Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 77 (2015) 271 – 278

Energy Procedia

5th International Conference on Silicon Photovoltaics, SiliconPV 2015

All-screen-printed dopant paste interdigitated back contact solar cell

Giuseppe Scardera, Daniel Inns, Gonghou Wang, Shannon Dugan, Jeffrey Dee, Thomas Dang, Karim Bendimerad, Francesco Lemmi, and Homer Antoniadis

DuPont Silicon Valley Technology Center, 965 E Arques Ave, Sunnyvale, California 94085, USA

Abstract

We report results on the development of a cost-effective all-screen-printed interdigitated back contact (IBC) solar cell process. The rear side interdigitated doping pattern is achieved using screen printed n-type and p-type dopant pastes, and thermal drive-in. Our process provides excellent spatial definition of the doping pattern necessary for fabrication of an IBC solar cell. The doping approach used in this work overcomes limitations associated with conventional pastes, notably poor lateral doping control and reduced bulk lifetime. We demonstrate that wafer lifetime remains high, well above 1.5 msec, at the end of the solar cell process, enabling high cell efficiencies. Contacts are also achieved using screen printed fire-through metal pastes. We present pilot line data for n-type CZ silicon, 156 mm pseudo-square cells achieving just over 21% efficiency.

Peer review by the scientific conference committee of SiliconPV 2015 under responsibility of PSE AG

Keywords: IBC solar cell; dopant pastes; screen printing;

1. Introduction

IBC solar cells are capable of achieving high efficiency. The concept of the IBC solar cell was first proposed by Lammert and Schwartz in the 1970's [1] and while such cells are being produced commercially [2], wide adoption of this cell structure in the solar industry is hampered by its complexity and high cost. Part of the complexity, in particular, comes from the need to create interdigitated doping patterns on the rear side of the cell, which typically requires multiple additional processing steps compared to standard cells. A number of approaches aimed at reducing the cost of manufacturing an IBC cell have been in development for a number of years, such as ion-implantation [3] or processes using furnace phosphorous and boron diffusions [4].

In this paper, we present an alternative approach which involves using screen printable dopant pastes to create interdigitated doping patterns on the rear side of the cell. In this approach the boron emitter and the phosphorus back surface field (BSF) are created using screen printed boron and phosphorus dopant pastes, respectively. The

Peer review by the scientific conference committee of SiliconPV 2015 under responsibility of PSE AG
doi:10.1016/j.egypro.2015.07.038

phosphorus front surface field (FSF) is created using conventional $POCl_3$ diffusion. This approach is especially attractive due to the simplicity of screen printing, which is already a well-established process in the solar cell industry. Conventional dopant pastes typically suffer from “auto-doping” (i.e. unintentional surface doping outside the paste area) and metal impurity contamination that hurts minority carrier lifetime. Our materials and process are capable of providing interdigitated p and n doping patterns with fine spatial resolution as well as the high bulk lifetimes that are necessary for fabrication of high efficiency IBC cells.

1.1. Conventional dopant paste challenges

Achieving patterned and localized doping using conventional dopant pastes is difficult due to the tendency of such pastes to outgas during the thermal treatments required to drive dopants into the underlying silicon wafer. At typical drive-in temperatures (above 800C) gaseous dopant species are released from the paste regions and are transferred onto non-paste regions as well as onto neighboring wafers. We refer to this effect as auto-doping. Gas phase distribution and auto-doping from phosphorus dopant pastes has been well documented [5-7].

We experienced similar auto-doping challenges with our first attempt at making boron dopant paste as highlighted in Fig. 1. The schematic in Fig. 1 (a) shows gas phase doping from printed paste regions during a quartz tube furnace drive-in. Airborne species from the printed regions are able to reach the non-printed regions of the wafer as well as across to the neighboring wafer. To demonstrate this problem we printed an H-bar test pattern of our first generation boron paste onto a high resistivity (10,000 Ohm-cm) polished wafer and loaded it into the furnace with a bare polished wafer facing it during the thermal drive-in step. The post-drive-in photos in Fig. 1(b) show that the H-bar pattern is no longer distinguishable on the printed wafer (left) and that a brown film has formed on the neighboring wafer (right). Fourier transform infrared (FTIR) spectra were measured at the center of both wafers and are shown in Fig. 1(c). Borosilicate glass (BSG) spectra are clearly observed on both wafers.

Another major challenge for using conventional dopant paste for IBC solar cells is their negative impact on wafer lifetime. It is likely that high impurity levels in the pastes inevitably degrade wafer lifetime during the high temperature treatment required to drive dopants into the wafer. Lifetime degradation of n-type wafers has been reported for both phosphorus and boron dopant pastes with severe degradation reported for boron paste [7]. Studies have also shown that conventional screen-printed phosphorus dopant pastes create more micro-defects in c-Si wafers compared to conventional doping techniques like $POCl_3$ [8].

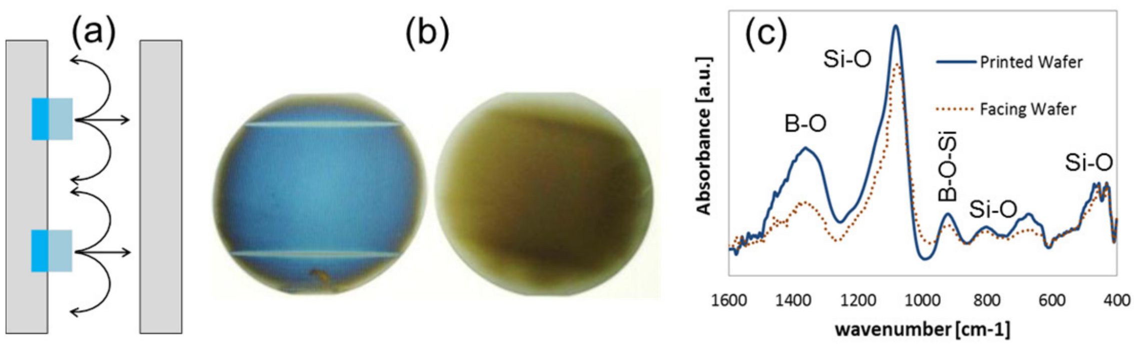

Fig. 1. (a) Schematic of a wafer with a dopant paste pattern facing a bare wafer during thermal drive-in; (b) photos of a boron pate H-pattern printed wafer and its neighboring bare wafer after thermal drive-in; (c) FTIR spectra from the wafers shown in (b) indicating BSG formation on both wafers.