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A novel low cost texturization method for large area commercial mono-crystalline silicon solar cells

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Abstract

Texturization of mono-crystalline silicon for solar cell fabrication is still a key issue due to consumption of large amount of costly isopropyl alcohol (IPA) in conventional NaOH/KOH solution. The need of IPA arises due to the improvement in the uniformity of pyramidal structures and elimination of spots caused by bubbles sticking on the wafer surface during the texturization process. We investigated a new texturization technique for mono-crystalline silicon solar cells with tribasic sodium phosphate (Na_3PO_4, $12H_2O$) solution with much less amount of IPA. The proposed texturization method of this paper is cost effective due to reduction in the consumption of expensive IPA. The cost comparison of our novel texturization approach with conventional NaOH texturization has also been reported in this paper. We are reporting for the first time such a novel approach of using tribasic sodium phosphate for texturization of mono-crystalline silicon surface with which solar cells of efficiency 14–14.8% are fabricated with more than 90% yield.

Keywords: Texturization; Tribasic sodium phosphate; Mono-crystalline silicon; Solar cell; Low cost

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1. Introduction

Reduction of optical losses in mono-crystalline silicon solar cells by surface texturization is one of the important issues of modern silicon photovoltaics [1]. Anisotropic chemical etching using a mixture of alkaline solution of sodium hydroxide (NaOH) or potassium hydroxide (KOH), and isopropyl alcohol (IPA) is widely used for texturization of mono-crystalline silicon wafers [2–4]. IPA is essentially required for the formation of pyramidal structured all over the crystalline silicon surface during alkali texturing with NaOH because IPA improves the wettability of silicon surface. In order to enhance the pyramid nucleation, the interfacial energy of silicon/electrolyte should be reduced so that sufficient wettability for the silicon surface can be achieved. The interfacial energy can be reduced by using surface active additives into the solution. IPA increases the wettability of the silicon surface but the rate of the silicon removal decreases strongly with increasing IPA concentration [5]. In typical texturing condition, the IPA concentration is higher than the NaOH (or KOH) concentration. Moreover, IPA is not only expensive but also a volatile compound. It has to be added frequently in the texturization bath during the batch process in order to compensate the evaporated amount, which leads to the higher consumption of IPA. Thus, the cost of IPA is dominant in the overall cost of texturing in the commercial NaOH/KOH technique. So, reduction in the amount of IPA during texturization of the commercial solar cell fabrication is the key issue of overall texturization cost reduction approach.

Some researchers have reported the texturization with potassium carbonate (K_2CO_3) solution [6,7]. One group of researchers reported the texturization of silicon surface with low cost sodium carbonate solution (Na_2CO_3) [8]. They claim that their techniques are superior to the conventional method in terms of cost because there is no need of IPA for texturing. They used $2.5\,cm \times 2.5\,cm$ mono-crystalline silicon samples for Na_2CO_3 texturization experiment. Moreover, they have neither shown any data related to texturization nor the results related to fabrication of the large area mono-crystalline silicon ($>103\,mm \times 103\,mm$) solar cells using batch process (at least 25 wafers at a time) in their approach without which a process cannot be claimed as commercial texturization. We are reporting the use of tribasic sodium phosphate (Na_3PO_4, $12H_2O$) solution for the texturization in mono-crystalline solar cell fabrication process for the first time.

Tribasic sodium phosphate (Na_3PO_4, $12H_2O$) can hydrolyse in water. The equation is as follows [9]: $PO_4^{3-} + H_2O \leftrightarrow HPO_4^{2-} + OH^-$. Due to low dissociation constant ($K_s^{\Phi} = 4.17 \times 10^{-13}$), the concentration of hydroxyl ion (OH^-) is very high in this solution. Therefore, Na_3PO_4, $12H_2O$ solution can be used for texturization of mono-crystalline silicon. In the Na_3PO_4, $12H_2O$ solution, the OH^- is generated which forms small pyramids and PO_4^{3-} or its compounds help for the formation of big pyramids. It is possible that Na_3PO_4 plays the role of a surface active agent to decrease the active energy of the etching reaction and then makes etching more effective, leading to the formation of big pyramids with less IPA requirement compared to NaOH texture bath in order to get better surface finish after texturization. In our experiment, IPA amount is almost half as compared to that needed in the conventional NaOH texturization. As the commercial wet texturization cost mainly comes from the huge amount IPA consumption, the texturization approach using the tribasic sodium phosphate can be effective to cut down the IPA consumption with the eventual reduction in production cost. Moreover, the texturization