



A STUDYING ABOUT THE HYDROGENATED SILICON THIN FILMS

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ABSTRACT

As the need for reliable, eco-friendly electricity continues to rise, the use of solar power offers a viable solution. Since thin film solar cells have the potential to be both highly efficient and inexpensive to produce, they have become a major technology in this area. This research focuses on the fabrication and characterisation of thin films for use in solar cells. Various materials and deposition methods were used to fabricate thin films for the study. Organic semiconductors, indium gallium selenide (InGaSe), copper indium telluride (CdTe), and amorphous silicon (a-Si) were all taken into account. Chemical vapor deposition (CVD), physical vapor deposition (PVD), and solution-based deposition processes were all used. After production, several analytical methods were used to characterize the thin films. Surface morphology was analyzed with scanning electron microscopy (SEM), crystal structure was determined using X-ray diffraction (XRD), and optical characteristics were probed with spectroscopic techniques including UV-Vis absorption and photoluminescence spectroscopy.

Keywords: - Electricity, Solar, Cells, X-ray, Chemical.

I. INTRODUCTION

The energy needs of our modern society have grown exponentially during the last several decades. Problems arise when nonrenewable resources must be used to meet the needs. The massive pollution caused by fossil fuel based energy and the scarcity of fossil fuels are two of the main issues. Long-term energy security for future generations can be guaranteed only by renewable energies, that is, energies whose use does not contribute to the depletion of natural resources. Solar energy has great potential and is one of several renewable energies that need to be developed. The sun

provides a vast amount of energy; in fact, the amount of energy needed to power the whole human population for a year may be met by the solar power received by Earth's surface in only one hour. Both heat and light are components of the sun's power. Through the solar photovoltaic approach, a solar cell is used to directly convert solar radiation into energy. A.-E. Becquerel's 1839 discovery of the photogalvanic effect marked the beginning of the field of photovoltaics. The first "usable" silicon solar cell, with an efficiency of 6%, was disclosed by Chapin et al. in 1954.

The photovoltaic effect is the fundamental



physical mechanism that allows a photovoltaic (PV) cell to convert solar energy into usable power. These cells are typically made of silicon crystal and include a single p-n junction. The cost of a single silicon crystal is quite high. Consequently, monocrystalline solar cells have become prohibitively costly. In addition, the material in this circumstance has been squandered. The evolution of the thin film solar cell is one approach to lowering this price. Thin film photovoltaic cells (TFPV) are another name for these thin film solar cells (TFSC). The primary benefits are:

1. Much less materials are required.
2. The fabrication requires much less energy.

As a result, the idea of thin-film solar cells has gained traction and is now at the forefront of the field. Modern solar cells, known as thin film solar cells, are made up of many thin film layers of various materials. These layers may be deposited on a wide range of substrates at room temperature. When compared to conventional p-n junction solar cells, the thicknesses of thin film layers are much less (few nanometers). Following are the many levels:

1. Transparent Conducting Oxide (TCO) layer.
2. Window layer (p- or n-layer).
3. Absorber layer
4. Doped layer (n- or p-layer to form built-in-potential).
5. Back Contact (metal layer).

The transparent conducting oxide (TCO) layer is both an electrode and a window via which incoming light enters the device. Because of its low resistivity and high

transmittance in the visible area, this highly degraded and broad band gap semiconductor is of great relevance. Because of this, solar energy is transmitted directly to the window layer (p or n layer) via TCO film with little loss. That's why TCO's electrical and optical qualities are so crucial to thin film solar cells' efficiency and performance. TCO layers have been created for use in solar cells, which is the focus of the first half of this thesis.

II. TRANSPARENT CONDUCTING OXIDE

Tin doped Indium Oxide

Tin-doped indium oxide (ITO) is widely recognized as the material with the ideal balance of high electrical conductivity and excellent optical transparency in the visible spectrum. These characteristics explain why ITO has found so much application as a Transparent Conducting Oxide (TCO). The optical band gap of indium tin oxide is 3.7 eV, making it a transparent material in the visible spectrum while being reflective in the infrared. Indium tin oxide (ITO) is synthesized by replacing In^{3+} atoms in the cubic bixbyite structure of In_2O_3 with tin atoms (Sn). The lattice parameter of ITO films is 10.2-10.3, which is close to that of In_2O_3 . This means that Sn may establish an interstitial connection with oxygen in two different ways, depending on whether the oxygen has a valence of +2 or +4. The conductivity of ITO films relies heavily on this valence state. Since the presence of SnO_2 indicates the presence of Sn^{4+} , SnO_2 must function as an n-type donor. X-ray diffraction (XRD) data uncovered by Senthilkumar et al. revealed that increasing Sn dopant concentration in the In_2O_3 lattice



reduced grain size in ITO films. ITO film produced using a magnetron sputtering technique achieved a resistivity of 104 cm when the deposition chamber was oxygen-free, as reported by Ray discovered that when oxygen is absent, a very good vacuum is connected to metallic coatings, causing less transparent ITO films to develop when formed using rf magnetron sputtering.

High conductivity in ITO is due to its formula, $\text{In}_2(\text{Sn}_x)\text{O}_3(2x)$, which indicates that both substituted tin and oxygen vacancies operate as source of carriers. In order to increase conductivity, an oxygen deficit in the film was necessary. Conversely, carrier conductivity is decreased when the valence state is lowered. The conductivity decreases because the hole serves as a trap. However, if there are an excessive number of oxygen vacancies in the film, they will behave as defects without contributing electrons, hence reducing the film's conductivity. The characteristics of the deposited film are significantly affected by the amount of oxygen present in the deposition chamber. Due to a greater concentration of carriers, Manavizadeh et al. postulated that the resistivity of ITO on glass is minimal. Crystalline development of ITO film along 111 allows for a greater number of interstitial oxygen atoms, as discovered by Kamei. The direct bandgap, plasma wavelength, and film refractive index are all affected by the oxygen pressure. However, the optical transmittance drops as the carrier concentration rises because more free carriers are absorbed. Transmission is found to be mostly unaffected by oxygen flow, while reflection is shown to vary drastically in the IR region

owing to a substantial rise in carrier concentration, since the plasma wavelength shifts toward shorter wavelengths as carrier concentration increases. It has been reported that exposure to hydrogen plasma reduces the transparency of ITO films (or causes whitening of the film). Hydrogen radical is a powerful reducing species and releases oxygen from ITO film, as reported by Banerjee et al.. Oxygen flaws and n-type carriers are created as a result of this decrease. Due to hydrogen's reducing capability, oxygen vacancies are produced in ITO thin films during reactive sputtering, as proposed by Lee. Therefore, films formed in an Ar + H₂ gas ambient have much lower resistivity than films produced in an Ar + O₂ ambient.

III. HYDROGENATED SILICON THIN FILMS

Amorphous Silicon Thin Films

In the late 1960s, scientists created hydrogenated amorphous silicon for the first time. Prior to that time, studies were conducted using a-Si that lacked hydrogen. The defect density in the unhydrogenated material is very high. Amorphous silicon does not have a regular atomic structure. This implies that the connection between pairs of atoms loses its structure after just a few interatomic spacings, allowing for the separation of only a few number of closest neighbor distances. These flaws eliminate the possibility of doping, photoconductivity, and other features essential to a functional semiconductor.

Hydrogen dilution really has a significant impact on the final film's characteristics. Hydrogen inclusion, which saturates Si dangling bonds and promotes the formation



of a more relaxed network topology, made it possible to exert control over the defect structure of amorphous silicon. In essence, the bandgap in hydrogenated amorphous Si is direct. Bandgap energy for hydrogenated a-Si is between 1.7 and 1.9 eV. Tanaka and Matsuda state that the H coverage factor and surface temperature jointly control the surface diffusion coefficient of adsorbed SiH₃ on the expanding surface of a-Si:H. The chamber pressure is crucial throughout the deposition process. As the overall chamber pressure rises, the total concentration of the reactant molecules in the gas phase rises, and the mean free route of the product species falls, as described by De et al. Because of this, the rate of deposition slows down with time.

It seems that metastable centers may be formed in a-Si:H films by prolonged illumination. Many of the characteristics of hydrogenated amorphous-silicon may be attributed to the presence of these centers, which are linked to dangling bonds in silicon. The above-mentioned centers were the subject of a model proposed by Carlson et al. The author made the assumption that hydrogen on the interior surfaces of microvoids may be induced to move by the presence of trapped holes. As a result of these factors, amorphous-silicon solar cells lose efficiency when placed under direct sunlight. This is a serious issue that can't be avoided when working with amorphous Si. The Staebler-Wronski effect describes this phenomena, which is brought on by hanging bonds in a disordered random network.

IV. THIN FILM SILICON SOLAR CELL

Stabilized efficiencies of hydrogenated

silicon-based solar cells have made great strides forward in the previous several decades. The p-i-n or n-i-p junction diode is the building block of a thin-film solar cell. Holes have a shorter lifespan than electrons and migrate to the p-layer when exposed to light. Since most of the photons are absorbed in the absorber layer, or the i-layer close to the p/i interface, it is more efficient to light the solar cell via the p-layer so that the holes may be collected there. In both setups, light enters the cells from the p-layer side. Glass is often utilized as the substrate in p-i-n solar cell construction. The glass substrate is coated with a TCO (transparent conducting oxide) layer with a textured surface. Then, three layers of Si:H are placed.

Amorphous Silicon Solar Cell

Small area hydrogenated amorphous silicon (a-Si:H) solar cells were initially produced by Carlson et al. 35 years ago, with an initial efficiency of 2.4%. Since then, there has been significant development in this area, both in the lab and in the marketplace. While huge a-Si modules are being built for commercial use, Yang et al. have shown an a-Si:H cell with initial efficiency more than 14%. Solar photovoltaic (PV) modules based on amorphous silicon are manufactured commercially by a number of businesses including Kaneka, Mitsubishi, Fuji, Schott Solar, etc. Using an i-layer with few microstructural flaws improves solar cell performance. Although there are several benefits to using inexpensive a-Si:H thin film technology, the main disadvantage of an a-Si:H solar cell is that its properties degrade when exposed to light. It loses effectiveness when exposed to sunlight.



Micro- or Nanocrystalline Silicon Solar Cell

Hydrogenated microcrystalline (c-Si:H) or nanocrystalline (nc-Si:H) silicon is seen as a potential material for silicon based thin film solar cells due to its resistance to light-induced deterioration. The short circuit current density of micro or nano crystalline silicon is greater than that of an a-Si solar cell because of the material's improved long wavelength response (up to around 1100 nm). Solar cells made of micro or nanocrystalline silicon often degrade very little when exposed to sunlight. A completely microcrystalline cell with a thickness of 1.7 μm and a conversion efficiency of 4.6% was reported by Meier et al. in 1994. Completely microcrystalline single p-i-n cells have attained efficiencies of 8.5% with no degradation from light.

The nanocrystalline cell that Yue et al. created had an efficiency of 9.23% and a short circuit current density of 27.6 mA/cm^2 . Microcrystalline silicon solar cells need thick i-layers to absorb most of the incoming light and achieve the maximum possible short circuit current density. This is because the absorption coefficient of c-Si:H is lower than that of a-Si:H. Therefore, the rate of c-Si:H deposition is a major concern. Using an improved i/p buffer layer, Yue et al. produced a nc-Si:H single junction solar cell with an initial active area cell efficiency of 9.23%. It is well known that a p-i-n solar cell's efficiency relies heavily on the characteristics of its window layer. Chen et al. achieved 9.2% efficiency of 1 μm thick microcrystalline solar cell by using microcrystalline silicon-carbide as window layer.

V. CONCLUSION

These nanocrystalline p-type silicon films, if used as the window layer in a p-i-n solar cell, might improve the cell's efficiency by increasing its open-circuit voltage and short-circuit current density.

Crystalline volume percentage and the number density of nucleation centers both rise with increasing p-layer X_c at the beginning of nc-i-layer development. The i-layer exhibits many c-Si orientations independent of the p-layer material. As p-layer X_c grows, the grain sizes of the i-layer drop somewhat. In the i-layer, the incubation zone thickness decreases with increasing p-layer X_c close to the p/i contact. The efficiency of solar cells is profoundly affected by the i-layer's incubation zone's electronic characteristics. When the p-layer's X_c is increased, the p-i-n silicon solar cell's J_{sc} and FF both increase dramatically. Using two p-layers deposited simultaneously at low and then at high power densities, the efficiency of a single junction nanocrystalline silicon solar cell has been increased to 6.34 percent.

Due to the existence of an Al_2O_3 layer at the interface, crystallization is reduced in the inverted Al/a-Si system, leading us to the conclusion that a-Si sandwiched between the substrate and the Al layer facilitates crystallization. The resulting polycrystalline-Si film has structural, morphological, and optical features that indicate it might be employed as the p-layer in an effort to develop high-efficiency solar cells.

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