Emerging solar technologies - Perovskite

Over the last 40 years photovoltaic (PV) technology has been steadily increasing in efficiency and decreasing in cost. This has resulted in a booming PV industry where PV research and development has continued to improve the technology. Currently, the primary material used in solar PV cells is crystalline Silicon; however there are other materials used such as gallium Arsenide (for ultra-high efficiency) and Cadmium Telluride (thin film cells). One of the more recent developments in PV research is the use of perovskites in solar cells.

The first liquid-state perovskite solar cell was introduced to the PV industry in 2006 and the first solid-state perovskite solar cell was introduced in 2012 (Green, 2014). In the last 3 years, perovskite solar cells have achieved an independently confirmed efficiency of 21.1% (NREL, 2015), an improvement unmatched by any other solar technology.

Perovskite is a class of compounds having a unique crystal structure that can be used as the active layer in a solar cell. It has both organic and inorganic components. Given that the label 'perovskite' relates only to the atomic structure of the material, many different types of perovskites can be created. The most common perovskite used as a solar cell material is Methylammonium lead trihalide ($CH_3NH_3PbX_3$). The 'X' in this compound is a halogen, such as iodine.

The diagrams below compare a silicon solar cell to a perovskite solar cell. As can be seen, they both have similar structures; a p and n type material to create a pn-junction, contacts to collect the current generated, and glass to encapsulate the cell. In silicon solar cells, the electron-hole pairs are generated by a photon in the bulk of the cell, separated by the PN junction, and collected by the top and bottom contacts.

When light hits a perovskite cell, the perovskite layer acts like the n-type layer and the hole transport medium acts like the p-type layer. In the perovskite cell, the top contact is a transparent conducting glass (often fluorine-doped tin oxide -

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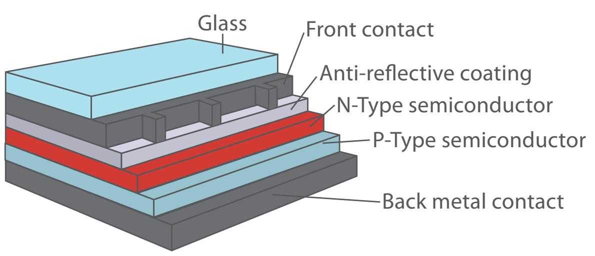

Figure 1 - Basic breakdown of an Si solar cell

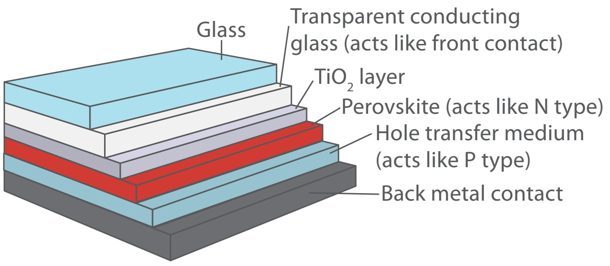

Figure 2 - Basic breakdown of a perovskite solar cell

FTO), reducing resistance in the cell and increasing the probability that an electron will be collected before it can recombine.

What are the advantages and disadvantages of perovskite solar cells?

Perovskite solar cells have several advantages over traditional silicon solar cells because of their relative ease of manufacture. The current materials used in perovskite solar cells can be applied in low temperature processes using either vapour deposition or spin coating. This liquid processing allows for faster manufacturing throughput, and is easily scalable. It is also much easier to achieve the high material purity required in the manufacture of solar cells. As a result, perovskite cells have the potential to be much cheaper than conventional silicon cells. In comparison, silicon solar cells have many different steps in their manufacture using high temperature processes on a very delicate and small substrate.

> *“perovskite solar material could be applied to windows or skylights for building integrated solutions”*

Because the active materials in a perovskite cell are liquid, they have the potential to be applied to surfaces in more convenient ways, such as painting or spraying. It also means a greater variety of substrate to which they can be applied, including curved surfaces. Researchers have suggested applications such as coating electric cars and roof tiles and with perovskite solar material, however these applications face different problems concerned with their implementation, such as installation and BOS costs; combined with low yields due to suboptimal orientation.

Another attractive quality of perovskite solar cells is that there is the possibility that they can be designed to be transparent. This means that a perovskite solar material could be applied to windows or skylights for building integrated solutions. They could also be used in tandem with a traditional solar module to further increase the efficiency. This is one of the more promising applications of perovskite solar cell research. A transparent perovskite cell can be simply stacked on top of a silicon solar cell, or a new device entirely can be manufactured which combines the silicon cell and perovskite cell. The perovskite solar cell can absorb the high energy photons and generate electricity, and then the photons pass through the perovskite solar cell, where they can be absorbed by the silicon solar cell. (See figure 3).

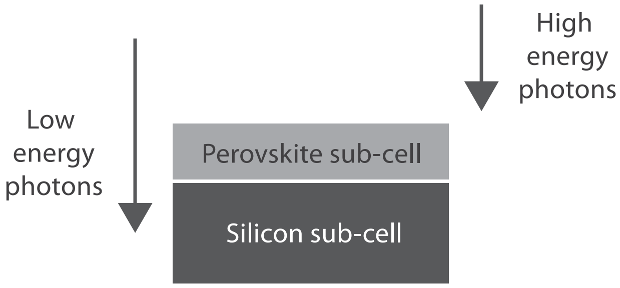

Figure 3 - The perovskite and silicon solar cells can be stacked in tandem.

Unfortunately, research has not yet been able to produce a perovskite solar cell that is stable enough to be used in the field. Current cells degrade quickly when they come into contact with moisture and oxygen. In this respect silicon is superior, being stable over long periods of time. Addressing this issue is currently the focus of much of the research in perovskite solar cells.

The other issue that people have identified with current perovskite solar cells is that they include lead in their composition. Lead is a toxic heavy metal, and so there are concerns regarding its use. Other materials (such as tin) have also been used; however these reduce the efficiency of the perovskite cell.

How could perovskites change the future of solar energy?

Perovskite solar cells have the potential to give the solar industry access to a lower-cost and higher efficiency standard of solar cell; especially with the prospect of tandem perovskite/silicon cells. It is important to note however that system costs are made up of many more factors rather than just equipment costs. Labour and balance of system costs are significant contributors to total installation cost. At a residential level therefore, having cheaper modules may not decrease the system cost significantly, as labour and balance of system costs will continue to dominate these system costs. However having higher efficiency modules in utility scale applications reduces the total amount of modules needed, and therefore reduces the amount of labour (and therefore cost) significantly.

Until perovskite solar cells become a stable contender, silicon solar cells will remain the market leader in PV systems; they have been designed to handle most environmental conditions, can last for over two decades and produce energy at a cost below grid parity. For now, perovskite remains an exciting prospect for the PV industry; however until the technology can weather environmental conditions and remove the need for lead, silicon will continue to dominate.

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