

DIFFUSION PASTE DEVELOPMENT FOR PRINTABLE IBC AND BIFACIAL SILICON SOLAR CELLS

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ABSTRACT

Increasing cell efficiency and lowering the cost of solar cell manufacturing is a continuous challenge in solar cell industries. Higher efficiency concepts like interdigitated back contact (IBC), and bifacial cells, with using thinner silicon solar cells are ways to reduce the total solar cell manufacturing cost. Typically the high efficiency concepts require costly extra processing steps. Developing the proper paste for printing application of high efficiency concepts could make these designs cost effective and easily manufactured. These pastes can be printable in a continuous manner using processes like screen printing or ink jet printing. This paper describes newly developed low cost phosphorous, boron, and diffusion barrier pastes. It shows the characterization of the newly developed phosphorous paste (99-038), boron paste (99-033), and diffusion barrier paste (99-001). These low cost pastes can easily be printed and make high efficiency concept cell designs a low cost reality. Characteristic features of sheet resistance, junction depth and minority carrier lifetime is discussed.

INTRODUCTION

The cost of silicon wafers has been increasing in recent years. Silicon solar cell manufacturers are trying to reduce manufacturing cost by using thinner silicon wafers (less than 200 μm) and high efficiency solar cell concepts. A major problem with Silicon wafers below 200 μm is bowing after Al back surface field (BSF) formation. A printable boron paste that can form BSF at typical processing temperature is an ideal solution to wafer bowing. Boron paste makes it possible to use both p-type and n-type wafers in typical solar cell manufacturing. It also makes it possible to fabricate bifacial solar cell by simultaneous diffusion of phosphorous and boron paste in a single diffusion step. Other high efficiency concepts like interdigitated back contact (IBC) cells and emitter-wrap-through (EWT) cells need n^+ diffusion (phosphorous paste), p^+ diffusion (boron or Aluminum paste) and a diffusion barrier to isolate the n^+ regions from the p^+ regions during contact formation. Diffusion barrier paste can easily be applied as the mask to isolate n^+ areas from the p^+ areas. The combination of the phosphorous, boron and diffusion barrier paste developed by Ferro can pave the way for the next generation of low cost high efficiency solar cells.

EXPERIMENTAL

The phosphorous diffusion paste 99-038, Boron diffusion paste 99-033 and diffusion barrier paste 99-001 are developed and screen printed on 100 cm^2 CZ wafers to investigate diffusion properties. Polished CZ wafers with thickness of 300 μm and resistivity of 1 to 2 $\Omega\text{-cm}$ were used. All the pastes were screen-printed using a 200-mesh screen with emulsion thickness of 0.5 to 0.7 mils. Measured deposited weights are about 1 to 2 mg/cm^2 and all pastes were dried at 200° C for 2 to 5 minutes. All the pastes were fired at different temperatures in air ambient in an infrared belt furnace. The resulting emitters were characterized by four-point probe and depth profiles were measured using spreading resistance analysis. The minority carrier lifetime is measured using quasi-steady-state photoconductance (QSSPCD) measurement.

RESULTS

Phosphorous Paste

Figure 1 shows measured sheet resistance for phosphorous paste as a function of diffusion temperature for different phosphorous concentration at 10 inches per minute belt speed. Measured minority carrier lifetime was improved after diffusion from 10 μsec to 25 μsec .

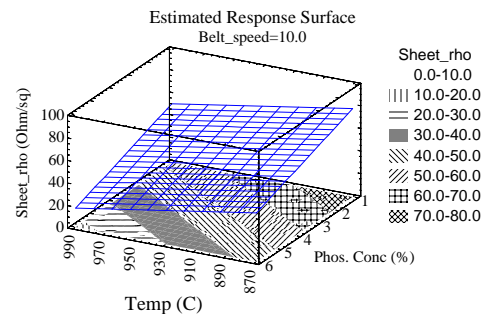


Fig. 1. Measured phosphorus sheet resistance as a function of phosphorus concentration and diffusion temperature.

Figure 2 shows the measured junction depth and surface concentration. Regions with higher phosphorous

concentration had emitter depth of 0.4 μm and surface concentration greater than 10^{20} cm^{-3} . Regions with lower phosphorous concentration show shallower emitter depth of 0.15 μm and surface concentration of 10^{19} cm^{-3} . This allows for selective emitter diffusion concept to be controlled by changing the phosphorous concentration and keeping the temperature constant.

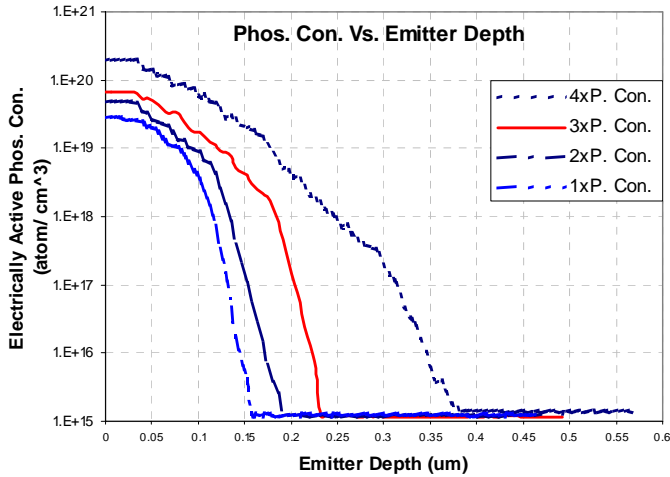


Fig. 2. Measured phosphorous concentration and emitter depth using spreading resistance technique.

Boron Paste

Figure 3 shows the measured sheet resistance and a linear model to describe the relationship between boron diffusion temperature and measured boron sheet resistance with 95% confidence limits.

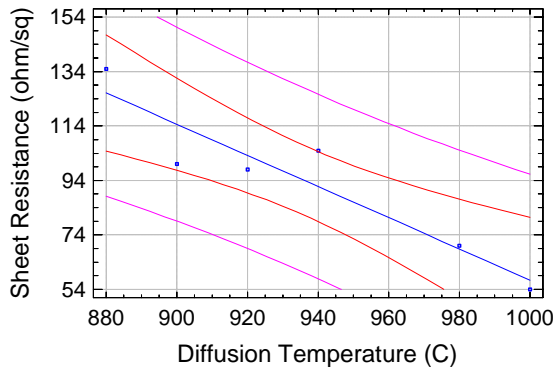


Fig. 3. Measured boron sheet resistance at different temperatures and a fitted linear model with 95% confidence limits.

Figure 4 shows the measured junction depth and surface concentration.

Boron diffusion will not cause any bowing for thin wafers and can be used for 150 μm thick wafers.

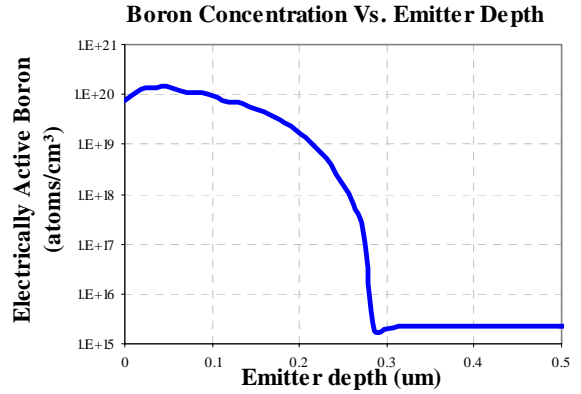


Figure 4. Measured boron concentration and emitter depth using spreading resistance technique.

Diffusion Barrier

99-001 developed diffusion barrier paste forms a TiO_2 layer after curing at 450 to 500°C. Silicon wafers were printed with diffusion barrier paste and after curing the diffusion barrier paste the wafers were screen printed with phosphorous paste. Then samples were heat treated at 980 °C for 5 minutes. Figure 5 shows measured spreading resistance after diffusion under the diffusion barrier layer. This shows that diffusion barrier 99-001 can easily be used to block phosphorous diffusion. 99-001 can make manufacturing of IBC type solar cells very simple.

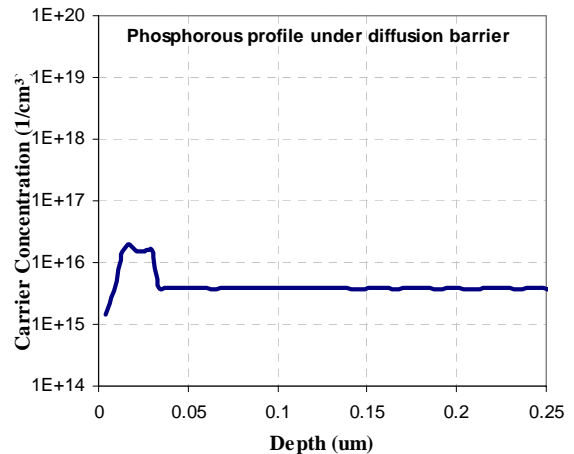


Fig. 5. Measured phosphorus concentration through diffusion barrier paste.

SUMMARY

Ferro has developed three diffusion related pastes; phosphorous paste 99-038, boron paste 99-033, and diffusion barrier paste 99-001. These new high quality diffusion pastes and diffusion barrier pastes can reduce manufacturing cost and make it possible to use less than 180 μm thick silicon wafers for selective emitter solar cells, IBC cells, emitter-wrap-through (EWT) cell design, and bifacial solar cell application.

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