Thesis: Photocatalytic water splitting in the presence of I$_2$/IO$_3^-$ shuttle redox mediator using twin reactor

Global warming becomes a serious problem due to the industrial revolution and the progress of the human civilization. The petroleum is also limited source on earth. The reason that the temperature increases on the earth is because of the greenhouse gases. One of the main greenhouse gases is CO$_2$ from the combustion of fossil fuel. One of the best routes to solve the problem is the photo process that utilizes solar energy to drive the water splitting reaction. A Z-scheme of water splitting has the potential to use solar energy to split water into hydrogen and oxygen. The Z-scheme system contains two types of photocatalysts, one is H$_2$ photocatalyst, and the other is O$_2$ photocatalyst. By irradiation of the visible light, electrons and holes are generated on both photocatalyst. With the help of redox mediator, we could utilize visible light to split water into hydrogen and oxygen.

In this research, we developed the visible-light driven photocatalysts. SrTiO$_3$:Rh was prepared by sol-gel method. This H$_2$ photocatalyst was to produce H$_2$ in the overall water splitting. The O$_2$ photocatalyst, WO$_3$, was received from a commercial manufacturer for the oxidation of water to form O$_2$. The H$_2$ photocatalyst and the O$_2$ photocatalyst were loaded with Pt by incipient wetness method. The former is reduced under H$_2$ and the later is calcined in air, respectively. The twin reactor is divided by Neosepta anion exchange membrane. We applied the H$_2$ photocatalyst and O$_2$ photocatalyst to run the overall water splitting in the presence of I$_2$/IO$_3^-$ redox mediators. The light source was 300W Xenon lamp. The optimized concentration of the redox mediator I$_2$/IO$_3^-$ was under 15 mM NaI solution initially for both side of the twin reactor, which was found to give the highest amount of hydrogen evolved. The results showed that 10 μmol/g•cat H$_2$ was evolved under the ratio of O$_2$/H$_2$ equal to 0.49 at the end of 6 hours. The amount of 13 μmol/g•cat H$_2$ was evolved under the ratio of O$_2$/H$_2$ equal to 0.63 at the end of 8 hours. The backward reaction of water splitting can be avoided by using the twin reactor. In addition, the cost of H$_2$/O$_2$ separation can be saved, and also the potential explosion of H$_2$/O$_2$ mixture can be prevented. In the twin reactor, H$_2$ photocatalyst and O$_2$ photocatalyst were separated so that light energy can be fully utilized.

Thesis: Duel function visible light photocatalyst in hydrogenation of carbon dioxide via hydrogen production

Global warming has become a major environmental issue to be considered in the 21th century. One possible solution of global warming is the reduction of carbon dioxide. The reduction of carbon dioxide could not only solve the crisis of global warming, but provide a high economic value. Carbon dioxide could be reduced to useful chemicals such as methane, methanol, and other hydrocarbons.

In this research, co-catalyst loaded GaN:ZnO is found to have the ability to perform both photocatalytic reduction of carbon dioxide and produce hydrogen (water splitting) simultaneously. Having the duel functions ability gives the advantages of increasing the conversion of solar energy. An interesting phenomena found while performing photocatalytic reaction of duel function catalyst is that providing the ability of water splitting, carbon dioxide reduction ability is enhanced through the hydrogenation of CO$_2$ [1] through the produced hydrogen. For the reaction in the hydrogenation of carbon dioxide to produce hydrocarbons, the change of Gibbs energy becomes a negative value meaning that the reaction is favorable and is spontaneous. Furthermore, the as produced methanol acted as an electron trap for the enhancement of hydrogen production [2]. Therefore the efficiency of the photocatalyst introduced in this research is higher than recent developed visible light catalyst. The result of Ni/NiO-GaN:ZnO showed a yield of 3.16, 1.12, 2.24, 0.312 μmol/h/g of hydrogen, methane, methanol, formaldehyde respectively.

Thesis: Remediation of phenol in wastewater by internally illuminated monolith reactor

Phenol is one of the major waster water pollutants in the world and wildly used in dye, resin synthsis industry. In the research, sol-gel prepared TiO$_2$ was coated on the monolith multiple times to form multilayer structure. The catalyst was calcined to transform into anatase state at 500 °C. From SEM images, uniform catalyst layer can be achieved by multiple times of coating. PMMA(Poly(methyl methacrylate)) with caves which can increase the side emission of light were put inside each channel of monolith. The depth of each cave was kept constant by a modified cutter. The end of each fiber contacted with the inner side of the reactor’s stainless steel wall, which was provided as a reflective plane to enhance the light irradiation. From the results of optical fiber illumination experiment, the light intensity can be enhanced for 30.7% for cutted optical fibers. The light source was a 200 W mercury lamp to provide 2 W/cm$^2$ light intensity. The batch reactor’s experimental results showd the best residence time for the internally illuminated monolith reactor system is 180 minutes. TiO$_2$ catalyst shows better performance that Mn loaded TiO$_2$ catalyst. The conversion achieved 0.259 with UVA light intensity of 2 W/cm$^2$ at 25°C.