A. Title Page

Ordered Quantum Dot Arrays for Application in Solar Cells

Dr. Daniel Bullock, Department of Electrical Engineering

B. Restatement of problem researched, creative work, or professional enhancement opportunity

Solar cells are devices that convert sunlight into electricity. Solar cells are also known as Photo-Voltaic (or PV) cells because they take a Photon of light energy and convert it into a Voltage of electricity. The most common PV cell in use today is made of a material known as Silicon. The Silicon based PV cells are relatively cheaper but only perform at an efficiency of about 8% for the most common type on the market today. This means that for every 100 particles of light, or photons, hitting the PV cell only about 8 electrons are produced for electricity. One reason this process is inefficient is because Silicon can only convert a specific color of light into electricity. The next generation of PV cells will increase efficiency by being able to convert the many different colors of light that make up sunlight into electricity.

One proposed material system is composed of extremely tiny crystals called Quantum Dots (QD).[1-4] QDs are interesting because we can produce all different sizes of them. Some of the smallest ones are composed of only 10 atoms where as the larger ones are composed of almost 1000 atoms. Another interesting thing about these QDs is that the light they absorb is directly related to their size. For instance the smaller the size of a QD the more blue light it can absorb, where as the larger the QD the more red light it can absorb. So the next generation of high efficiency PV cells will be composed of millions of these different sized crystals absorbing almost all the colors from the sunlight.

One of the major challenges with QDs is that when they are produced they occur at random positions on a surface. What is needed is a method for forming ordered arrays of these QDs that will allow the engineer to place QDs of various sizes in specific locations at the nanoscale (10^{-9} m). A technique that has shown some promise is to use a small probe with a hole drilled through it. The backside of the probe is filled with Indium metal and the probe is charged with a voltage of ~40 V. When the probe is brought into contact with a surface its discharges the voltage in just a few milli-seconds. This creates enough energy to melt some of the Indium metal where the probe contacted the surface. The metal droplet size is directly correlated with the hole size on the probe. When this metal droplet is exposed to a well controlled Arsenic flux an InAs (Indium Arsenide) quantum dot is formed.

C. Brief review of the professional enhancement opportunity, creative work, or research procedure

The bulk of the work was performed at the University of Arkansas' Nanoscience Research Building. We have been able to modify an *Omicron* Multiscan system to incorporate an atomic force microscope (AFM) probe. The Multiscan system is the perfect tool for this experiment because it incorporates a scanning electron microscope (SEM) with a scanning tunneling microscope (STM). SEM offers a large field of view so the user can find features over a large area and the STM offers atomic scale resolution of features. The modified AFM probe has a hole drilled through the end that is approximately 50 nm in diameter. The holed was drilled using a technique known as Focused Ion Beam Milling. In addition to the hole the AFM probe was also coated with ~ 1 μm of Indium metal. This metal will be used to form the droplets on the surface of the GaAs semiconductor.

The next challenge in performing the experiment was to design a pulsed power supply to deliver a high voltage pulse (in varying time pulses) to the AFM probe. We have designed and implemented a power supply that can deliver a single voltage pulse from 0 – 200 V for different pulse widths from 5 – 5000 ms. In addition to the power supply we had to isolate these high voltage pulses from the sensitive internal electronics of the *Omicron* Multiscan system. To do this we installed a mercury-wetted reed switch. These switches are magnetic activated and are compatible with ultrahigh vacuum environment of the instrument.

D. Summary of findings, outcomes, or experiences had.

We still have some challenges to overcome. We would like to control the quantum dot size by using different hole sizes on the AFM probe. Additionally, we would like to design a method to deposit patterns of thousands of quantum dots while being able to control each one's size and spatial location and have the whole process take only minutes instead of hours. Given these challenges some further work is needed to make this process commercially viable, but we do have some ideas for a new prototype system.

E. Conclusions and recommendations

In conclusion we have made significant progress in implementing a system to engineer well ordered quantum dot arrays. Not only can this have applications in the field of solar cells but also in developing micro-sized phased array antennas and optical waveguides for optical computing.

REFERENCES

1. Alivisatos, A. P. *Science* **1996**, 271,933.
2. Weller, H. *Angew. Chem., Int. Ed. Engl.* **1993,** 32,41.
3. Schmid, G., *Clusters and Colloids;* VCH Press: New York, 1994.
4. Ashoori, R C. *Nature* **1996**, 379, 413.