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Ni/Cu electroplating, a worthwhile alternative to use instead of Ag screen-printed front side metallization of conventional solar cells

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ABSTRACT

For commercial purposes, it is necessary to manufacture high-efficiency and low-cost solar cells using simple processes. The front contact formation is one of the most critical steps in solar cell processing. Although silver paste screen-printed solar cells are the most widespread on the photovoltaic market, their efficiency is strongly limited as a result of shading and resistive losses, or more precisely the high contact resistance. Cu metallization for crystalline Si solar cells has attracted much attention as an alternative to the screen-printing technology. The low-cost Ni/Cu metal contact is regarded as the next generation of metallization processes to still improve the efficiency with a low specific contact resistance; it is formed using low-cost electroless plating and electroplating. A diffusion barrier should be placed between Cu and Si, to prevent Cu diffusion. Ni is shown to be an adequate barrier to Cu diffusion. For these reasons, geometry optimization of metal contacts of the front face, deposited by commercial processes, is investigated in this paper, in order to improve the spectral response of conventional multicrystalline mc-Si silicon solar cells. Their efficiency variation is analyzed as a function of changes in cell parameters (finger separation distance, height and width of finger, sheet resistance emitter...) using simulation programs in MATLAB, using contours to represent the efficiency evolution in terms of two variables. Efficiency gain of more than 0.7% has been achieved in this study. The simulation results were then compared with experimental data in order to be validated.

1. Introduction

Front side metallization of solar cells with silver (Ag) pastes is the most important cost factor in current cell technologies [1-2], beside the silicon wafer [3]. An average silver price of 1000 U.S. Dollars/kg in February 2013 resulted in costs of 20 U.S. cents per cell (i.e. 4.9 U.S. cents/Wp), which represents 30% of the total cell processing costs. Therefore it is necessary to reduce paste utilization to decrease the manufacturing cost. Silver should be replaced by a more cost effective material. Copper can provide a similar conductivity at a lower cost (factor cost of about 100) [4], thus the cost of the solar cell could be reduced just by using a copper-based metallization (instead of silver). Fig. 1 shows the quantity of silver remaining after the metallization operation, for a 156×156 mm^2 cell, according to the study carried out by ITRPV in March 2013 [5]. The process that allows the use of copper instead of silver, that is the plating technology,

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1369-8001/

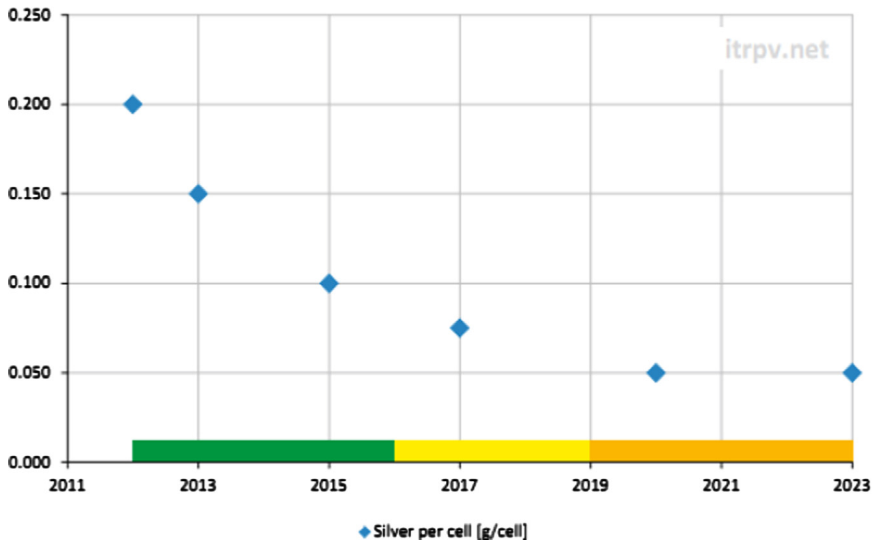

Fig. 1. Proportion of silver per cell (156 × 156 mm^2). A technological development is expected to replace silver by copper, starting around 2015 (ITRPV) [5].

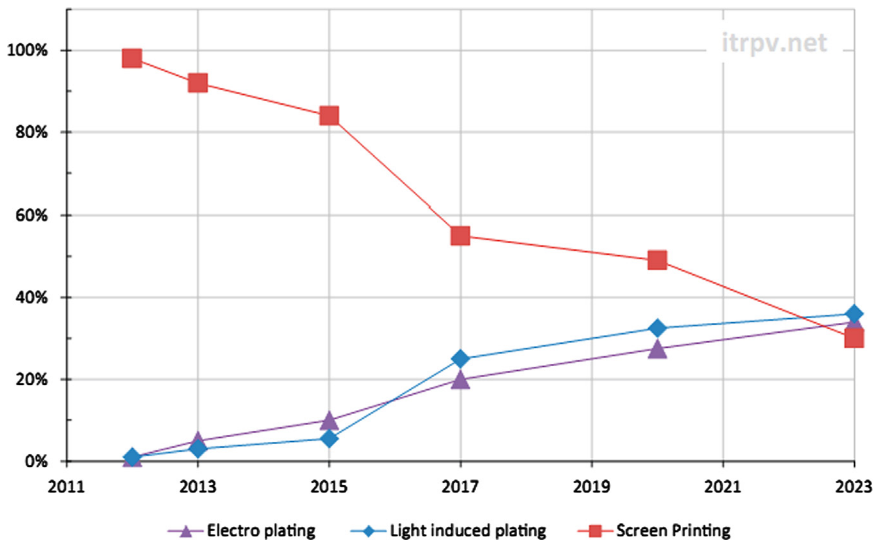

Fig. 2. Predicted shares of different metallization technologies in cell processing (ITRPV).

confirms the possibility to achieve higher solar cell efficiencies.

Plating technologies are expected to occupy a more prominent position among deposition technologies, as shown in Fig. 2 (ITRPV).

In order to optimize solar cells, front face metallization must be improved, as it has a direct impact on the series resistance (via contact resistivity and line resistivity) which results in high efficiency [6]. Although screen printing is the simplest and most dominant process in the PV market, it still presents some weaknesses such as shading losses which are caused by a low aspect ratio. In addition to the high contact resistance between the silicon surface and the screen printed contact, another one, due to the presence of glass frit in the Ag paste, limits the solar cell efficiency [7]. Good contact formation requires a good adhesion, a high aspect ratio, high line conductivity and a low ohmic resistance. Therefore, a new metallization method is to be studied in order to reduce the series resistance [8].

The two-step process, which has gained great interest in recent years, is based on the use of two metal layers on top of each other. In the first step, the seed layer is deposited by electroless plating, an auto-catalytic chemical process used to deposit a Ni layer onto the silicon wafer. This layer behaves as a diffusion barrier which prevents copper from diffusing into the bulk silicon. Nickel is an excellent choice for the first layer, for several commercial and industrial reasons [6]. Extensive research about electroless nickel plating for making ohmic contacts to n and p doped silicon was published in 1957 by Sullivan and Eigler. Years later, electroless plating became significantly important in silicon solar cell technology [9]. In the second step, the so-called step-growth, the seed layer is enhanced by