

6th International Conference on Silicon Photovoltaics, SiliconPV 2016

Light trapping by micro and nano-hole texturing of single-crystalline silicon solar cells

Serra H. Altinoluk^{a,b,*}, Hande E. Ciftpinar^{b,c}, Olgu Demircioglu^{a,b}, Firat Es^{a,b},
Gulsen Baytemir^{b,c}, Orhan Akar^d, Akin Aydemir^d, Adem Sarac^d, Tayfun Akin^{a,d,e},
Rasit Turan^{a,b,c}

^aMicro and Nanotechnology Department, Middle East Technical University, Ankara and 06800, Turkey

^bCenter for Solar Energy Research and Application (METU-GUNAM), Middle East Technical University, Ankara and 06800, Turkey

^cDepartment of Physics, Middle East Technical University, Ankara 06800, Turkey

^dMicro-Electro-Mechanical Systems Research and Application Center (METU-MEMS), Middle East Technical University, Ankara 06800, Turkey

^eDepartment of Electrical and Electronics Engineering, Middle East Technical University, Ankara 06800, Turkey

Abstract

The efficiency of a solar cell strongly depends on the interaction between the incoming light beam and the surface of the device. Any process enhances light-surface interaction increases absorption probability of the light; thus, improves generated current, in turn. Generated current could be improved either by light trapping or by increased device thickness. Considering fabrication costs and recombination losses, mechanically thin optically thick wafers are being focused on in terms of light trapping properties. Surface texturing among the other methods is an effective and more lasting technique in reducing reflections and improving light trapping. In order to maximize the absorption of light and the efficiency of the cell, various light trapping schemes have been proposed so far. In this study, texturing silicon (Si) wafer surface with periodic holes using two top-down fabrication techniques: Metal Assisted Etching (MAE) and Reactive Ion Etching (RIE) was focused on. Following the design of optical masks with patterns of different hole sizes and distributions, hole-textured surfaces with dimensions varying from micron scale to submicron scale were fabricated using both etching techniques. Hole-textured surfaces with desired hole depth values could be successfully fabricated. It was observed that surface having periodic holes with 4 μm diameter, 5 μm gap between holes and 8 μm depth could result in 15.7% efficiency.

© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer review by the scientific conference committee of SiliconPV 2016 under responsibility of PSE AG.

* Corresponding author. Tel.: +90 312 210 7651; fax: +90 312 210.
E-mail address: serraa@metu.edu.tr

Keywords: Light trapping; texturing; periodic hole texturing.

1. Introduction

The traditional solar cell production is based on formation of random pyramids on the surface through an anisotropic etching process [1]. Although random pyramid approach is well-established and successful for standard wafer sizes, it is not the most preferable method for the wafers with low physical thicknesses. Various other surface structures have been proposed to create effective light-trapping for high absorption in crystalline Si solar cells [2,3]. Among them, formation of periodic micro- and nano-hole structures on the surface was shown to be promising approach for high efficiencies in solar cells with lower thicknesses [4,5]. Both MAE, and RIE were used to form periodic arrays of nano and micro holes on Si wafers. In both cases optical lithography was used to define the geometry and distribution of the holes. In the end, solar cells were fabricated on these surfaces using standard cell procedures to observe the effect of surface micro structures on cell performance.

2. Experimental part

With optimizing process conditions for different masks having various distribution of holes, hole-textured surfaces with dimensions varying from micron level to submicron level have been fabricated using both RIE and MAE methods. Depending on hole diameters, resist thickness should be defined properly. After clarifying correct lithography process parameters, pattern transfer could be successfully achieved which was examined by optical microscope imaging. Once pattern was defined, depth scaling was done by controlling etching parameters. Different metals with different film thicknesses, and different surface cleaning conditions for a successful etching, and removing metal from the surface could be counted as the important etching parameters to be controlled. MAE results in desired structures on the surface, unless there is no residual resist left after lift-off process. Else, it would result with an unsuccessful etching. In order to prevent it, an appropriate cleaning procedure was carried out [6]. Also for RIE, if the process parameters are not chosen in a proper way for the dimension of designed holes, then it may end up with an undesirable etch profile. For both etching techniques, appropriate process parameters were defined, and utilized. process. After fabrication of desired surface structure, corresponding solar cells were fabricated, which was followed by optical and electrical characterization steps.

Following surface patterning and necessary cleaning steps, fabrication sequence for standard cell structure was applied. The first process step is doping through which p-n junction is obtained by means of POCl_3 diffusion in a tube furnace at low vacuum conditions. Glass layer formed during diffusion is etched by dilute hydrofluoric acid (HF) dipping which is followed by standard cleaning procedure. After cleaning, dry oxidation at low temperature is carried out to form a thin silicon dioxide (SiO_2) layer with a thickness less than 10 nm to enhance surface passivation by saturating dangling bonds. Oxidation is followed by silicon nitride (SiN_x) deposition onto front surface of the cell which will both act as an antireflection coating and also improve surface passivation quality. SiN_x deposition is carried out in a parallel plate, PECVD system at around 400 °C. Metallization is the step following silicon nitride deposition. Front side metal pattern is defined by industrial screen printing method as an H patterned silver (Ag) grid whereas rear side metallization was done by thermal evaporation of aluminum (Al) due to adhesion problems of industrial Al pastes onto polished surfaces. Firing of front side metal grid is carried out in an industrial 8-zone firing furnace which is followed by laser edge isolation. Then, optical and electrical characterization tests were carried out.

2.1. Structure

In the cell process demonstrated in Fig. 1., p-type silicon wafers with <1-0-0> orientation having thickness of 525 μm and resistivity of 1-5 Ω -cm were used as substrate. Prior to MAE process, lift-off method was used to obtain the metal film in the regions where holes were intended to form. During RIE process, we applied a short plasma descum, in order to get rid of resist residues and make efficient etching on surface.

Download English Version:

<https://daneshyari.com/en/article/5446591>

Download Persian Version:

<https://daneshyari.com/article/5446591>

[Daneshyari.com](https://daneshyari.com)