Fundamental study of field-induced gas and water dissociation near nanostructured electrodes

by

Seongyul Kim

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Examining Committee:

Theodorian Borca-Tasçiuc, Thesis Adviser

Nikhil Koratkar, Thesis Adviser

Diana Borca-Tasçiuc, Member

Saroj Nayak, Member

Rensselaer Polytechnic Institute
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ABSTRACT

Nanostructured materials (i.e. carbon nanotubes, metal nanorods) have been broadly researched for their electrical and electrochemical applications as electrodes. Due to their unique mechanical, electrical and thermal properties, they have been considered as a strong candidate for the application of field induced gas ionization sensor and water electrolyzer, etc. Our objective in this work is to study in-depth the fundamental mechanism for nanostructured electrodes.

We investigated the field enhancement with vertically aligned carbon nanotubes electrode on Inconnel substrate and tungsten nanorods on Si to explore the feasibility on detecting gases via field-ionization. For carbon nanotubes array electrode with large gap (~100 um) we explored the effect of sharp tips of carbon nanotubes on the gas breakdown characteristics and detection of oxygen and dichloro-difluoro-methane gases in mixture with helium. The tests show that the breakdown voltages of gases are lower than the one with the traditional gas ionization sensing device. In addition to that result, oxygen (13.61 eV) and dichloro-difluoro-methane (11.75 eV) gases having low ionization potential show significantly higher breakdown voltages than the breakdown voltage of helium gas whose ionization potential (24.58 eV) is higher than both the gases. We show that this is because both oxygen and dichloro-difluoro-methane gas have low mean free path resulting in more interaction between gas molecules during the breakdown process, and both gases are electro-negative gases which tend to re-attach electrons quickly during the ionization process.

As well as carbon nanotubes array electrode, tungsten nanorods array is tested for detecting dichloro-difluoro-methane gas in mixture with helium gas. In this test we

carefully designed a device having a small spacing (~2 μm) between the electrodes to study whether there is less screening effect on the electric field near the nanoscale tips of the electrode. The test indicates that with small gap device can detect the dichloro-difluro-methane gas in helium gas at significantly lower concentration than the device with large spacing.

We explored the effect of nanostructured electrode on over potential and energy consumption during the process of water electrolysis. Firstly ruthenium nanorods array electrode was investigated. The results show the increased surface area decreases the over potential and energy consumption of the electrolyzer. We also tested different length of nanorods since longer nanorods should have larger surface area. However the test result and AFM (Atomic Force Microscope) measurement indicate that the only cap area of the nanorods is chemically active during the process because nanorods are highly dense.

It is known that carbon nanotubes can be heated very efficiently by exposure to IR (Infrared) light. To understand the effect of this heating on water electrolysis we tested a free standing carbon nanotubes paper electrode exposed to laser light in a standard electrolysis cell. This work shows that laser can heat the carbon nanotubes paper electrode resulting in decreasing the required electrical energy to electrolyze water into hydrogen and oxygen gases.