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Anomalous Hydrogen Production during Photolysis of NaHCO3 Mixed Water

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Abstract— Production and enhancement of hydrogen on large scale is a goal towards the revolution of green and cheap energy. Utilization of hydrogen energy has many attractive features, including energy renewability, flexibility, and zero green house gas emissions. In this current research the production and the enhancement of hydrogen from the NaHCO3 mixed water have been investigated under the action of diode pumped solid state laser with second harmonic of wavelength 532nm. The efficiency of the hydrogen and oxygen yields was found to be greater than the normal Faradic efficiency. The parametric dependence of the yields as a function of laser irradiation time, Laser focusing effect and other parameters of the electrolysis fundamentals were carefully studied.

Index Terms— Photo catalysis, Electrolysis of water, Hydrogen, Laser interaction, Electrical signals, Oxygen.

1. Introduction

We are at the edge of an era of energy crises. The current energy sources are not able to handle the incoming huge population needs. Hydrogen is used at large scale for production of ammonia, for refining the petroleum and also refining the different metals such as uranium, copper, zinc, tungsten and lead etc. The main source of energy on earth is fossil fuels which cause severe pollutions and cannot last for long time use. Nuclear energy is very expensive and having disposal problems. The other sources such as tidal and wind schemes are not sufficient. The solar, thermal and hydral energy sources are feasible but required a lot of capital. An alternative source is water, which is cheap, clean and everlasting source of global energy

Hydrogen gas can be easily obtained by the electrolysis. However, direct decomposition of water is very difficult in normal condition. The pyrolysis reaction occurs at high temperatures above 3700Co. 1) Anomalous hydrogen generation during plasma electrolysis was already reported. 2-5) Access hydrogen generation by laser induced plasma electrolysis was reported recently. 6-9)

Water in the liquid state has the extremely high absorption coefficient at a wavelength of 2.9 µm.10) The effect of generation of an electric signal, when IR-laser radiation having the power density below the plasma formation threshold interacts with a water surface, was discovered by.11) The electrical signals induced by lasers were already reported.12,13) A lot of research has been done on photo catalytic hydrogen production. The photo catalytic splitting of water using semiconductors has been widely studied. Many scientists produce hydrogen from water by using different photo catalysts in water and reported hydrogen by the interaction of lasers.14-18) In addition to this photolysis of water has been studied using UV light.19) Solar energy has been used to obtained Hydrogen from water by photo catalytic process.20) But these methods are not economical and the yields of hydrogen is not to an extent.

Our work on lasers has revealed the important parameters which played a critical role in the enhancement of hydrogen from water by laser. Most of the research work basis on photo catalysis has carried out by flash lamps. A very little work is done by lasers.21) Since laser light has special properties like monochromatic, coherent, intense and polarize, so it was of great interest to use the laser beams as an excitation source in water. The second parameter is that the most of the work has done on light water, distilled water and heavy water; we have used drinking water for production of hydrogen. We have used NaHCO3 electrolyte. The diode pumped solid state laser having a green light of wave length 532 nm was used as an irradiation source. We investigated the different parameters of the laser by monitoring the rate of evolved gases i.e. hydrogen and oxygen. We inspected the dependence of hydrogen and oxygen yields as a laser exposure time, the effect of laser beam power and the laser focusing effect.

2. Experimental Setup

A schematic diagram of the hydrogen reactor is shown in Figure 2.The reactor contained a glass made hydrogen fuel cell having dimension 10 inch x 8 inch. Fuel cell contained a window for irradiation of laser, an inlet for water and electrolyte, two outlets for hydrogen and oxygen gasses, an inlet for temperature probe and a D.C power supply model ED-345B.Two electrodes steel and Aluminum were adjusted in the fuel cell. A CCD camera and a computer triggered with fuel cell for grabbing, a multimeter and gas flow meter are arranged with the fuel cell. The diode pumped solid state laser with second harmonics DPSS LYDPG-1 model DPG-2000 having green light of wavelength 532 nm was placed near the fuel cell for irradiation during electroly-

sis of water. The DPSS laser spectrum is shown in figure 1.The drinking water 40 ml mixed with 10mL NaHCO3. In order to start the electrolysis current was applied by D.C source through steal and aluminum electrodes. The laser beam from diode pumped laser was incident on water through window of the fuel cell. The hydrogen and oxygen produced were measured by gas flow meter. The laser beam power was measured by a power meter model Nova Z01500.The temperature of the water was measured by a Temperature probe thermocouple thermometer and mercury thermometer. The current was measured with the help of multimeter. The entire experimental run time was 90 minutes. The data was recorded after every minute of the run.

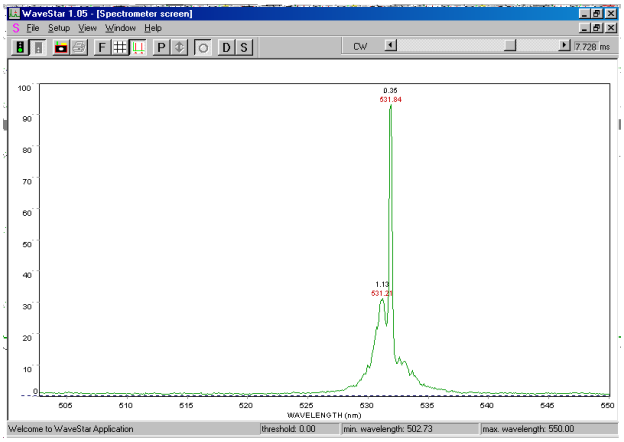

Figure1: DPSS laser spectrum

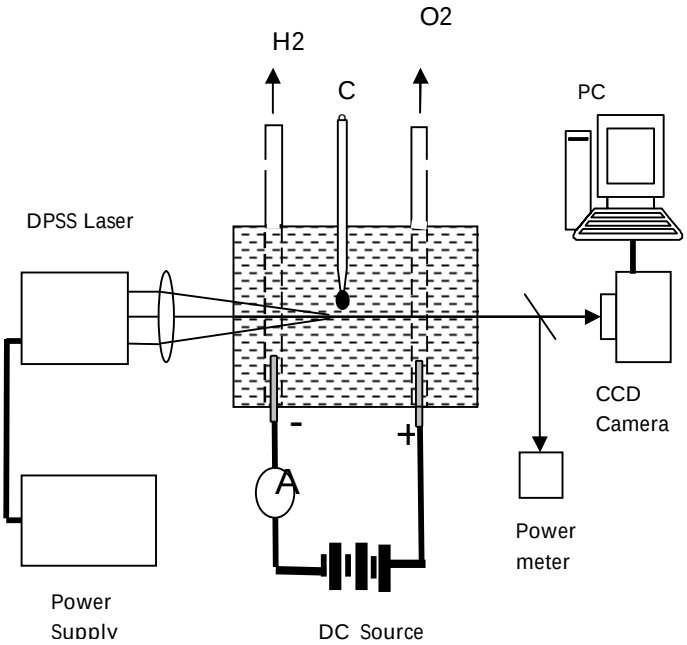

Figure2: Schematic diagram of hydrogen reactor

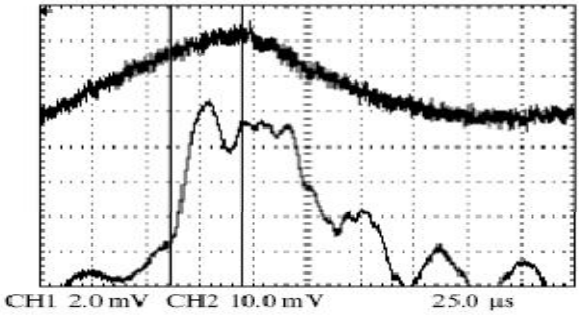

Figure 3. Oscillograms of electrical signal Peaks [7]

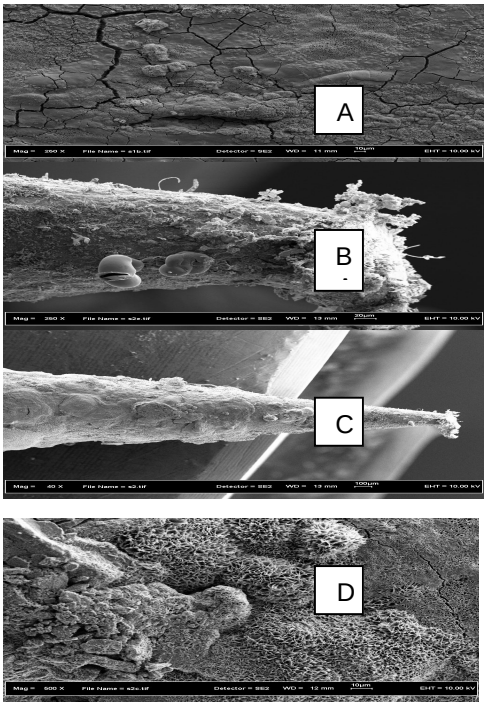

Figure 4. SEM micrographs corrosion on the electrode

Reaction Mechanism

$$H_2O + h\nu \xrightarrow{electrolyt\ e} H_2 + \frac{1}{2}O_2 \text{ ---------- (1)}$$

The energy deposited to the water

$$E = VIt + h\nu \qquad \text{---------- (2)}$$

The criteria for splitting water is

$$E \geq E_d$$

and

$$E = Ed + K_H + K_O \text{ ----------(3)}$$

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Where E is the total energy deposited to the water, is the laser energy, V is the applied D.C voltage, I is the D.C current, t is the current rising time ,Ed is the bond dissociation energy of water, KH is the kinetic energy of hydrogen and KO is the kinetic energy of oxygen.

3. Result and discussion

In order to investigate the role of electrolyte as a photo catalyst for water splitting under the influence of laser, various experiments were performed. It has been observed that various important factors affected the yield of hydrogen and oxygen.

(i) Effect of laser Power
(ii) Laser focusing effect
(iii) Effect of Temperature

3.1 Effect of Laser power

The one of the important factors which affected the product yields was Laser power. This effect is shown in figure 5. It has been detected that hydrogen and oxygen yields increased with increase in laser input power. Initially yields were found to be increased linearly with laser power. When the laser power reached at 1 watt a sudden increase was seen in the yields. At this point the hydrogen yield was found to be 0.17cc where as oxygen yield was at 0.1cc. It was due to a sharp electrical signal generated by the laser. This electrical signal peak had enough energy to overcome the bond dissociation energy of water. The hydrogen yield was found to be greater than the oxygen yield. It was all due to the fact a lot of oxygen was used to oxidize the electrodes. So a lot of oxygen was used in corrosion process shown Figure 4.

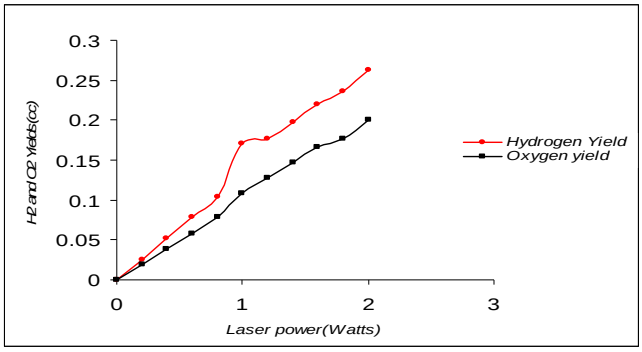

Figure 5. A graph of laser power versus hydrogen and oxygen yields

3.2 Laser focusing effect

It was revealed that the laser focusing effect also affected the yields. The experimental facts showed that when the hydrogen reactor was near the focus of the laser beam, the yield of hydrogen was found to be large. As long as the distance from the focus was increased the production observed to be less. Figure 6 represents this effect. The maximum yield 0.000051 cc was observed at 14 cm distance from the focus where as minimum yield 0.000042 cc was observed at 68 cm from the focal point. It was due to the fact that when reactor was near the focus the intensity of beam was large, at that point powers density became large, so yield of hydrogen found to be large. Similarly when the distance form the focus was increased power density also decreased, so hydrogen yield also observed to be less. The non linear behavior of the curve in the figure 6 shows the moment of the focus point due to stirring of the water. At a distance of 40 cm from the laser focus a sudden change in hydrogen production was observed. This sudden change was may be due to external disturbance produced by the stirring effect.

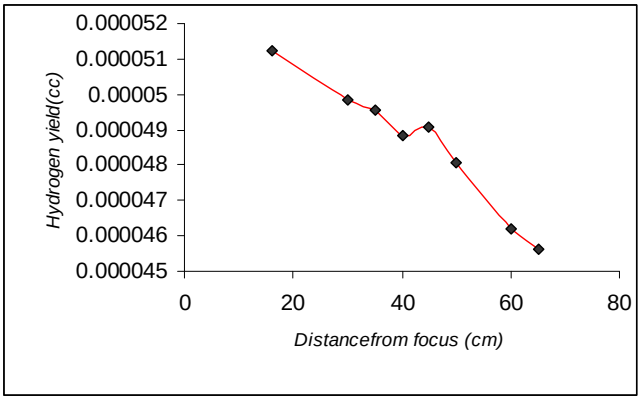

Figure 6. Hydrogen yield versus distance from the laser focus

3.3 Effect of Temperature

The other important factor which affected the product yields was the temperature of the water. It has been observed that temperature of the water rose with time.

It was because of Joule heating effect.

$$H = I^2 Rt \text{ (Joules)}$$

Where H is heat dissipation, R is the resistance of water and electrolyte and t is the current rising time. Figure 4 shows this effect. It has also observed that as long as temperature raised yield of hydrogen and oxygen also increased (Figure 7). It was due to the fact that as temperature of water raised, bonding of the water became week and splitting of water became prominent. The Figure 8 represents the relationship between the laser exposure time

and the efficiency of hydrogen and oxygen yields. It was observed that the efficiency of yields increased rapidly after one minute of the run and reached at 95%.After that efficiency slightly decreased 90% and maintained this value throughout the run of experiment. This efficiency found to be greater than normal faradic efficiency.

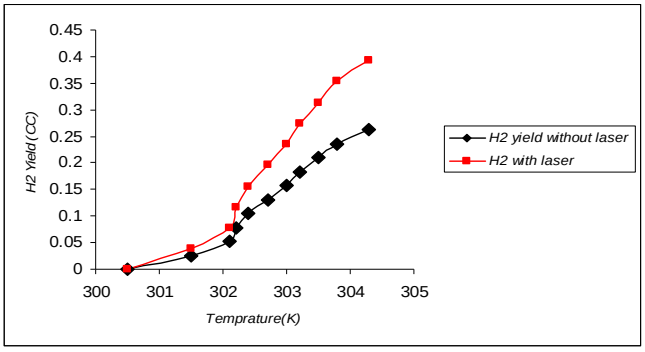

Figure 7. Comparison of hydrogen yields with and without laser

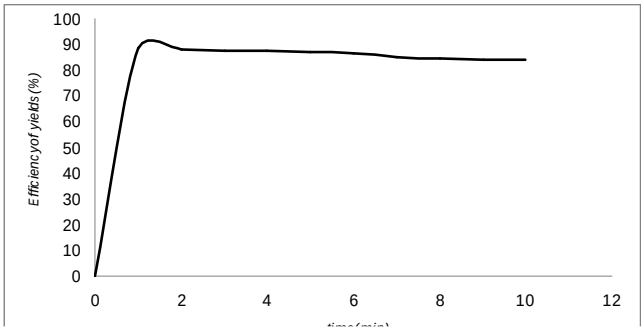

Figure 8. A graph of laser exposure time versus efficiency of yields

3 Conclusion

The experimental results revealed that, the diode pumped solid state laser with second harmonics having a green light of wave length 532nm is highly efficient in photo splitting of water into hydrogen and oxygen during plasma electrolysis of NaHCO3 water. The laser power, focusing effect and temperature of the water have a significant role in enhancement of the hydrogen production photolysis of water.

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