred Anson. After a year of post-doctoral studies at Bell Laboratories with Adam Heller, he became a staff scientist at the Ames Laboratory. He then joined the Solar Energy Research Institute in Golden, Colorado in 1981 as a senior scientist. In 1985 he moved to the Central Research and Development Department of the DuPont Company where he worked until he became Professor of Chemistry at Colorado State University in 1991. His research covers a wide range of areas including materials chemistry, surface chemistry and photoelectrochemistry.

Michael Woodhouse (presenter) is a fourth-year PhD student under Dr. Parkinson. Prior to graduate school, he was a high school Physics and Chemistry teacher for three years. His career interests are centered on materials research and development for solar energy applications.