LASER-DOPED METAL-PLATED BIFACIAL SILICON SOLAR CELLS

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ABSTRACT

The objective of the experiments reported in this article was to develop a fabrication method for laser-doped p-type bifacial Si solar cells using self-aligned metal-plated electrical contacts to both cell polarities. A key enabler for the fabrication of these cells was the recognition that p-type Si regions can be made cathodic by forward-biasing the p-n junction of the solar cell. Used in conjunction with LIP for metallisation of the n-type contact regions, this new plating method, which will be referred to as field-induced plating (FIP), was used to form Ni/Cu grids on both semiconductor polarity surfaces of a cell and thereby metallise bifacial solar cells.

INTRODUCTION

A bifacial solar cell is able to increase its power output by capturing albedo radiation from the rear of the solar cell, however to date manufacturing these solar cells is expensive because both P and B diffusions are required and screen-printed Ag grids are used on both surfaces. An alternative metallisation and doping technique could significantly reduce the cost of producing bifacial cells. Light-induced plating has been shown as an effective way of using the light-induced current to provide a source of electrons for metal plating [4] and formation of metal contacts onto n-type Si [5-9]. It can result in low-cost metallisation due to the use of Cu as the main conductor, relatively simple electrolytes (i.e., no reducing agents required) and minimal bath maintenance where the metal concentration is maintained from the corrosion of anodes comprising the same metal species. However, the method can only be used to metallise the n-type regions of a p-n junction solar cell. Consequently, an alternative method is required to form plated contacts to the p-type regions of Si solar cells.

Electrons are minority carriers in the p-type regions of a solar cell, therefore they are not available at sufficient concentration to enable the reduction of metal ions at a p-type Si surface. However, by forward-biasing the p-n junction, electrons can be directed through a p-n junction to make a p-type surface [9-13] cathodic thereby allowing metal ion reduction to occur at that surface.

DISCUSSION

In 2010, a contactless electroplating (CLEP) method was developed by Vais with the objective of plating to p-type surfaces of p-n junction solar cells in a contactless arrangement [2]. The main advantage of CLEP was that no physical contact was required between the contacting electrodes and the solar cell. It was proposed that use of CLEP could potentially increase processing yields for cells using thinner wafers as wafer thickness were predicted to decrease to 140 μm by 2026 [1].

Initially, the experimental process was designed as shown in Figure 1 using p-type bifacial cells where both surfaces were passivated by SiNx layers. The SiNx, which also acted as a plating mask, was patterned using a continuous wave 532 nm laser and liquid spin-on sources to form laser-doped openings in preparation for metal deposition. The thus-patterned cells were placed inside a container in which an isolation barrier was used to separate a ‘negative chamber’ in which the n-type surface of the cell was exposed and a ‘positive chamber’ where the p-type surface of the cell was exposed. The two isolated chambers were filled with plating electrolyte (acid-based $CuSO_4$)

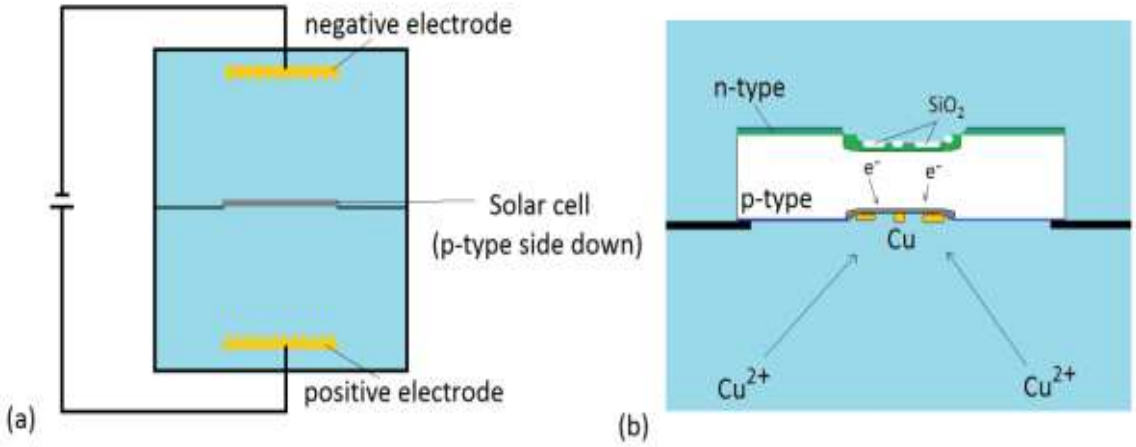

Figure 1. (a) The experimental arrangement used in CLEP; and (b) predicted chemical reactions at each surface of the solar cell.

In the plating process, the cell was forward-biased by the application of an external voltage applied between electrodes that were not in contact with the cell [see Figure 1 (a)]. In the CLEP concept, provided that there was a high resistance through leakage paths existing in the barrier, it was hypothesised that current would flow through the cell due to the applied electric field with electrons accumulating at the p-type openings where metal ions (e.g., Cu2+) could be reduced. The forward-biased current flow through the cell required that a balancing anodic reaction occurred at the n-type Si openings. Vais proposed that the anodic and cathodic chemical reactions that occurred were:

Anodic: $Si + 2H_2O \rightarrow SiO_2 + 4H^+ + 4e^-$

Cathodic: $Cu^{2+} + 2e^- \rightarrow Cu\ (s)$

In order to sustain the metal plating process, 1% (w/v) hydrogen fluoride (HF) was added to the $CuSO_4$ electrolyte so that the formed SiO_2 at the n-type openings could be etched. The experimental arrangement was as shown in Figure 2 [14-18]. The patterned cell was placed in the middle plastic container over a square hole which formed an opening in the isolation barrier so that the p-type surface was exposed to the electrolyte in the bottom container.[19-24]

$$SiO_2+6HF \rightarrow H_2SiF_6+2H_2O$$

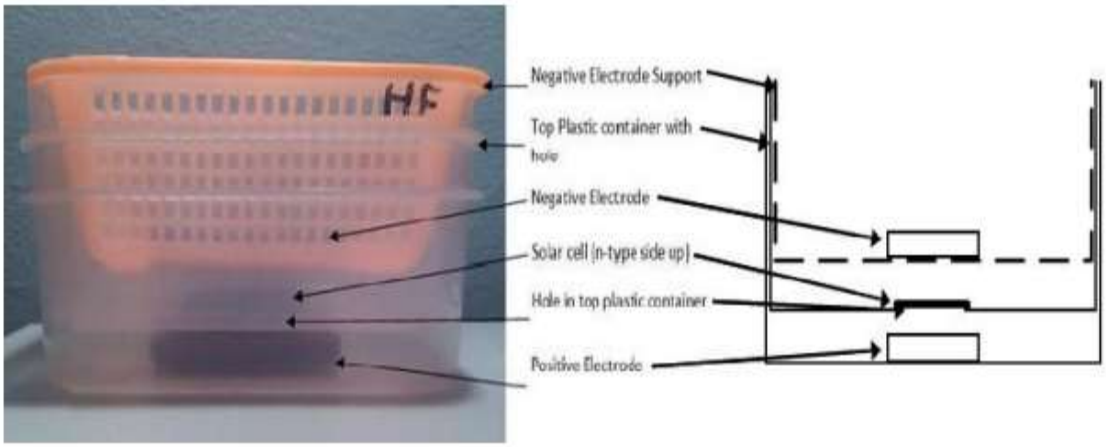

Figure 2. The experimental arrangement for CLEP (from [3])

Vais showed that within 10 min, more than 10 μm of Cu could be deposited on to the laser-doped p-type Si [see Figure 3(b)].

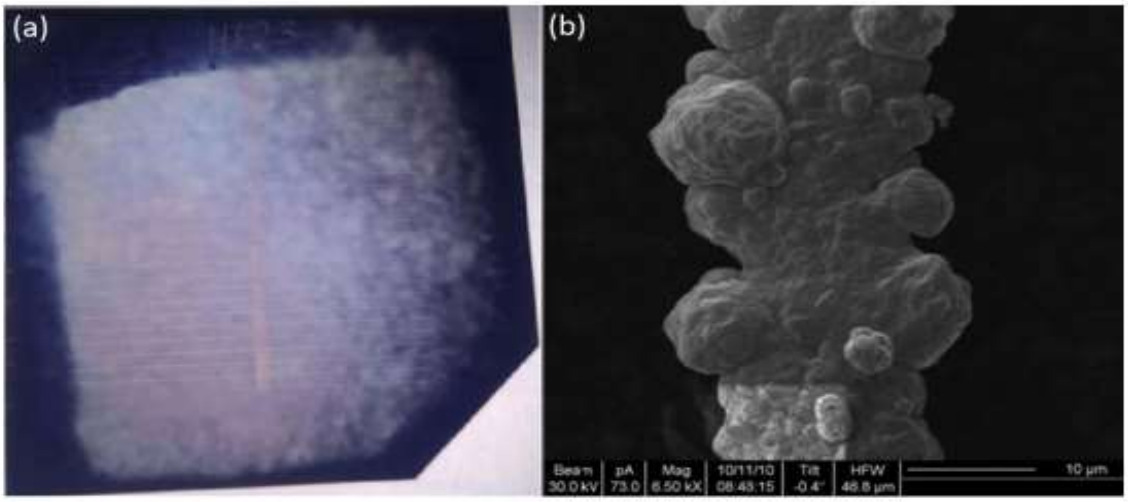

Figure 3. (a) Digital photo of an n-type surface showing excessive etching of SiNx; and (b) SEM image of plated Cu over a p-type laser-doped groove providing evidence of CLEP

CONCLUSION

In short, The 'lumpiness' of the deposit suggested that the plating rate had not been well controlled, but this result demonstrated that plating to p-type Si by forward-biasing the junction was potentially feasible. However, the added HF in the electrolyte in the upper container continuously etched the SiNx layer on n-type surface of the cell during plating. The etching rate of the SiNx was accelerated over that expected from immersion in 1% HF because the anodic potential at the surface predisposed it to being etched [see Figure 3 (a)]

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