Ultrathin Single Crystalline Silicon Solar Microcells for Unassisted Photoelectrochemical Water Splitting

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Water splitting system
- Electrolysis uses electricity to decompose water molecule into oxygen and hydrogen. When high enough electric potential is applied, anode oxidizes water molecule into oxygen and proton, while cathode reduces the proton into hydrogen.
- Photoelectrochemical water splitting promises a solution to the problem of large-scale solar energy storage. However, its development has been impeded by the poor performance of photoanodes, particularly in their capability for photovoltage generation.
- It is an artificial photosynthesis process in a photoelectrochemical cell used for the dissociation of water into its constituent parts, hydrogen and oxygen using sunlight.
- Hydrogenated microcrystalline silicon thin films promise new solar-cell materials. Their advantages include minimal use of semiconductor resources, large-area fabrication using low-cost methods, and no photodegradation of solar cell characteristics.
- The minimum potential difference (voltage) needed to split water is 1.23V at 0 pH.

Skills Learned
- It is a multiple-step sequence of photolithographic and chemical processing steps during which electronic circuits are gradually created on a silicon wafer.
- Nitride film deposition
- It is formed on the wafer by CVD method using silane and ammonia gas.
- RCA clean is the procedure to remove the organic contaminants, thin oxide layer, and ionic contamination
- Photore sist coating
- The wafer is uniformly coated with a thick ultraviolet (UV) light sensitive liquid called photore sist.
- The coating is applied while the wafer is spinning.
- Masking
- Masking is used to protect one area of the wafer while working on another.
- This process is referred to as photolithography or photo-masking.
- Exposure
- A photo aligner aligns the wafer to a mask and then projects an intense light through the mask and through a series of reducing lenses, exposing the photoresist with the mask pattern.
- Opaque regions on the mask block the UV light.
- Etching
- The wafer is then "developed" (the exposed photore sist is removed) and baked to harden the remaining photore sist pattern.
- Doping
- Atoms with one less electron than silicon (such as boron), or one more electron than silicon (such as phosphorous), are introduced into the area exposed by the etch process to alter the electrical character of the silicon.
- These areas are called P-type (boron) or N-type (phosphorous) to reflect their conducting characteristics.
- Prove testing
- Mechanical probe station utilizes manipulators which allow the precise positioning of thin needles on the surface of a semiconductor device.
- It is used to acquire signals from the internal nodes of a semiconductor device

Objective & Impact of Professor Jongseung Yoon’s Research
- The goal is to develop approaches that can achieve an efficient utilization in silicon solar cells without sacrificing their performances.
- The production cost.
- Silicon solar cells can produce abundant material on earth and has been dominantly used in photovoltaics. However, massive implementation has been limited due to the high cost as raw wafer materials account for more than 50% of the production cost.
- Ultrathin silicon can reduce the amount of silicon used in the device.
- If the electrons and holes were not charged, this diffusion process would have remained. However, the performance is limited due to the weak optional absorption of photovoltaic and semiconductor structure.
- The photovoltaic effect refers to photons of light exciting electrons into a higher state of energy, allowing them to act as charge carriers for an electric current.
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- When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material.
- If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of electricity.
- The n-p junction
- P-n junctions are formed by joining n-type and p-type semiconductor materials.
- Since the n-type region n (negative) has a high electron concentration and the p-type region p (positive) has a high hole concentration, electrons diffuse from the n-type side to the p-type side. Similarly, holes flow by diffusion from the p-type side to the n-type side.
- Due to the difference in concentration, it creates an electrical field inside the semiconductor structure.
- If the electrons and holes were not charged, this diffusion process would continue until the concentration of electrons and holes on the two sides were the same.

How This Relates to My STEM Coursework
- In my high school science classes, the experiments I do usually have set procedures and known results. We are given the methods to prove the textbook results.
- The actual research labs I have worked in at SHINE requires me to apply the physics, chemistry, and calculus knowledge that I have learned to prove the hypothesis through various experiments.
- This experience strengthened my prior knowledge and expanded my overall skill in STEM research.
- I will continue to pursue my interest in chemical engineering.
- I am also planning to join a research group in college.

Next Steps for Myself and Advice for Future SHINE students
- Choose the department that interests you
- You do not have to be sure of what you want to major in college because almost all the research done in this program involves different fields of engineering.
- Even though my research group focused more on chemical engineering, it also required the knowledge of electrical and mechanical engineering. The fun part is that the program gives high school students opportunities to explore their potential majors and participate in the advanced laboratory.

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Introduction
- During the eight weeks of SHINE Program, I worked under Professor Jongseung Yoon who focuses his researches on chemical engineering. Even though there were several projects going on at the same time, they all had the same purpose, which is to maximize the performance of monocrystalline silicon in photovoltaic systems. This is important because silicon can produce renewable and sustainable power sources. The solar energy produced will not only reduce utility costs, but also minimize effects on global climate.

Principle
- Photovoltaics
- Photovoltaics (PV) is the method of converting solar energy into direct current electricity using semiconducting materials
- The photovoltaic effect refers to photons of light exciting electrons into a higher state of energy, allowing them to act as charge carriers for an electric current.
- When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of electricity.

Working Principle of Solar Cells

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