



Manufacturing & Prototyping

Silicon/Carbon Nanotube Photocathode for Splitting Water

The combination of materials is expected to increase the efficiency of the redox reaction.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proof-of-concept device is being developed (see figure) for hydrogen gas production based on water-splitting redox reactions facilitated by cobalt tetra-aryl porphyrins (Co[TArP]) catalysts stacked on carbon nanotubes (CNTs) that are grown on n-doped silicon substrates. The operational principle of the proposed device is based on conversion of photoelectron energy from sunlight into chemical energy, which at a later point, can be turned into electrical and mechanical power.

The proposed device will consist of a degenerately n-doped silicon substrate with Si posts covering the surface of a 4-in. (≈ 10 -cm) wafer. The substrate will absorb radiation, and electrons will move radially out of Si to CNT. Si posts are designed such that the diameters are small enough to allow considerable numbers of electrons to transport across to the CNT layer. CNTs will be grown on top of Si using conformal catalyst (Fe/Ni) deposition over a thin alumina barrier layer. Both metallic and semiconducting CNT will be used in this investigation, thus allowing for additional charge generation from CNT in the IR region. Si post top surfaces will be masked from catalyst deposition so as to prevent CNT growth on the top surface.

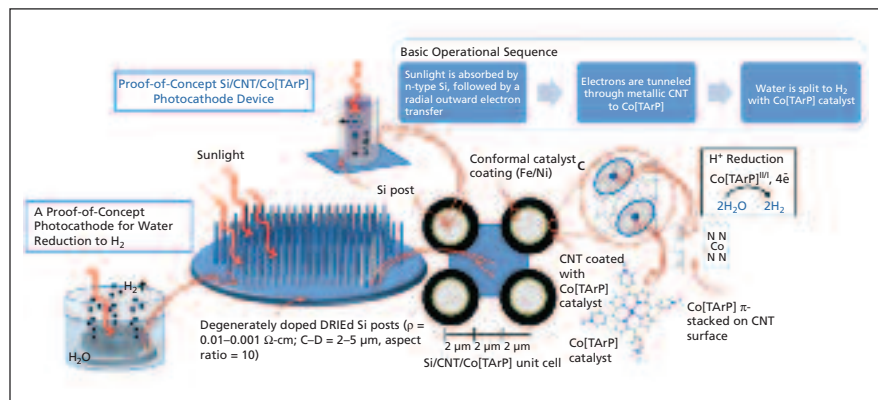


Diagram and basic operational sequence of the proof-of-concept Si/CNT/Co[TArP]. The bioinspired catalyst, Co[TArP], lowers the activation barrier for the photoactivated water splitting reaction. Rapid electron transfer from degenerately doped Si posts to metallic CNT enables the water reduction reaction. CNT material serves not only as an excellent "wire" for the electron, but as an unsurpassed substrate for the catalyst, since the mechanism (π -stacking) by which it binds Co[TArP] does not lead to significant changes in catalytic activity. The unique combination of Si, CNT and Co[TArP] is a very promising approach with a high potential to become a major breakthrough in the field of photocatalytic water splitting research and technology areas.

A typical unit cell will then consist of a Si post covered with CNT, providing enhanced surface area for the catalyst. The device will then be dipped into a solution of Co[TArP] to enable coating of CNT with Co(P). The Si/CNT/Co[TArP] assembly then will provide electrons for water splitting and hydrogen gas production. A potential of 1.23 V is needed to split water, and near ideal

band gap is approximately 1.4 eV. The combination of doped Si/CNT/Co[TArP] will enable this redox reaction to be more efficient.

This work was done by Xenia Amashukeli, Harish Manohara, Harold F. Greer, Lee J. Hall, Harry B. Gray, and Bryan Subbert of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46951

Advanced Materials and Fabrication Techniques for the Orion Attitude Control Motor

Rhenium is ideally suited for high-temperature applications.

Marshall Space Flight Center, Alabama

Rhenium, with its high melting temperature, excellent elevated temperature properties, and lack of a ductile-to-brittle transition temperature (DBTT), is ideally suited for the hot gas components of the ACM (Attitude Control Motor), and other high-temperature applications. However, the high cost of rhenium makes fabricating these components using conventional fabrication

techniques prohibitive. Therefore, near-net-shape forming techniques were investigated for producing cost-effective rhenium and rhenium alloy components for the ACM and other propulsion applications.

During this investigation, electrochemical forming (EL-Form™) techniques were evaluated for producing the hot gas components. The investiga-

tion focused on demonstrating that EL-Form processing techniques could be used to produce the ACM flow distributor. Once the EL-Form processing techniques were established, a representative rhenium flow distributor was fabricated, and samples were harvested for material properties testing at both room and elevated temperatures. As a lower cost and lighter weight alterna-

tive to an all-rhenium component, rhenium-coated graphite and carbon-carbon were also evaluated. The rhenium-coated components were thermal-cycle tested to verify that they could withstand the expected thermal loads during service.

High-temperature electroforming is based on electrochemical deposition of compact layers of metals onto a mandrel of the desired shape. Mandrels used for electro-deposition of near-net shaped parts are generally fabricated from high-density graphite. The graphite mandrel is easily machined and does not react with the molten electrolyte. For near-net shape components, the inner surface of

the electroformed part replicates the polished graphite mandrel.

During processing, the mandrel itself becomes the cathode, and scrap or refined refractory metal is the anode. Refractory metal atoms from the anode material are ionized in the molten electrolytic solution, and are deposited onto the cathodic mandrel by electrochemical reduction. Rotation of the mandrel ensures uniform distribution of refractory material. The EL-Form process allows for manufacturing in an inert atmosphere with deposition rates from 0.0004 to 0.002 in./h (10.2 to 50.8 $\mu\text{m}/\text{h}$). Thicknesses typically range from microns to greater than 0.5 in. (13

mm). The refractory component produced is fabricated, dependably, to within one micron of the desired tolerances with no shrinkage or distortion as in other refractory metal manufacture techniques. The electroforming process has been used to produce solid, non-porous deposits of rhenium, iridium, niobium, tungsten, and their alloys.

This work was done by Sridhar Gorti and Richard Holmes of Marshall Space Flight Center, and John O'Dell, Timothy McKechnie, and Anatoliy Shchetkovskiy of Plasma Processes, Inc. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32852-1.