Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 57 (2014) 47 – 55

Energy Procedia

2013 ISES Solar World Congress

Influence of the aluminum paste surface density on the electrical parameters of silicon solar cells

Izete Zanesco*, Vanessa Alves Gonçalves, Adriano Moehlecke

Solar Energy Technology Nucleus (NT-Solar), Faculty of Physics, Pontifical Catholic University of Rio Grande do Sul (PUCRS), Av. Ipiranga, 6681, Prédio 96A, Porto Alegre – RS, CEP 90619-900, Brazil

Abstract

The industrial process of silicon solar cells is mainly based on the aluminum back surface field (Al-BSF) performed by the conventional screen printing and firing in a belt furnace. The goal of this paper is to present the analysis of the influence of the amount of the Al paste on the electrical parameters and on the minority carrier diffusion length. The silicon solar cells were processed in p-type Czochralski solar grade wafers. The amount of Al paste deposited to form the BSF, denominated of Al paste surface density, was ranged from 2.8 mg/cm^2 to 8.8 mg/cm^2. The peak firing temperature for each amount of Al paste was optimized and the depth of the Al-BSF was estimated. The best results were found for the Al paste surface density of 3.5 mg/cm^2 and the peak firing temperature of 840 °C, resulting in the efficiency of the solar cells of (15.0 ± 0.1) %. In this case, the depth of the Al-BSF was (5 ± 1) µm. Taking into account the peak firing temperature obtained for each Al paste surface density, we observed that the short-circuit current increased up to the average Al paste amount of 3.5 mg/cm^2. On the other hand, the fill factor decreased with the increasing of the Al paste surface density. The open circuit voltage was slightly affected by the Al paste amount. The minority carrier lifetime rose from 30 µs to 120 µs after the phosphorus diffusion. A strong improvement in the minority carrier diffusion length was observed after the firing process and depends on the Al paste amount. The measured average values were 500 µm, 1280 µm and 780 µm for the Al paste surface density of about 2.8 mg/cm^2, 3.5 mg/cm^2 and 8.8 mg/cm^2, respectively.

Keywords: Silicon solar cells; Al-BSF; Al paste surface density

* Corresponding author. Tel.: +55 51 33203682; Fax: + 55 51 33203616.
E-mail address: izete@pucrs.br.

doi:10.1016/j.egypro.2014.10.007

1. Introduction

The main industrial technology to fabricate silicon solar cells is based on the aluminum back surface field (Al-BSF) performed by the conventional screen printing metallization. The aluminum paste is deposited on the rear face of the p-type Czochralski (Cz-Si) wafers and fired in a belt furnace.

The formation of full-area screen-printed Al-BSF and its effect on the efficiency of the solar cell had been studied. During the firing process, Si diffuses into the Al, with Al then diffusing into the Si [1]. Aluminum spikes are formed in the Si surface. These spikes expand parallel to the silicon surface and join to each other. During cooling, the Al spikes retract and form the Al-BSF [1]. In this process, agglomerations can be formed, leading to a laterally inhomogeneous Si recrystallization and resulting in no homogeneous Al-BSF that reduces the solar cell efficiency [2].

If the firing peak temperature or time of the peak temperature is higher than a critical value, the p^+ region can present thickness variations. This critical temperature is lower for thicker Al layers [3]. Results obtained from float-zone silicon wafers demonstrated that for high peak temperature times more Si dissolves into the molten Al-Si and more Si recrystallizes during the cooling [2]. In a given agglomeration, the thicknesses can range from 15 μm to 40 μm and this variation may be related to large pyramids with height up to 20 μm. Near the agglomeration, the thickness can be lower than 2 μm, where almost no Al-Si eutectic layer was formed, indicating that Al-BSF was no homogeneous. The increasing of the Al paste amount or the decreasing of the peak temperature improves the uniformity in Al-BSF thickness [2].

The formation of the Al-BSF using Al paste deposited by the screen printing technique can produce gettering and improve the minority carrier lifetime. The gettering process is helpful mainly in low quality material as solar grade silicon because reduces the concentration of metal impurities such as iron, copper, nickel and other metals. These impurities act as recombination centers, reducing the minority carrier diffusion length and, consequently, the solar cell efficiency. The Al gettering depends on the segregation coefficient of the metal impurities, the impurity concentration of the Al layer, the impurity concentration in the silicon wafer, the thickness of the Al-Si eutectic layer as well as the firing temperature and time [4]. Results obtained by simulation showed that the thickness of the Al layer is a less important parameter [4].

Silicon solar cells fabricated in Si-Cz wafers with homogeneous high sheet resistance phosphorus emitter (85 Ω/□ – 95 Ω/□) and Al-BSF performed with Al paste fired in a belt furnace achieved the 18.3 % efficiency [5]. Emitter sheet resistance in the range from 65 Ω/□ to 105 Ω/□ was contacted with low average series resistance, resulting in fill factors of 0.789 to 0.768, respectively.

Solar cell processed in FZ-Si wafers with Al-BSF, laser-doped selective emitter and screen-printed metallization reached the efficiency of 19.6 %. When the front contact was formed by light-induced nickel and silver plating, the efficiency obtained was 20.1 %. This cell was modeled with the PC-1D computer program and the minority carrier length of 1150 μm was set [6].

The efficiency in industrial production is lower. Commercial c-Si solar cells, p-type and n-type, have efficiencies in the range from 15 % to 22 % [7]. The high efficiency solar cells, called IBC (interdigitated back contact) and HIT (heterojunction with intrinsic thin layer) were developed by SunPower Corp. and Sanyo, respectively. The average efficiency is around 16.5 % in p-type Cz-Si solar cells with Al-BSF, with the throughput of the lines in between 750 to 2400 pieces per hour [8].

Taking into account that the amount of Al paste and the firing temperature affect the Al-BSF and, consequently, the efficiency of the solar cell, the goal of this paper is to present the analysis of the influence of the amount of the Al paste on the electrical parameters and on the minority carrier diffusion length of the solar cells processed in solar grade Si-Cz wafers by using a typical industrial process.