Chapter 1
New Trends in Solar Cells

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ABSTRACT

Photovoltaic (PV) power generation technology is one of the most promising renewable energy technologies because of the possibility of solving environmental problems and limited sources of energy. In order to realize widespread deployment of solar photovoltaics and contribute to further development in civilization, further development in the science and technology of PV is very important. That is, further improvements in conversion efficiencies and reliability and lowering the cost of solar cells and modules are necessary. Regarding conversion efficiencies of solar cells, because there is the Shockley–Queisser conversion efficiency limit of 31% at 1-sun and 41% under concentration for single bandgap solar cells, several approaches to overcome the Shockley–Queisser limit should be made. This book will provide readers some guidance to overcome the limit. This chapter presents the current status of solar cells and new trends in solar cells from the viewpoint of conversion efficiency.

INTRODUCTION

Photovoltaics (PV) is the technology that generates electrical power from mainly semiconductors, recently from organic and other materials, when they are illuminated by photons. PV power generation technology is one of the most promising renewable energy technologies because of possibility of solving environmental problems and limited sources for energy. Table 1 shows sustainable potentials of renewable energy sources presented by N. S. Lewis (2005). From the 1.2×10^5 TW (the Solar constant is 1.76×10^5 TW) of solar energy that strikes the earth's surface, a practical sitting-constrained terrestrial global solar power potential value is about 600 TW. Thus, for a 10% efficient solar farm, at least 60 TW of power could be supplied from terrestrial solar energy resources. Therefore, solar energy is the only renewable energy resource that has enough terrestrial energy potential to satisfy a 20 TW or more carbon-free supply.

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According to the world energy vision 2100 recommended by WBGU (German Advisory Council on Global Change) (WBGU, 2003) as shown in Figure 1, solar electricity, including PV, is expected to become a major energy source with a share of about 20% in 2050 and about 70% in the total energy of the world in 2100. Thus becoming the major energy resource in the world because of its resource potential and clean energy. That means PV will play an important role in contributing to solving global environmental problems as the major energy resource in the world. In order to realize such a vision, further development in science and technology of PV is very important. That is, further improvements in conversion efficiencies and reliability, and lowering cost of solar cells and modules are necessary. Regarding conversion efficiencies of solar cells, because there is the Shockley-Queisser conversion efficiency limit (Shockley & Queisser, 1961) of 31% at 1-sun and 41% under concentration for single bandgap solar cells, several approaches to overcome the Shockley-Queisser limit should be made. This book will provide readers some guidance to overcome the limit.

This chapter presents the current status of solar cells and new trends in solar cells from the viewpoint of conversion efficiency.

CURRENT STATUS OF VARIOUS SOLAR CELLS

Dissemination of PV systems has been advanced and solar cell module productions have also been significantly increased in the world as a result of R&D and national government and regional government programs. Such a rapid growth in PV system installation in the world needs production of large-scale PV systems. That means necessity for development of higher efficiency and lower cost solar cell modules. Table 2 shows characteristics of various types of solar cells developed for terrestrial applications. Although crystalline Si solar cells are mainly used for terrestrial power applications, various types of solar cells are studied and developed. This section presents the current status of various types of solar cells.

Table 1. Sustainable potentials of renewable energy sources (Lewis, 2005)

Renewable Energies	Theoretical Potential (TW)	Technically Feasible Potential (TW)	Economically Feasible Potential (TW)
Hydro Electric	4.6	1.5	0.9
Geothermal	30	11.6	
Ocean Energy	2.7		
Wind	50		2
Biomass	20	5-7	3
Solar Photo-voltaics	$1.2x10^5$	600	60

Crystalline Si Solar Cells

Even crystalline Si solar cells, solar cells are very sensitive to defects, impurities, surface, and interface in solar cell materials. Figure 2 shows calculated results for changes in conversion efficiencies of single crystal Si solar cells as a function of minority-carrier lifetime and surface recombination velocity. Key issues for achieving higher efficiencies are reduction in bulk recombination loss, reduction in carrier recombination loss at surface and interface, passivation of crystalline grain boundary, and defects in grains, gettering of heavy metal impurities, reduction in optical reflection loss at surface, reduction in series resistance and parallel resistance, carrier confinement, and photon confinement. R&D trends in the field of crystalline Si solar cells and materials are rear surface junction, hetero junction structures, thinner Si wafer, effective utilization of low-grade Si such as Solar Grade (SOG)-Si and Metallurgical Grade (MG)-Si.