ARE THIN FILM SOLAR CELLS THE SOLUTION FOR ENERGY CRISIS?

W. G. Chaturanga Kumarage
Board of Study in Chemical Sciences

Most of the energy we use comes from fossil fuels, such as coal, natural gas and crude oil which were created several hundreds of millions years by decaying plants and animals under high pressure and temperature at the earth crust. Consequently, these are called as non- renewable energy sources. As a result of rapid usage of these non-renewable energy sources, the world is suffering from impending death of fossil fuels and serious pollution by releasing carbon monoxide and sulfur dioxide due to the combustion of fossil fuels, which may result in acid rain and global warming. On the other hand, increasing energy demand has made a new crisis for scientists and researchers all over the world. As the report by the World Energy Out Look 2014 says "Global energy demand is set to grow by 37% by 2040", scientists have to find alternatives which are renewable, non-polluting, green and silent for the future energy demand. There are several alternative renewable energy sources such as hydro power, wind power, bio mass, geo thermal power and solar cells. Harvesting energy from the sun is more fascinating due to low cost, reliability, durability and stability.

The best possible answer to harvest solar energy is the SOLAR CELL. Solar cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. There are several types of solar cells called, multi-junction cells, single junction cells, crystalline Si cells, thin film cells. With the discovery of Silicon solar cell in 1954, research on solar cells has becoming attention-grabbing topic between scientists and researchers, more over among business holders. Consequently, the science and technology of solar cells (PV devices) and systems have undergone revolutionary developments from 1954. Today, the best single crystal Silicon solar cells have reached an efficiency of 24.7%, compared with the theoretical maximum value of 30% which are already in the market [1]. In 2014 the world has come to a remarkable mile-stone due to the cooperate work of Soitec and CEA-Leti, France, together with the Fraunhofer Institute for Solar Energy Systems ISE, Germany, by introducing a multi-junction solar cell; which converts 46% of the solar light into electrical energy in direct conversion of sunlight into electricity in the laboratory level [2]. But the problem of high cost involved with Silicon solar cells and multi-junction solar cells was recognized right from the beginning. So the next problem that has to be answered by the researchers is how to introduce low cost solar cells. It has also been recognized that cheaper solar cells can be produced only if cheaper, more delicate materials and lower cost technologies are utilized. The best possible answer given by scientists, researchers and engineers is thin film solar cells. For this answer not only low cost, there are several facts that have contributed such;

(1) Small thickness required due to high absorption, small diffusion length & high recombination velocity
(2) Materials economy, very low weight per unit power
(3) Various simple & sophisticated deposition techniques
(4) A variety of structures available : amorphous, ploycrystalline, epitaxial
(5) Different types of junctions possible –homo, hetero, Schottky
(6) Tandem and multi junction cells possible
(7) In-situ cell integration to form modules

Thin film photovoltaic devices take advantage of absorption of IR-VIS-IR light by semiconductors and convert light to power. Thin film technologies have a common device structure: *substrate, base electrode, absorber, depletion layer, top electrode, patterning steps for monolithic integration and encapsulation* but in a reverse order. Thin film CIGS (Copper Indium Gallium Selenide solar cells), cells and modules are 21.7% and 15.7% [3, 4] efficient and CdTe cells and modules are 20.4 % and 17% [5, 6] efficient. CdTe and CIGS PV modules have the potential to reach cost effective PV-generated electricity. They have slowly transitioned from the laboratory to the market place over the last decade.

The most nominated heterojunction structure of CdS/CdTe cells is with n-type cadmium sulfide (CdS) as a transparent window layer, and are generally fabricated in a superstrate configuration (Figure 1). This structure generally consists with the lattice mismatch of above 10% between CdTe and CdS. The formed heterojunction has an excellent electrical behaviour, leading to a high fill factor of 0.77 in produced solar cells [7]. Therefore, this structure is favoured by a variety of world-leading corporate. Recently, First Solar has launched one project to double its manufacturing capacity of CdS/CdTe solar cells from 1.5 GW at the beginning of 2011 to nearly 3 GW by the end of 2012 [8].

Currently, there are several challenges for the further development of CdS/ CdTe thin-film solar cells:

(1) Short minority carrier lifetime due to the recombination of electron-hole pairs at the defect centres in CdTe layers and at the interface between CdS and CdTe.
(2) Insufficient transparency of transparent conductive oxide (TCO) and CdS window layers.
(3) Lack of good ohmic contact between CdTe layers and back contacts.
(4) Possibility in doping p-type CdTe films in a stable way.

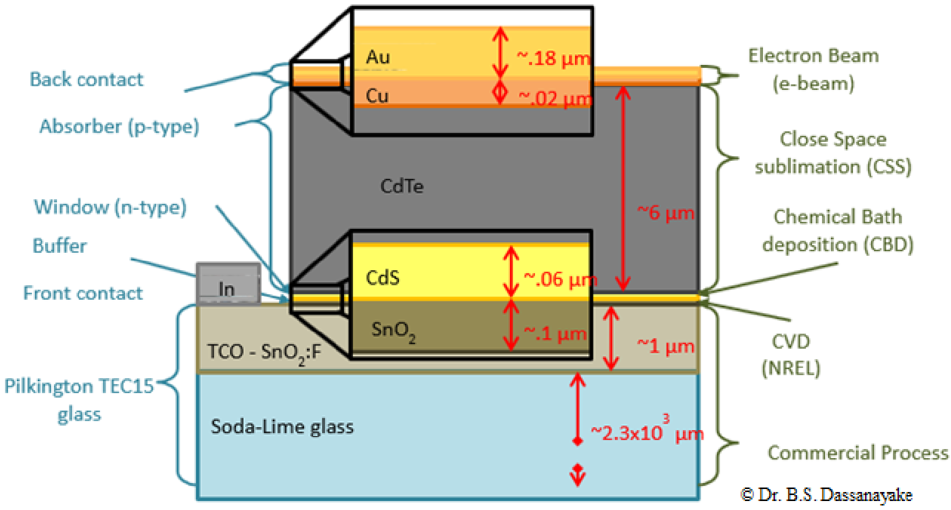

Figure 2: CdS/CdTe inorganic solar cell structure

The first three problems can be addressed with fabrication technology, structural design, and choice of back contact, respectively. Consequently, numerous ways have been employed to synthesize group II-VI thin films by various researchers in order to address the above aspects: Radio frequency sputtering (R. F. Sputtering), close-spaced sublimation (CSS), and chemical bath deposition (CBD) for CdS preparation, while electrodeposition (ED), screen printing (SP), and CSS for CdTe thin-film formation [9].

The second methodology to improve efficiency is the modification on the structure of CdS/CdTe solar cells. In here there are two methods: nanostructure and tandem cells. Nanostructures are considered to be the most encouraging method to achieve high efficiency and low cost from structural phase [10]. By substituting a nanopillar instead of a planar CdS layer, this provides excellent transparency of CdS layer, if the size of nanopillars is much smaller than the wavelength of visible light. Looking the other way, light absorption is boosted simultaneously due to the quantum confinement effect. In addition, this approach also offers more flexibility, since the optical gap can be altered by size variation of nanopillars. The other popular structural explanation to increasing efficiency is tandem cells. Tandem solar cells can either be individual cells or connected in series. Series connected cells are simpler to fabricate, but the current is the same through each cell so this constrains the band gaps that can be used [11]. Tandem solar cells can be illuminated from both sides and more importantly, long-term stability can be improved.

The third aspect is to find a perfect back contact. Since, p-type CdTe has high electron affinity, the Fermi level pinning would be formed between the absorption layer and the metal layer. Consequently, a reverse-biased potential would be formed at the CdTe-metal interface to limit the holes' transport and would enormously reduce the cells' efficiency. Hence, an ohmic contact is essential. So several techniques have been discovered to suppress the large Schottky barrier and reduce the contact resistance at the CdTe-metal interface. One interesting attempt was ZnTe as a buffer layer between the CdTe layer and the Cu and Au back contact as in Figure 1.

According to the discussion made here, it is still believed that CdS/CdTe solar cell will be a crucial runner for global low-cost solar cells market in future as the best answer for the world energy crisis. By understanding this crisis and the imperativeness of the thin film solar cell, Department of Physics, University of Peradeniya has started working on low cost thin film solar cells specially focusing on extremely vigorous CdS/ CdTe systems with tremendous potential expertise in the field and working closely with University of Illinois at Chicago and Sivanathan laboratories at USA.

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