Development of Polycrystalline Silicon Films for Photovoltaic Cells

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Photovoltaic devices (Solar Cells) convert sunlight directly into electricity. This research project is directed toward decreasing the cost of solar cells.

"Yearly the earth receives 6000 more times energy from sunlight than humans use. **Photovoltaic solar cells** produce no greenhouse gases, so their use could reduce the probability of global warming and climate change. In 1997, solar cell module shipments jumped to 125 million watts, resulting in more than $1 billion in sales. At present growth rates (which averaged 24% for the last 5 years) module shipments will surpass 10 billion watts per year by 2020. This would represent a direct photovoltaic market greater than $15 billion and an indirect market double that. Today, the solar cell industry creates about 3000 direct and indirect jobs for every $100 million of module sales. As this industry grows toward its potential, it will generate hundreds of thousands of jobs." [National Center for Photovoltaics]

"Currently, the photovoltaic research work likely to make the largest impact upon the industry has been that allowing a transition from silicon wafer-based technology, to that of thin films supported on a foreign substrate, such as glass, stainless steel or polyimide. The material intensiveness of the wafer-based approach limits the potential for cost reduction and hence the possible long-term impact of the technology. It seems likely that a mature thin film approach will displace wafer technology over the next 10 years." [M. Green: Key Center for Photovoltaic Engineering, University of New South Wales (UNSW), Australia]

Purpose of Experiment

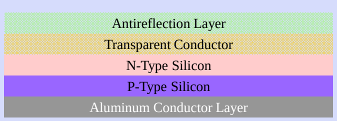
These experiments were designed as a first step toward developing more cost efficient solar cells. To realize this goal, low cost fabrication techniques to deposit thin polycrystalline films of materials necessary to create photovoltaic cells must be developed. Current techniques to deposit the thin films require high temperatures to promote crystalline growth. These high temperatures limit the type of substrates that can be used.

Our technique involves using an unique deposition system that has been under development at UW-Eau Claire. This system incorporates a unique plasma source with capabilities that, in theory, should allow the deposition of crystalline films at low substrate temperatures on a variety of substrates.

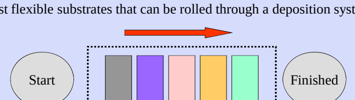
These initial experiments were designed to investigate whether thin polycrystalline silicon films can be fabricated with this system.

Photovoltaic Cell Design & Fabrication Technique

The most efficient photovoltaic cell designs involve depositing an N-type crystalline silicon layer epitaxially on top of a P-type crystalline layer. Epitaxially means that the atoms of each film line up with other perfectly. The more perfect the crystal structure the higher the efficiency of the cell. Next a transparent conductor is deposited on the surface of the N-type silicon and an aluminum layer is deposited on the bottom of the P-type layer. Finally an antireflection coating is deposited on the top of the conducting layer.



To lower the cost of photovoltaic cells a "roll-to-roll" deposition process must be developed. This involves forming the photovoltaic cell on low cost flexible substrates that can be rolled through a deposition system.

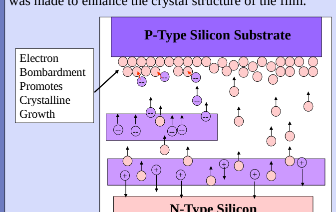


Dual Plasma Arc Thin Film Deposition System

Electron Beam Assisted Deposition Technique

A plasma can be created using the DC-TRIODE ion source system. Ions are accelerated out of the plasma and impinge on the target. Subsequent collisions between the these incident ions and the target cause atoms from the target surface to be ejected toward the substrate. These atoms deposit on the surface to create a thin film.

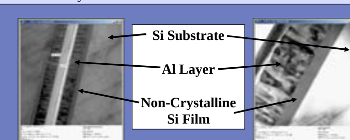
A second plasma arc is created and electrons are accelerated toward the substrate to bombard the growing film and alter the film's properties to enhance certain characteristics. In this case the attempt was made to enhance the crystal structure of the film.



Film Properties

The efficiency of the photovoltaic device design being investigated depends critically on quality of the crystal structure of the film. To assess the crystal structure samples were analyzed with a transmission electron microscope (TEM). This instrument provides a magnified image of the film which can be used to assess crystal structure.

The pictures below show a thin film of silicon deposited on a single crystal silicon substrate. A layer of aluminum has been deposited to determine its effect on promoting further crystallization. The pictures indicate that a crystalline film did not form.



Conclusion & Future Directions

The results of this project are thus far inconclusive. TEM pictures indicate that crystalline films are not forming.

Instabilities in the plasma are causing fluctuations in the electron beam current which causes changes in the substrate temperature.

Future experiments will concentrate on developing a more efficient electron beam current control system. This will result in tighter temperature control. We will also investigate deposition on stainless steel and aluminum substrates which will get us closer to a true roll-to-roll process deposition process.

Acknowledgements

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