Chapter 72
CuInGaSe Based Thin Films for Photovoltaic Solar Cells

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ABSTRACT

The authors present a brief overview of thin film photovoltaics, focusing on technologies that could play an important role in the manufacturing of next generation of solar cells. Over the past decade, there have been tremendous research and development efforts worldwide, to address the issues and challenges that thin film photovoltaic technologies are facing. Recently however, there has been great hope that advances in nanotechnology may open the door for breakthroughs in photovoltaics research. In particular, significant opportunities exist in the area of nanostructured materials, fueled by recent advances in equipment and processes that allow manipulation of materials at the atomic and molecular level, thus facilitating precise fabrication techniques and device characterization at the nanometer scale.

This chapter mainly focuses on two promising technologies, Copper Indium Gallium Selenide (CIGS) and nanocrystalline silicon solar cells. Heterojunctions based on CIGS have been studied for several years, and have shown very stable performance in field tests.

INTRODUCTION

We'll discuss various preparation methods for CIGS solar cells, the effects of composition ratio on the performance, doping profiles, alternative buffer layers, low cost fabrication techniques as well as global market trends. We will also investigate incorporation of nanoparticles such as quantum dots and quantum wires, and material growth on flexible substrates. Nanocrystalline silicon films have also recently attracted attention for use in photovoltaic solar cells as they provide an approach which results in lower cost and higher efficiency than conventional solar cells. Furthermore, silicon based nanoparticles or superlattices may be integrated with other materials for bandgap-engineered devices. Designed appropriately, variation of the effective bandgap

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across the device allows a larger portion of the solar spectrum to be coupled into the solar cell increasing the conversion efficiency.

Non-vacuum methods for absorber deposition promise significantly lower capital expenses and reduced materials costs, and have been used to produce devices with efficiencies of up to 14%. Such efficiencies are already high enough for commercial up-scaling to be considered and several companies are now trying to develop products based on non-vacuum deposited CIGS absorbers.

The goal of the US Department of Energy (DOE) through its SunShot Initiative is to reduce the cost of solar energy systems to reach grid parity. The $300 million over the next five years, Photovoltaic Manufacturing Consortium (PVMC) initiative awarded to the College of Nanoscale Science and Engineering (CNSE) and to International SEMATCH from DOE will be presented. The PVMC is primarily focused on CIGS thin film technology. The goals of the PVMC is to promote supply chain collaboration in the US, advance large-scale solar manufacturing, boost American competitiveness, reduce cost, and drive the deployment of solar energy. Currently the cost of CIGS thin film based panels is at $1.10/Watt.

As the demand for sustainable and environmentally friendly energy sources continues to increase, there exists an urgent need to develop materials, products, and processes that will make these sustainable energy conversion technologies more efficient and economically attractive. Solar energy conversion, and in particular photovoltaics, is in the forefront of the sustainable technologies holding promise to provide a clean, inexhaustible source for the production of electric power. Although the increasing demand for clean energy has motivated a record expansion of photovoltaic facilities worldwide in recent years, to date this technology represents only a fraction of a percent of the total electricity production. Tremendous opportunities exist for the technology to become much more pervasive, provided that there will be advances in areas such as cost reduction in the materials and installation, development of solar cells with increased quantum efficiency, and expanded application space, such as for example, flexible modules, building integrated photovoltaics, lightweight modules for portable applications, etc.

According to European PV Industry Association, while the European Union has dominated the world market for years, the rest of the world has clearly the biggest potential for growth. In 2010, the EU was the world's largest PV market. With more than 13 GW installed in 2010, its total installed PV capacity surged from 16 to almost 30 GW. PV makes economic as well as environmental sense and is a sustainable solution to the energy needs of countries around the Equator. Driven by local and global energy demand, the fastest PV growth is expected to continue in China and India, followed by South-East Asia, and Latin America. The PV potential of the Sunbelt countries could range from 60 to 250 GW by 2020, and from 260 to 1,100 GW in 2030, representing 27% to 58% of the forecast global installed PV capacity by then (European PV Industry Association, 2011). The rest of the world accounts for a 3 GW market for PV. Japan and the USA approached the GW mark in 2010 and are expected to continue growing in 2011.

The vast majority of commercially available photovoltaic solar cells and modules are made of silicon, in its various forms (Ullal, 2007). Typically, either single-crystalline, or polycrystalline, or amorphous silicon are used in the fabrication of solar panels both for residential and large scale commercial photovoltaic systems. Each of these technologies offers a well-established price to performance ratio and specific cost and benefit advantages depending on the particular application, location, available area, aesthetics, etc. However they are all "first generation" technologies suffering from performance limitations due to the properties of the bulk silicon material used. Some improvements in the performance have been achieved with optimization in the solar cell design such as the SANYO Heterojunction