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LIQUID FUEL VIA ARTIFICIAL PHOTOSYNTHESIS

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ABSTRACT

Photosynthesis is a process used by plants and animals and other organisms to convert light energy into chemical energy. Artificial Photosynthesis is a process that replicates natural photosynthesis. It is commonly referred to any scheme used for capturing and storing light energy in chemical bonds of a fuel. It is basically achieved by the use of artificial leaf. The leaf device combines a commercially available solar cell (Silicon) and pair of inexpensive catalysts made of cobalt and nickel which split water in hydrogen and oxygen. This water splitting is the core process of natural photosynthesis. The artificial leaf converts around 10% of the sun's incident energy while the normal leaf converts only 1%. The hydrogen produced from the splitting is fed to a genetically enhanced bacteria called Ralstonia Eutropha H16. This bacteria in presence of carbon dioxide and hydrogen converts the hydrogen in liquid fuel in the form of isopropanol, isobutanol, trace amounts of isopentanol and ethanol.

Keywords: Photosynthesis, Ralstonia Eutropha, Solar cell, Artificial leaf

1. INTRODUCTION

Artificial photosynthesis is a chemical process that replicates the natural process of photosynthesis. It is commonly used to refer to any scheme for capturing and storing the energy from sunlight in the chemical bonds of a fuel (a solar fuel). This Leaf device combines a commercially available solar cell (Silicon) with a pair of inexpensive catalysts made of Cobalt and Nickel that split water into Oxygen and Hydrogen. The hydrogen can be stored and used as an energy source. (For example, to power a fuel cell). The collection and storage of the sun's energy is a key step in overcoming one of the limitations of solar power. Photocatalytic water splitting converts water into hydrogen and oxygen bubbles [10].

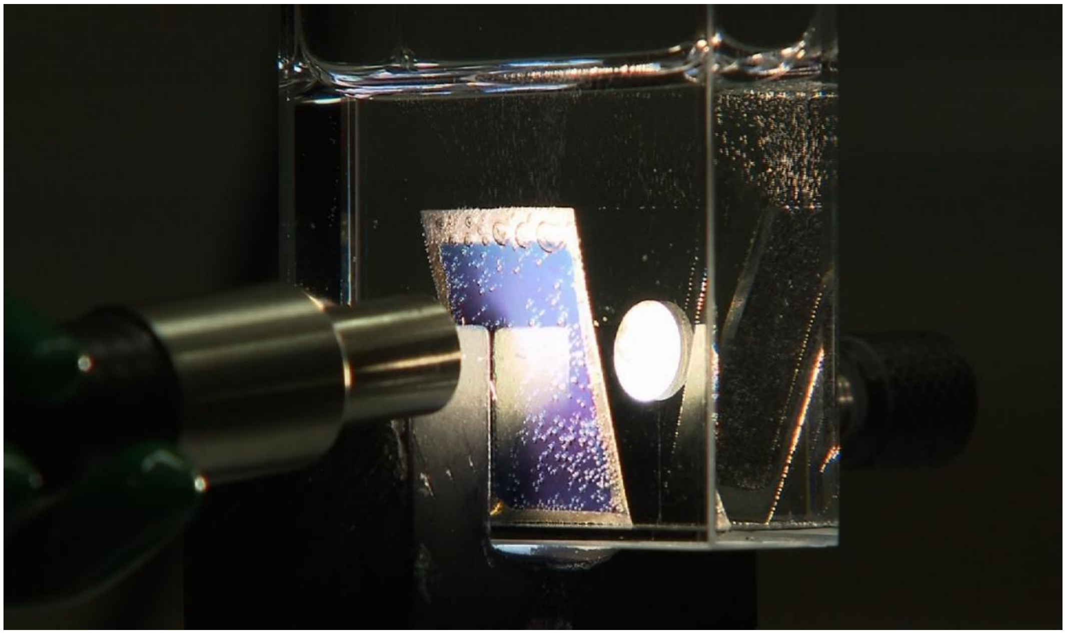

Fig 1: Experimental Set up of Artificial Leaf in Water

2. CONSTRUCTION OF THE ARTIFICIAL LEAF

The artificial leaf is made of various layers which are made up of inexpensive materials. The layers are explained below.:

- Stainless steel plate of the size of a playing card is base.
- Amorphous Si-Ge alloy junction and amorphous silicon on the plate.

- Layer of Indium-Tin Oxide
- Cobalt Based Catalyst As an oxygen Evolution catalyst
- Nickel-Molybdenum-Zinc alloy is deposited on the other side.
- Plate is then submerged in the container of water and illuminated by light [(9)(6)].

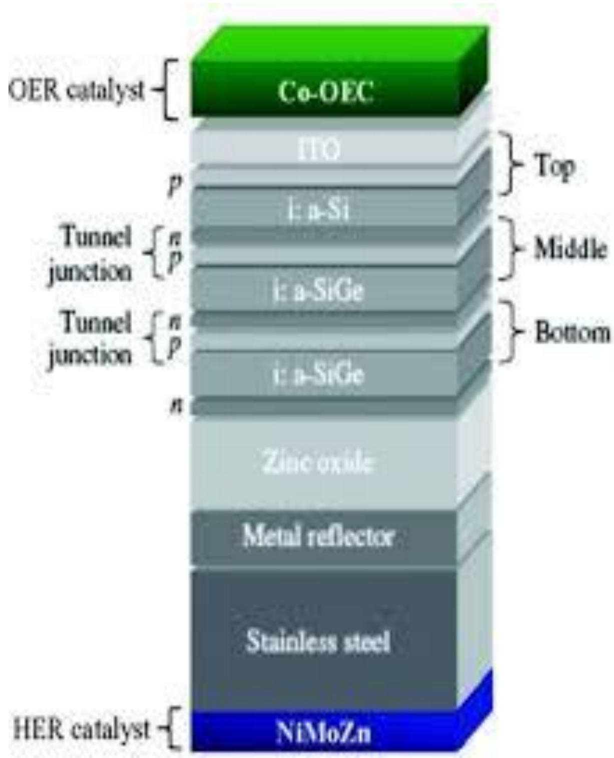

Fig 2: Electron diffraction patterns of the icosahedral ZnMgHo quasicrystals – 10 fold symmetry(1)

Because Co-OEC operates in neutral water, and not harsh conditions, nonprecious metals may be used in place of Pt to produce hydrogen. A NiMoZn cathode for H2 may be electrodeposited from Ni(aq)2þ solution, sodium molybdate and anhydrous zinc chloride in the presence of pyrophosphate, bicarbonate, and hydrazine followed by a base leaching solution. Molybdenum leaches from the alloy to furnish high surface area material. The alloy achieves current densities of 700 mA/cm2 at 100 mV overpotential and, with continued leaching, can attain activities as high as at 1000 mA/cm2 at an overpotential of 35 mV. The leaf is made of abundant earth materials that operates under simple conditions has been realised by interfacing

Co-OEC (Oxygen evolution catalyst) NiMoZn catalyst on the other end with a triple junction amorphous Si-Ge solar cell. It is a three-junction p-n junction diode. The triple junction produces about 8 $mAcm^{-2}$ of current at 1.8V at an overall efficiency of 6.2%. On the p side of the cell is protected by an ITO layer on which the Co-OEC is electrodeposited. The stainless-steel plate is not required but is used only as a support for the rest of the materials. The NiMoZn can be deposited directly on the Silicon (10)(7)(3)(4).

3. WORKING

The function of these layers is to split the water molecule by distributing the charge. When the leaf is illuminated by light one side of the leaf becomes positively charged and the other becomes negatively charged. Sunlight / Light source illuminates the submerged artificial leaf its energy absorbed by the semiconductor. Electrons in the valence band are exited and move to the conduction band, hole is generated in valence band. Holes generated are used by Cobalt-OEC to produce Oxygen Molecules. OEC brings together 2 oxygen atoms and removes electron from each to satisfy the holes. The 2 oxygen atoms combine to form Oxygen molecule. Protons are as a by-product of the OEC reaction. They are transferred to the other side to the Hydrogen evolving catalysts. Hydrogen is evolved. A minimum of 1.23V of potential difference is needed for the water splitting to happen. (5) The efficiency of water splitting process is around 2.5%.

Owing to the low solubility of O2 and H2 in water, the solar-to-fuels conversion process may be driven in the absence of a membrane. Overall solar-to-fuels efficiencies (SFE) were observed to be as high as 4.7% (for a 7.7% solar cell) when Ohmic losses are minimized. Noting that the overall solar-to-fuels efficiency is a product of the overall efficiency for water splitting and solar cell efficiency is as high as 60%. Based on solar cell efficiency higher overall cell efficiencies (>10%) may be readily achieved through the use of more efficient photovoltaics. Even further increases in Solar-to-fuel efficiency may be realized by implementing engineering designs that minimize Ohmic resistances arising from ion transport (10)(4).

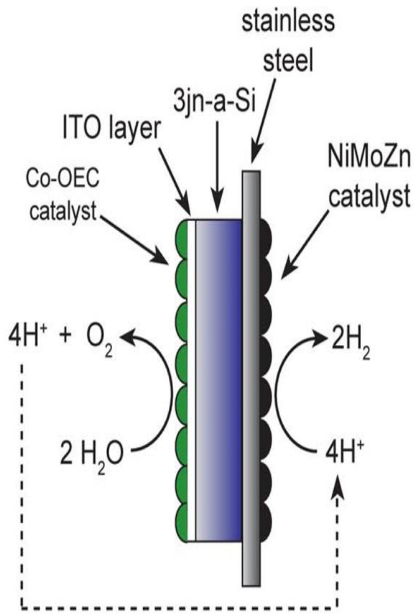

Fig 3 : Electrode Reactions when the artificial leaf is dipped in water

4. RALSTONIA EUTROPHA H16 BACTERIA

The evolved hydrogen is fed to a genetically engineered bacteria which consumes carbon dioxide and hydrogen to give fused alcohols. Ralstonia Eutropha H16 is a bacterium that can be found in sludge etc. The bacteria can live in the normal temperature and pressure conditions. Like any bacteria it also multiplies when put in water. The hydrogen bubbles produced from the catalyst are fed to this bacterium. In this bacterium a gene, hydrogenase has been introduced which makes the bacteria eat the hydrogen bubbles and CO2 in air and produce isopropanol. The bacteria don't need light to produce this fuel [7][4].

5. CONCLUSIONS

The artificial leaf achieves direct solar-to-fuels conversion at 1sun (AM1.5,100mAcm^{-2}) under benign conditions, using earth-abundant materials, and without the use of wires. The artificial leaf mimics nature inasmuch as it stores solar energy in water splitting by conforming to the functional elements of a leaf. We note that the actual leaf does not use hydrogen but stores it as a solid fuel, for example, carbohydrate. In the case of the artificial leaf, the hydrogen is available for combination withCO2 as new catalysts for this process are discovered.

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