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A Combinatorial and Distributed Search for Semiconducting Oxides that Photoelectrolyze Water

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The increasing need for carbon free energy has focused renewed attention on solar energy conversion. Although photovoltaic cells excel at directly converting of solar energy to electricity, it does not directly produce stored energy or fuels that account for more than 75% of current energy use. Direct photoelectrolysis of water has the advantage of converting solar energy directly to hydrogen, an ideal non-carbon and nonpolluting energy carrier, by replacing both a photovoltaic array and an electrolysis unit with one potentially inexpensive device. Unfortunately no materials are currently known with the required properties to efficiently photoelectrolyze water that are stable under illumination in electrolytes for many years. Nanostructured semiconducting metal oxides could potentially fulfill these requirements, making them the most promising materials for solar water photoelectrolysis, however no oxide semiconductor has yet been discovered with all the required properties. We have developed a simple, high-throughput combinatorial approach to prepare and screen many complex oxides for water photoelectrolysis activity. The approach uses ink jet printing of overlapping patterns of soluble metal oxide precursors onto conductive glass substrates. Subsequent pyrolysis produces metal oxide phases that are screened for photoelectrolysis activity by measuring photocurrents produced by scanning a laser over the printed patterns in aqueous electrolytes. Several promising and unexpected compositions have been identified. We are in the process of optimizing and understanding the physical structure, electronic structure and catalytic ability of some of these new photocatalysts. In addition, due to the millions of possible combinations to be printed and screened, we have developed a distributed research project that uses simple and inexpensive printing and screening devices, such as Lego Mindstorm® kits, to enlist many undergraduate and high school student researchers into the search for the “Holy Grail” of materials. The Solar Hydrogen Activity research Kit or SHArK project has now expanded to over sixty sites.