

BCSC(Buired contact Solar cell)의 전극형성
Metallization of Buired contact Solar cell

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ABSTRACT

The metallization is the key to determining cell costs, cell performance, and cell and system reliability. The Buried Contact Solar Cell (BCSC) was specifically desinged to be compatible with low cost, mass production techniques and avoid the conventional metallization problem. By using electroless plating technique, we performed this metallization inexpensively and reliably. This paper presents the details of the optimization procedure of metallization schemes on laser grooved cell surfaces. Commercially available Ni, Cu and Ag plating solutions were applied for the cell metallization. The application of those solutions on the buried contact front metallization has resulted in an cell efficiency of 18.5%. The cell parameters are an open circuit voltage

of 651 mV, short circuit current density of 38.6 mA/cm², and fill factor of 73.5 %..

1. INTRODUCTION

The concept of the buried contact solar cell evolved initially as a screen-printing approach for overcoming many of the fundamental limitations associated with conventional screen-printed metallization schemes. In the case of printed contacts, expensive silver metal, poor metal aspect ratios, low conductivity of the screen-printed metals, the inability to produce fine lines and a relatively high contact resistance have placed severe limitations on the efficiencies achievable from conventional commercial approaches. The key feature of the buried contact solar cell which differentiates it from the conventioanl

screen printed technology is the front grid metallization unlike an screen printed technology. the buried contact front metallization allows for both low shading losses because of closely spaced, very fine metal lines and low series resistance losses due to the large cross sectional area of the metal in the grooves. In addition, the closely spaced metal fingers and low series resistance losses allow an highly doped emitter, providing excellent response to short wavelength of light. Another feature of the buried contact solar cell which allow high efficiency operation is the heavy groove diffusion. Following an economic evaluation of conductor layer metals for silicon solar cell metallization, base metal system utilizing copper, an inexpensive base metal, is a potential alternative to silver or solder. Copper, however diffuses rapidly into silicon at low temperatures, degrading solar cell properties[1]. Nickel is shown to be a suitable barrier to copper diffusion as well as a desirable contact metal to silicon[2]. Metallization of buried contacts can be achieved by a variety of methods such as aluminium sputtering, evaporation, screen-printing and plating. The significant benefits of plated contacts are low cost process, reduced material usage (metal is deposited only where required), their suitability to textured surface and independence of contact shape(metal is easily deposited in the groove).

Interest in electroless plating has continued unabated since its invention by Brenner and Riddell[3] in 1946. In

this work, the metallization is carried out by plating metal on the oxide free surfaces within the grooves by electroless chemical deposition and detailed discussion on the problem of metallization of BCSC cells and its solution. The metals are nickel, copper and silver[4].

2. EXPERIMENTAL PROCEDURE

Float zone wafers of $0.5\Omega\text{cm}$ and $500\mu\text{m}$ thickness were used as substrates. The reflection losses of the buried contact technology are adequately minimised by chemically texturing the top surface in the 2% NaOH solution. Emitter diffusion was carried out on the diffusion furnace by using phosphorus pentoxide. For antireflection control high quality surface passivation as well as good metal contact passivation the textured surface was oxidized. The metal grid was defined by scribing through the masking oxide. The scribing was done by laser scribing. Phosphorus was diffused in the grooves to dope the silicon beneath the metal contact. Aluminium was deposited onto rear of the cell by vacuum evaporation and sintered to form an ohmic contact and back surface field. The wafers are immersed in the buffered HF acid bath for a predetermined etch time(1.0~3.0 min). The aim of deglazing step is to remove all the oxide from the grooves. If the grooves are not completely cleared of oxide then the subsequent nickel plating step will not work. The buffered etching solution consists of hydrofluoric acid(49% HF) and ammonium fluoride(40% NH_4F). To deposit a thin layer of nickel on the bare silicon

surface in the grooves and on the rear surface we used ammonia based nickel plating solution. The pH of the solution was above 8.5 and the temperature was 85-90°C. After nickel plating wafers were sintered to form a good electrical and mechanical contact between the silicon and the nickel at 300-400°C in a non-oxidizing ambient. The wafers were immersed in Cu plating solution to fill the grooves with copper so as to provide adequate current carrying capacity while minimizing the shading loss on the top surface of the cell. The composition of the plating solution should be controlled to fill the groove completely. Silver was plated to form a protective coating on the copper so as to prevent oxidation of the copper and to provide a readily solderable surface without the use of corrosive soldering flux. As a measurement method, the technique using reference cell was used. The reference cell was calibrated at Sandia National Laboratory, U.S.A and University of New South Wales, Australia. Figure 1 shows schematic diagram of a buried contact solar cell fabricated on single crystalline silicon.

3. RESULTS AND DISCUSSION

Electroless nickel plating on silicon is based on a catalytic oxidation-reduction reaction between nickel ion (Ni^{2+}) and hypophosphite ($H_2PO_2^-$) ion at the catalytic (conductive) surfaces. The oxide in the grooves forms during the phosphorus groove diffusion and this oxide removed throughly in order to plate nickel in

the groove. Figure 2 shows deglazing times and their effects on the cell parameters. The short circuit current and open circuit voltage are given by

$$J_{sc} = \left[1 + \left(\frac{R_s}{R_{sh}} \right) \right]^{-1} \cdot \left[J_o \left(\exp \left(- \frac{q J_{sc} R_s}{A k T} \right) - 1 \right) - J_L \right]$$

$$V_{oc} = \left(\frac{A k T}{q} \right) \cdot \ln \left[\frac{J_L - \left(\frac{V_{oc}}{R_{sh}} \right)}{J_o} + 1 \right]$$

Notation

- J_o Reverse saturation current density
- R_s Series resistance
- R_{sh} Shunt resistance
- q Electronic charge
- J_L Short circuit current density
- A Diode ideality factor
- k Boltzmann's constant
- J_L Photogenerated current density

If the deglazing time is short nickel plating will not work well and the grid line is not continuous because nickel will not plate on an insulating oxide and the series resistance will be high. Figure 3 shows the grid line after copper plating. The efficiency increases as the deglazing time increases. Nickel was plated on top of pyramid when deglazing time is too long. Figure 4 shows the nickel spot plated on the top of the pyramid. The textured front surface may lead to non-uniformity in etching the oxide on the front surface. This problem is aggravated by the heavy phosphorus diffusion to which the oxide-coated pyramids are exposed during the heavy groove diffusion. Phosphorous doped

oxide etches more quickly and the peaks of the pyramids are more exposed to the etching solution. During the subsequent copper plating all over the surface was covered with copper because copper is easily plated on the nickel on the top of the pyramid. Figure 5 shows optical microscope photographs of the top of the copper plated groove with copper plating time. Copper started to plate from the wall of the groove filling the groove and the copper finger width increased with increasing plating time. Width of copper fingers should be no more than $50\mu\text{m}$ to reduce shading loss.

4. CONCLUSION

Nickel will not plate on an insulating oxide and the grooves must be thoroughly deglazed. Nickel was plated on the top of the pyramid when the deglazing time is too long. Care must be taken to ensure that the thickness of the masking oxide at the peak of the pyramids after deglazing is adequate to effectively mask against copper plating.

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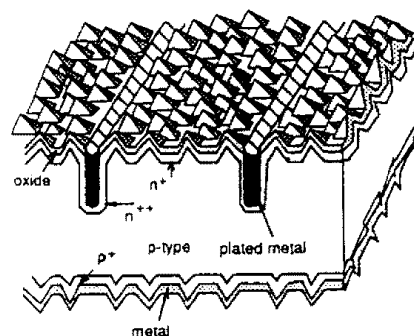


Fig. 1. Schematic diagram of a buried contact solar cell fabricated on single crystalline silicon.

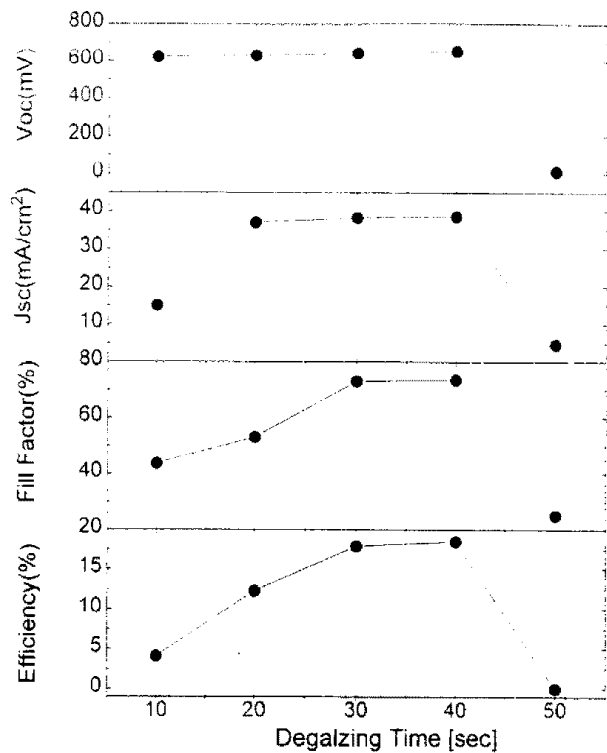


Fig. 2. Cell parameters of BCSC as a function of the deglazing time.

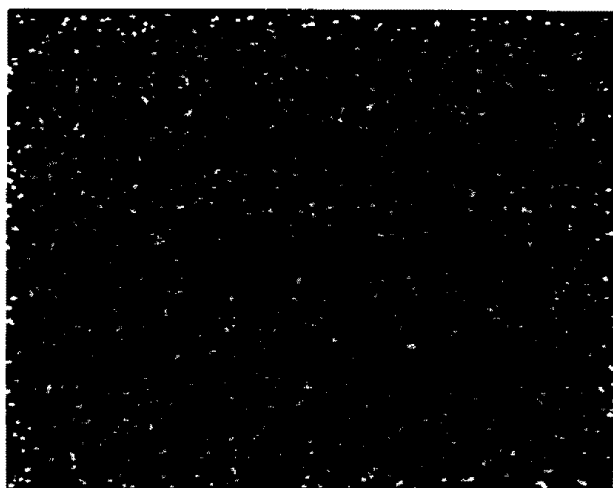


Fig. 4. Optical microscope photograph(x500) of front surface after nickel plating. Deglazing time was 180 sec.

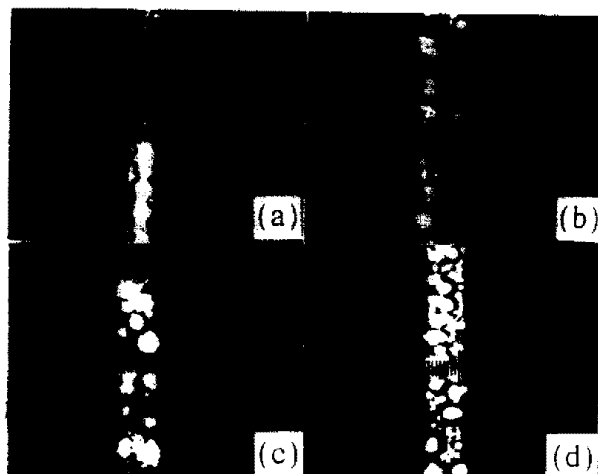


Fig. 3. Optical microscope photographs of grooves after copper plating. Deglazing time was 10sec for (a), 20 sec for (b), 30sec for (c) and 40sec for (d).

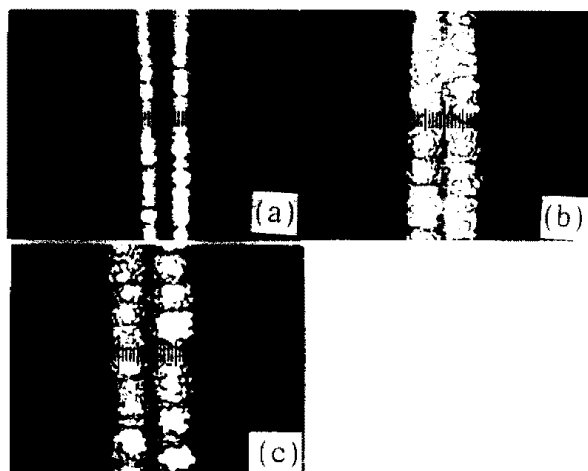


Fig. 5. Optical microscope photographs(x500) of the top of the groove after copper plating. Copper plating time was 2hr for (a), 3hr for (b) and 4hr for (c).