Advanced Materials Research Vol. 324 (2011) pp 465-468
Online available since 2011/Aug/22 at www.scientific.net
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doi:10.4028/www.scientific.net/AMR.324.465

Contribution of the luminescence phenomena of nc-Si to the performances of the industrial mc-Si solar cells

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Keywords: silicon nanocrystal, solar cells, silicon nitride, photo-luminescence, I-V characterization

Abstract: In this study, we attempt the contribution of the silicon nanocrystal nc-Si luminescence phenomena to the performance of the conventional multicrystalline mc-Si solar cells. These nc-Si are embedded in the hydrogenated silicon nitride dielectric layers. The experimental results are obtained by different characterizations. It was found that the optimum temperature is around 720°C with a good homogeneous distribution of nc-Si (3-5nm). However, to validate our results on silicon solar cells, we deposited silicon-rich silicon nitride layers on p-type (0.5 ohm.cm) and diffused $POCl_3$(40 ohm/sq) substrates. Then, we performed thermal annealing at 720°C under mixture of gas (N_2/H_2) during one hour. After, we made the screen printing metallization. The I-V measurements under AM1.5G are carried out and they showed 0.4% increase of the absolute efficiency.

Introduction

Recently, the SiN_x:H layers have been widely used in the industrial silicon solar cells as photon energy converter[1]. Indeed, the privilege of these converters is based on remarkable luminescent properties of nc-Si embedded in the layers SiN_x:H. These new materials have the ability to convert high energy blue photons to low energy red photons that can be absorbed by the bulk of the crystalline silicon [2]. Furthermore, optimizing the performance of the third generation solar cells can be done through appropriate monitoring of the characteristics of nc-Si (size, density, passivation, etc..), the quality of the layer and the technological conditions of annealing. Through previous research, scientists have shown the possibility of forming nc-Si during the deposition 'in situ' layers SiN_x:H [3] by PECVD at low temperatures or after deposition 'ex-situ' by using thermal annealing under controlled atmosphere [4]. Indeed, the use of thermal annealing promotes the coalescence of silicon atoms resulting mainly from the breaking of molecular bonds Si-H and Si-N. It also improves the passivation of defects at interfaces nc-Si/SiN_x:H. However, we report in this paper the contribution of these down converters to the efficiency of the mc-Si solar Cells.

Experimental Study

The investigated solar cells are fabricated from a 125x125mm² multi-crystalline silicon wafers doped P (ρ = 0.1Ωcm) with 200 µm of thickness. A pyramidal texturization silicon wafers is performed in a chemical bath KOH at 80°C, followed by a 40 Ω/□ diffusion of phosphorus at 825 °C using a $POCl_3$ source (Surface concentration $N_s=5.10^{20}cm^{-3}$). After phosphorus glass 'PSG' removal, an antireflection coating based on silicon nitride (refractive index n = 2.05 and thickness d = 80nm) is been deposited within a PECVD reactor using a mixture of gases silane and ammonia. The deposition temperature is about 300°C and the pressure is close to 10^{-2}mbar. However, the antireflective layers were thermally annealed at different temperatures 600°C-900°C and atmospheres (N_2, N_2/H_2 and O_2). It should be noted that in this study, we use the temperature at its ideal value about 720°C.