Optimizing Silicon Growth Conditions to form P-N Junction for Silicon Solar Cells

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Abstract

Creating an efficient solar cell that produces the best electric current under the most efficient procedure has been the goal of thin film material science for decades. My research was guided by the article "Direct-current sputtering epitaxy of Si and its application to fabricate n+ emitters for crystalline-Si solar cells" written by Wenchang et al.[1]

This article established the proper conditions to create good p-n junctions using silicon wafers. The process of doping the silicon is the "heart" of solar cells manufacturing. Silicon wafer was etched with HF to remove native Si-oxide and thin silicon film was deposited using magnetron sputtering. Crystallinity was tested by RHEED (Reflective High Energy Electron Diffraction). The application method used in the article reports growth rate of silicon using sputtering at different temperatures and pressures. I-V characteristics of the deposited diode structure were measured. My results were not exactly the same as the article because deposition rate achievable in our system was lower than the rate which affected the single crystal growth. Lower deposition rate could allow more impurities to be trapped in the deposited material.

Methods

To properly clean a silicon wafer requires you to use the following:

- Wash the p-type wafer with acetone to clean organic contaminants, following by deionized water and IPA (Isopropyl alcohol) and then drying with a flow of Nitrogen gas.
- Etching is a step that requires using a lab hood. Here we used HF(%5), for one minute to removes all oxides including native SiO_2 that can hinder mono-crystalline silicon growth.

- An AJA Orion-8 sputtering system was used to deposit the n-type silicon. We used an n-type wafer as the target.
- Deposition rate was 0.7 Å/sec and films were prepared at different temperatures (175, 200 & 250°C). The base pressure was at 10^{-8} Torr range and deposition rate was set to 3mTorr.

Introduction

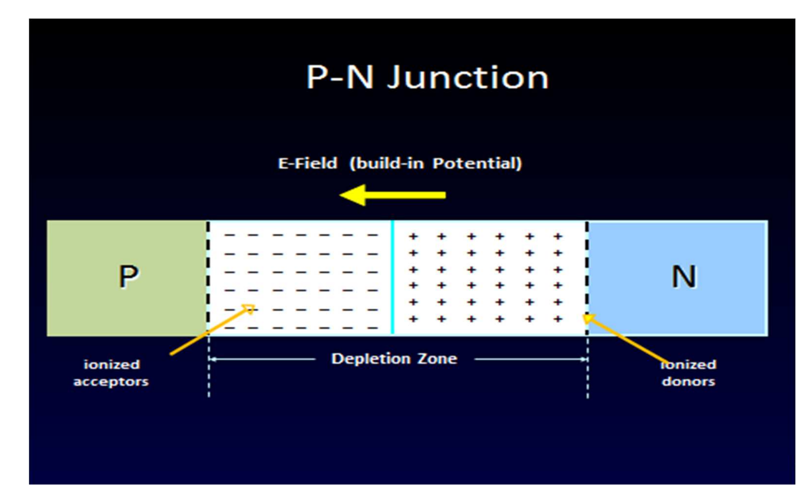
Creating solar cells is an important process for today's society. With the focus to find new energy sources, harvesting solar energy and creating the most efficient solar cell that would produce the best electrical current from the power collected from the sun.

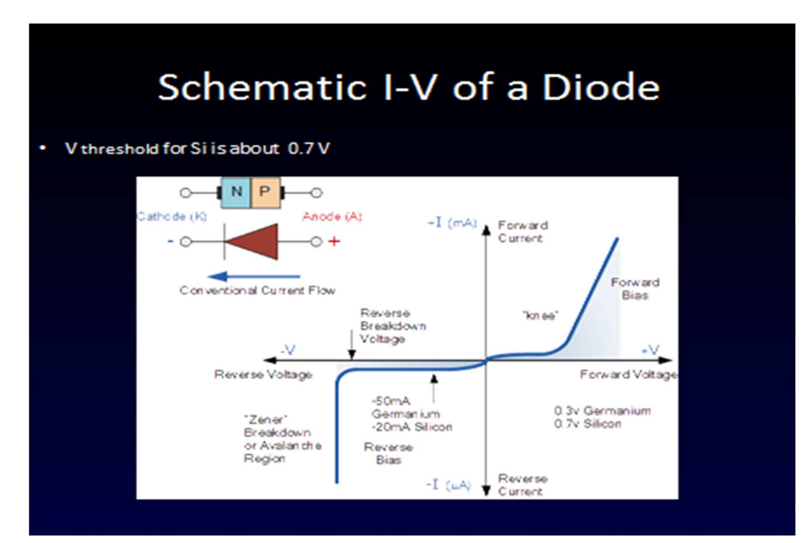
Diodes (a p-n junction)

Doping contaminants such as boron and phosphorus into a silicon wafer creates different types of silicon being called p-type or n-type.

Having two silicon types with different energy levels allow us to create diodes when attaching these two media together.

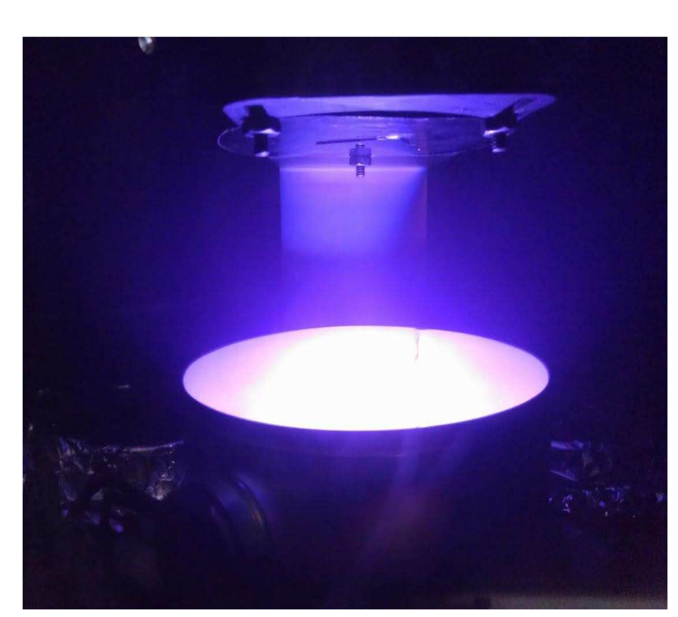
The upper image schematically shows how a P-N Junction will look in a diode in order to produce an electric field and rectify current. Following diagram shows the Voltage-Current characteristic of a typical diode.





Sputtering

Magnetron sputtering is the method based on the bombardment of the target with heavy and accelerated Ar-ions(Ar-plasma), creating the atmosphere for silicon target to be deposited on the substrate and form amorphous or epitaxial film under proper temperature and deposition rate.



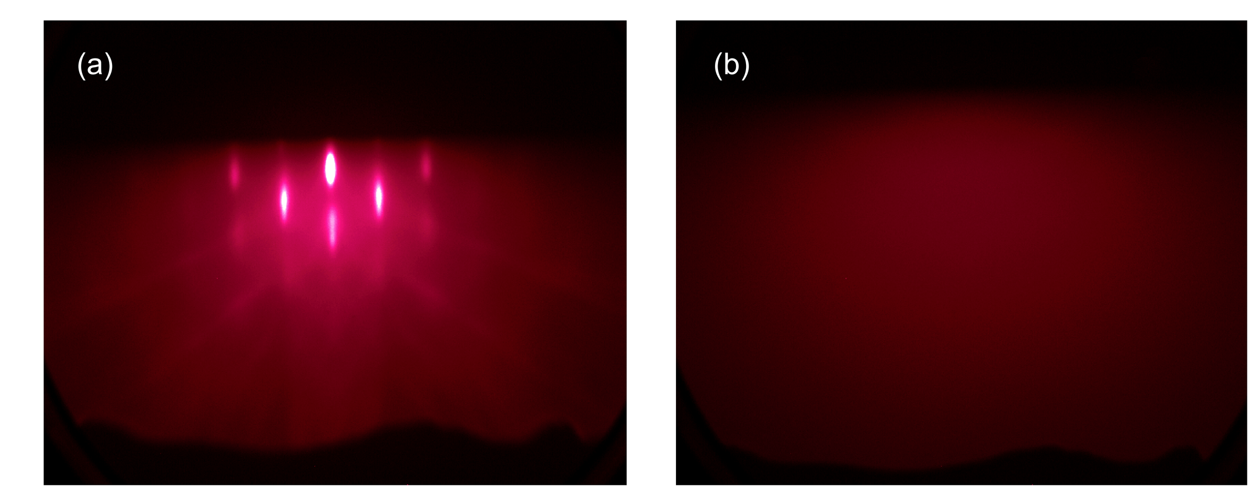
The image shows the gun and the plasma created and also, the substrate that faces down towards the gun.

Results and Discussion

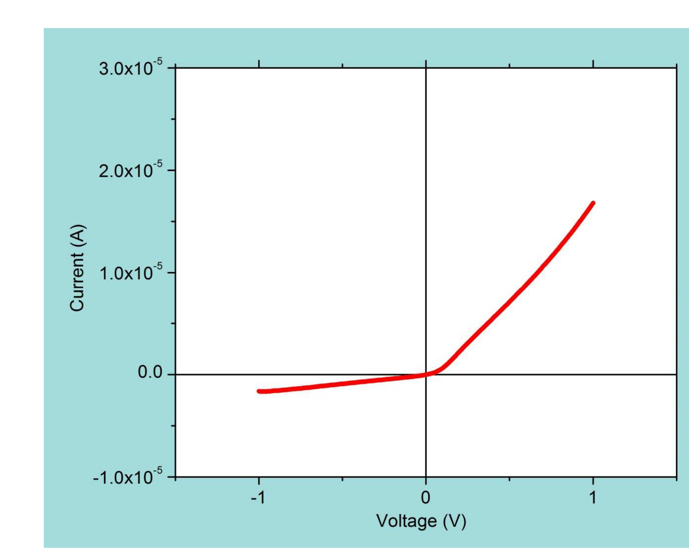
Picture (a) shows the RHEED image of the silicon wafer(p-type) after etching and before deposition of the n-type silicon at (100) direction. The sharp bright lines represent the quality of the single crystal wafer.

Picture (b) obtained after depositing 500nm n-type wafer at 175°C at the same direction, pointing the amorphous structure of the film.

Samples at different temperatures (200 & 250°C) also were made, but there was no distinct change in the results.



Voltage-Current measurement shows the rectifying effect of the diode that was made, but improving its quality requires eliminating oxygen from being incorporated in the structure during deposition.



References

- ✓ Holgate, Sharon Ann, ***Understanding Solid State Physics***, CRC Press: A Taylor& Francis Book, New York, 2010.
- ✓ Wenchang Yeh et al., **Direct-current sputter epitaxy of Si and its application to Fabricate n+-emitters for crystalline-Si solar cells**, Japanese Journal of Applied Physics, 53, 2014.

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