Silicon
https://doi.org/10.1007/s12633-021-01032-4

REVIEW PAPER

From Crystalline to Low-cost Silicon-based Solar Cells: a Review

M. Okil[1] · M. S. Salem[2,3] · Tarek M. Abdolkader[1] · A. Shaker[4]

Received: 8 December 2020 / Revised: 18 February 2021 / Accepted: 22 February 2021

Abstract

Renewable energy has become an auspicious alternative to fossil fuel resources due to its sustainability and renewability. In this respect, Photovoltaics (PV) technology is one of the essential technologies. Today, more than 90 % of the global PV market relies on crystalline silicon (c-Si)-based solar cells. This article reviews the dynamic field of Si-based solar cells from high-cost crystalline to low-cost cells and investigates how to preserve high possible efficiencies while decreasing the cost. First, we discuss the various types of c-Si solar cells with different device architectures and report recent developments. Next, thin-film solar cells with their recent advancements are given. Then, Si nanowires solar cells and their recent results are discussed. Finally, we present the most encouraging tendencies in achieving low-cost solar cells utilizing cheap materials like heavily doped silicon wafers.

Keywords Crystalline silicon · Thin films · Nanowires · Npn microstructure · Low-cost high efficiency

1 Introduction

Solar energy has become a viable alternative to traditional energy resources due to its sustainability and renewability [1]. Photovoltaics technology converts solar energy directly into electricity. It is one of the essential technologies used in this field [2].

Silicon solar cells are the most recognized solar cell technology and are projected to overshadow the market as more than 90 % of the global PV market relies on c-Si based solar cells [3]. Compared to other PV existing materials, c-Si is among the most suitable candidates for solar cell construction due to its natural abundance, good stability, non-toxicity, and cost competitiveness [4]. Its indirect bandgap is 1.12 eV, which is well fitted to the solar spectrum as it corresponds to the cut-off wavelength of light absorption, which is approximately 1160 nm. Also, it is closer to the optimum value for converting solar energy into electrical energy utilizing a single light absorber. On the other side, it has a relatively small absorption coefficient near the infrared region. But with appropriate light control design, such as surface texture, antireflective coatings, and rear surface mirrors, effective light absorption is achieved with relatively thin wafers (down to 100 μm, whereas the typical thickness is presently 180 μm).

Due to Silicon indirect bandgap, the radiative recombination is weak, which implies that photo-generated carriers will have relatively long lifetimes. Consequently, the primary recombination process in silicon is Auger recombination which is a nonradiative process. The previous argument is theoretically valid; however, in practice, the presence of impurities or crystallographic defects can influence or even dominate silicon carrier recombination. Recently, the electronic quality of c-Si wafers has enhanced to such an extent that the developments in solar cells currently depend primarily on enhancements in contacting systems and surface passivation. Passivation is used to eliminate the generated carriers' recombination on the silicon surface. Effectual surface passivation is generally accomplished by dielectric materials like aluminum oxide, silicon nitride, silicon carbide, hydrogenated amorphous silicon and silicon oxide [5].

c-Si solar cells are configured based on either mono or multi-crystalline Si wafers. The casting process is the most widely used method for preparing multi-crystalline silicon (mc-Si) blocks. The Si feedstock is firstly melted, then cast into molds, and solidified into blocks. Although mc-Si has a lower price compared to mono-

✉ A. Shaker
ahmed.shaker@eng.asu.edu.eg

1 Department of Basic Engineering Sciences, Benha Faculty of Engineering, Benha University, Benha, Egypt

2 Department of Computer Engineering, College of Computer Science and Engineering, University of Ha'il, Ha'il, Saudi Arabia

3 Department of Electrical Communication and Electronics Systems Engineering, Faculty of Engineering, Modern Science and Arts (MSA) University, Cairo, Egypt

4 Department of Engineering Physics and Mathematics, Faculty of Engineering, Ain Shams University, Cairo, Egypt

Published online: 06 March 2021