CHARACTERISTICS AND PROPERTIES OF NICKEL/COPPER CONTACT CRYSTAL SILICON SOLAR CELLS

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Abstract

This atricle deals with issues regarding contact formations using Ni/Cu metal stacks for crystalline silicon solar cells. The key issues for the discussed technology are: an effective Ni seed layer formation, and the development of Cu metal contacts by the LIP process. In this section, we will give an overview of the process conditions for such metallization schemes and of the current research work as well as the challenges and issues that have emerged. The sections are dedicated to addressing the most important topics in detail.

Keywords

Introduction

In silicon solar cell technology, metallization plays an integral part in outlining the cost and efficiency of solar cells. Indeed, the development of better techniques for the metallization of silicon solar cells is vital for achieving higher efficiencies. Presently, screen-printed contacts are primarily employed in photovoltaic industry as they can be realized easily with high throughputs. However, screen-printing technology has the draw-backs of higher contact resistance and lower aspect ratios, degrading the solar cells' performance. In recent years, an overall decrease in the photovoltaic module price index has occurred, while the higher cost of silver has disturbed this decrease adversely [1-2]. This chapter deals with issues regarding contact formations using Ni/Cu metal stacks for crystalline silicon solar cells. The key issues for the discussed technology are: (i) an effective Ni seed layer formation, and (ii) the development of Cu metal contacts by the LIP process. In this section, we will give an overview of the process conditions for such metallization schemes and of the current research work as well as the challenges and issues that have emerged. The sections are dedicated to addressing the most important topics in detail.

Silver vs. copper metallization

Currently, the photovoltaic industry is primarily occupied by metallization schemes composed of silver-based (Ag-based) screen-printed contacts. The key attribution is a simple process control with an attainable mass production on the industrial scale. However, the efficiencies of cells with screen-printed electrodes are degraded by factors such as the finger width and fill-factor (FF). Ag-based screen-printed contacts usually offer high contact resistance and have lower metal conductivity, and junction shunting can occur during the contact firing process. Such issues degrade the FF of the cell, which is why screen-printed contacts typically offer FFs within the range of 75-78%. On the other hand, the FFs of the contacts patterned with the photolithography process lies within the range of 81-82% [1, 3, 4]. Moreover, screen-printed contacts offer higher shading losses because of larger finger widths (usually ≥ 100 μm wide).

The metallization of solar cell has a vital role in contributed to cell performance and it also determines a considerable number of cell processing costs. On average, about 40% of expenses are associated with the pastes used for front-and rear-side metallization [1-2]. This shows that the overall cost of the solar modules can be reduced drastically if the expensive Ag paste is replaced by relatively cheaper materials, such as copper. The schematics of both the metallization concepts are shown in Figure 1.

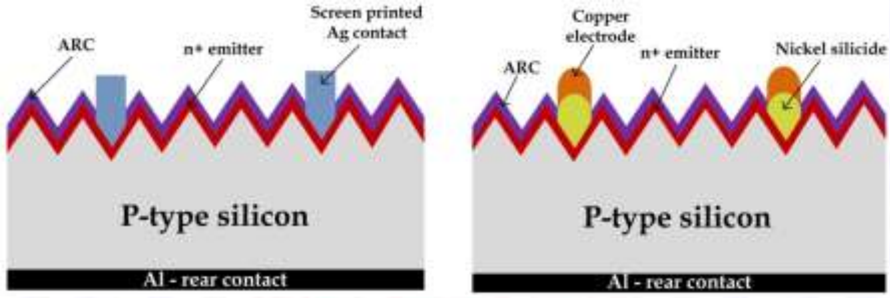


Figure 1. Schematic structures of solar cells composed of metal contacts formed with screen-printed Ag paste (left) and Ni/Cu plating (right).

Considering the higher cost of Ag and tarnished cell parameters due to shading losses and lower FFs, screen-printed contacts offer an opportunity for replacement by an alternate metallization. Recently, metal contacts composed of Ni/Cu metal stacks have emerged and are considered to be a potential candidate for future crystalline silicon photovoltaic cells. Ni/Cu has shown some good results for solar cell performance in terms of improved FFs and higher efficiencies. The overall cost per watt-peak (W_p) can also be decreased as the copper is cheaper than Ag (about 100 times) and is almost equally conductive [1, 5, 6]. It has been reported that Ni/Cu-in comparison to Ag paste-has higher electrical conductivity and lower contact resistance, even at lower doping concentrations (N_s) [1, 7]. Cu is usually deposited by a self- aligned electro-plating process which helps to plate electrodes with finer line widths. The electrodes are plated and processed at lower temperatures (250-450 °C) [23-27], considerably lower than the temperatures (700-850 °C) required for Ag pastes. The low temperature process is favourable for cell processing, as the degradation of the passivation layers can occur at higher temperatures. Furthermore, the rear side Al contact may be melted as well if Ag pastes are fired at higher temperatures. Although Cu offers certain advantages, it can create highly active generation/recombination centres if diffused in silicon [8]. In order to prevent Cu diffusion in silicon, a barrier layer is required. It has been reported that Ni plays a vital role in reducing the contact resistance as well acting as an effective diffusion barrier between Cu and silicon [1, 9].

Ni/Cu contacting schemes

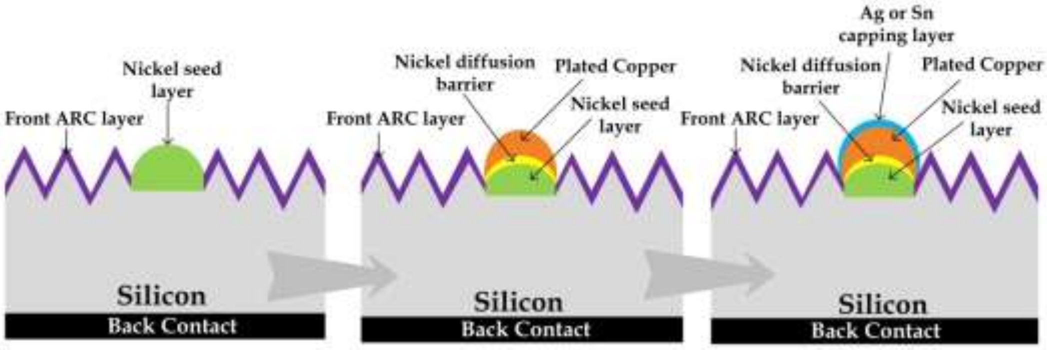
Cu metallization offers greater resistance against electron migration and has been implement- ed widely for ultra-large-scale integrated circuits (ULSIs). However, it has a major weakness as being a deep-level impurity in silicon and can disturb the electrical performance of the device. These impurities tend to generate traps which act as generation/recombination centres and degrade the minority carrier lifetimes in the substrates [1, 10, 11]. To avoid the Cu from being diffused in the silicon, Ni, as a diffusion barrier, has been employed successfully. Ni not only acts as a diffusion barrier but also promotes adhesion between Cu and silicon [1, 12, 14]. Cu along with a Ni seed layer has given some promising results in terms of the efficiency of the crystalline silicon solar cells. The metallization technique using Ni/Cu metal stacks mainly involves two steps:

1. Ni seed layer deposition.
2. Cu deposition by LIP.

The two step process (seed and plate) for the metallization of solar cells increases the efficiency potential considerably [1, 13,]. After depositing Ni/Cu metal stacks, a thin capping layer of silver (Ag) or tin (Sn) is usually electroplated above the Cu [19-22]. The purpose of this capping layer is to prevent the Cu metal lines from being oxidized. Moreover, these capping layers help to solder the interconnecting tabs and also prevent the Cu interacting with the EVA encapsulant. The processing steps involved in metalizing the Ni/Cu/Ag or Sn metal stacks are shown in Fig. 2. However, the schematics for these steps are shown in Fig. 3.

Figure 2. Processing steps involved for depositing Ni/Cu/Ag or Sn metal stacks.

Figure 3. Schematic structures of the steps involved in the formation of Ni/Cu/Ag or Sn-based metallization schemes.



Contact adhesion

Cu exhibits poor adhesion to silicon and requi res a seed layer to form an effective and adhesive metal contact. However, Ni has shown some promising results in providing ohmic contact with good adherence to silicon. Further improvements are required to satisfy the standard heat-quenching and peel force tests. Bath-ageing, acidity and residues on the substrate surface have been found to affect contact adhesion adversely [1, 15, 16]. Various research institutes are currently working to improve the adhesion between Cu and silicon in order to resolve this issue completely. So far, IMEC has presented Ni/Cu metals stacks with adhesions within the range of 1~2.7 N/mm [1, 17]. A research team at Fraunhofer ISE has also presented a two-stage process for etching the back of unreacted Ni and re-plating it [1, 18]. Adhesion strengths of up to 2.5 N/mm were achieved by adopting just such a two-stage process at Fraunhofer ISE.

Conclusion

A detailed overview of research activities in the field of Ni/Cu-based metallization for crystalline silicon solar cells has been presented. Many research groups across the globe have taken on the challenge of working on crystalline silicon solar cells with Ni/Cu contacts. The Ni/Cu plating, which was the topic of this section, has enormous potential in realizing improved solar cell efficiency and low cell and module costs. The generic built-up process for such metallization starts from the deposition of the Ni seed layer, which offers lower contact resistance when sintered at specific temperatures. A Cu metal is electroplated on top of this stack and after confining this layer by a top Ag or Sn capping layer. The Ni seed layer acts as a potential barrier to block Cu diffusion into the silicon and the capping layer prevents the Cu from being oxidized.

Promising results in the form of solar cells with a higher FF and improved efficiency have been reported recent years. FFs of the range approaching 80% and efficiencies above 20% have already been reached at various research institutes. More recently, at IMEC, an industry- feasible Ni/Cu plating scheme for i-PERC-type solar cells with a best cell efficiency of 20.5% has been presented.

If we consider material cost and cell performance, Cu as an electrode seems to be the best alternative to the existing screen-printed Ag contacts. However, its implementation on the industrial scale is still limited by a number of obstacles. Recent reports suggest that there has been progress in finding a solution to the hurdles of background plating and adhesion. Surface pre-treatment prior to passivation layer deposition and the low stress handling of the samples yielded an ARC surface with decreased background plating. A uniform Ni seed layer covering the contact area resulted in good adhesion strengths of the Cu lines to n-type and p-type emitters.

However, the challenge of finding sustainable and reliable contacts is vital in creating viable Ni/Cu contacts for solar cells on the industrial scale.

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