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High-quality p-type emitter using boron aluminum source for n-type TOPCon solar cells

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ABSTRACT

In the current landscape of n-type Tunnel Oxide Passivated Contact (TOPCon) solar cell production, challenges persist with conventional gas boron sources used for the fabrication of p-type emitters, including their influence on emitter recombination and metal-semiconductor contact recombination. This research introduces a novel approach involving the diffusion of a boron-aluminum source via spin-coating, proposed as a replacement for the conventional gas boron source. This method facilitates a higher quality p-type emitter, at drive-in temperature of 900 °C and 30 min. The surface doping concentration of the p-type layer reached 3.18×10^{19} cm^{-3}, with a peak doping concentration of 5.36×10^{19} cm^{-3}. Studies show that the p-type emitter prepared with boron-aluminum source can reduce metal-semiconductor contact recombination and Auger recombination, due to its high surface doping concentration and shallow junction depth. Moreover, the overall process temperature for preparing p-type emitters with the boron-aluminum source is low, and the duration is short, which is advantageous for reducing energy consumption. Additionally, Quokka3 simulation results show that the efficiency of TOPCon solar cells prepared with the boron-aluminum source is 0.43 % higher than that of TOPCon cells prepared with the gaseous boron source.

1. Introduction

Since the advent of solar cells, a variety of cell structures have been introduced. Crystalline silicon-based solar cells have predominantly gained substantial traction in the photovoltaic industry due to their abundant raw materials, ease of manufacturing, and cost-effective maintenance [1,2]. Among the plethora of crystalline silicon-based cell structures, TOPCon solar cells have garnered considerable interest due to their streamlined processing and potential for high efficiency. TOPCon solar cells are characterized by a back surface passivation with a thin layer of silicon oxide and a polycrystalline silicon structure, offering superior rear-side passivated contact and a theoretical efficiency of up to 28.7 % [3,4]. When TOPCon is combined with Interdigitated Back Contact (IBC) structures, the cell efficiency escalates to 26.1 % [5]. Furthermore, n-type TOPCon solar cells demonstrate high compatibility with existing PERC solar cell production lines, facilitating industrial upgrades and resulting in significant cost savings. Owing to these advantages, TOPCon solar cells have emerged as the archetype of the new generation of crystalline silicon solar cells [6–8].

At present, n-type silicon wafers serve as the primary substrates for TOPCon solar cells, with boron atom doping effectively applied to the surface of the silicon wafers to form a p^+ layer. The primary diffusion doping source has been shifted from gaseous BBr_3 to gaseous BCl_3. Although this substitution has led to certain improvements in emitter quality, the gaseous boron source diffusion process still faces several limitations, such as the need for high temperatures and extended diffusion times [9–11]. In response to these challenges, researchers have proposed a spin-coating boron source process for the preparation of the p-type layer, with doping sources encompassing boric acid liquid sources and solid sources of boron nitride [12]. Regardless of the technique used to prepare the boron emitter, the requirements for doping concentration remain consistent: Firstly, achieving a low emitter dark

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