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Study of metal assisted anisotropic chemical etching of silicon for high aspect ratio in crystalline silicon solar cells

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ABSTRACT

Textured surface is commonly used to enhance the efficiency of silicon solar cells by reducing the overall reflectance and improving the light scattering. In this study, a comparison between isotropic and anisotropic etching methods was investigated. The deep funnel shaped structures with high aspect ratio are proposed for better light trapping with low reflectance in crystalline silicon solar cells. The anisotropic metal assisted chemical etching (MACE) was used to form the funnel shaped structures with various aspect ratios. The funnel shaped structures showed an average reflectance of 14.75% while it was 15.77% for the pillar shaped structures. The average reflectance was further reduced to 9.49% using deep funnel shaped structures with an aspect ratio of 1:1.18. The deep funnel shaped structures with high aspect ratios can be employed for high performance of crystalline silicon solar cells.

1. Introduction

The textured surface morphologies are used to enhance the light absorbing capability of silicon solar cells by improved light scattering and lower reflectance [1–5]. The textured surface structures increased the light absorption and the short circuit current density (J_{sc}) of solar cells [1,20,21]. Various texturing techniques like wet chemical etching, mechanical grooving, laser sculpturing and plasma etching have been used to texture the crystalline silicon (c-Si) and glass substrates. The wet chemical etching is preferred due to the low cost and less experimental process steps [2]. If the etching reaction is same in any direction then the etching is known as isotropic etching, whereas anisotropic etching is to remove the material in specific directions to get often flat and intricate shapes. The alkali solution is commonly used to form pillar shaped (standard pyramid) structures for crystalline silicon solar cells since 1974 [3,8]. The surface texturing for funnel shaped (inverted pyramid) structure was introduced in 1989 for high efficiency of passivated emitter and rear cell structured (PERC) solar cells [4,5].

Recently, metal-assisted chemical etching (MACE) has attracted an increasing interests due to its simplicity and low cost. The MACE can also control the Si orientation of nanostructures (e.g., nanowire, pore) relative to the substrate. Recently, Chern et al. used non-lithographic patterning with metal-assisted-chemical etching (MACE), to produce silicon nanowire arrays with defined geometry and optical properties in a manufacturable fashion [11]. The influence of etching solution composition has been found to be an important parameter in metal-assisted silicon chemical etching as reported by Chartier et al. [9]. Few detailed studies of metal-assisted silicon chemical etching have been reported by Huang et al. [6] and Li [8].

In this paper, we reported the funnel and deep funnel shaped structures with various aspect ratios (ARs) by metal assisted chemical etching (MACE). Metal materials such as Ag, Pt, Au, etc. with lower electro-negativity were deposited on the silicon surface and then etching was carried out by using HF solution. Since the oxidation occurred actively around the metal, the direction of etching was along the metal, vertical to the surface. The MACE method is quite simple to reduce the reflectance by light trapping [6,7]. The porous and oxide layers were formed at the reacted surfaces as the etching was carried out [9]. These layers need to be removed for the solar cells as they act as surface defects. The surface was partially etched by MACE and then the defects were removed by damage remove etching (DRE). Since the surface was etched by DRE, deep funnel shaped structures were realized by controlling

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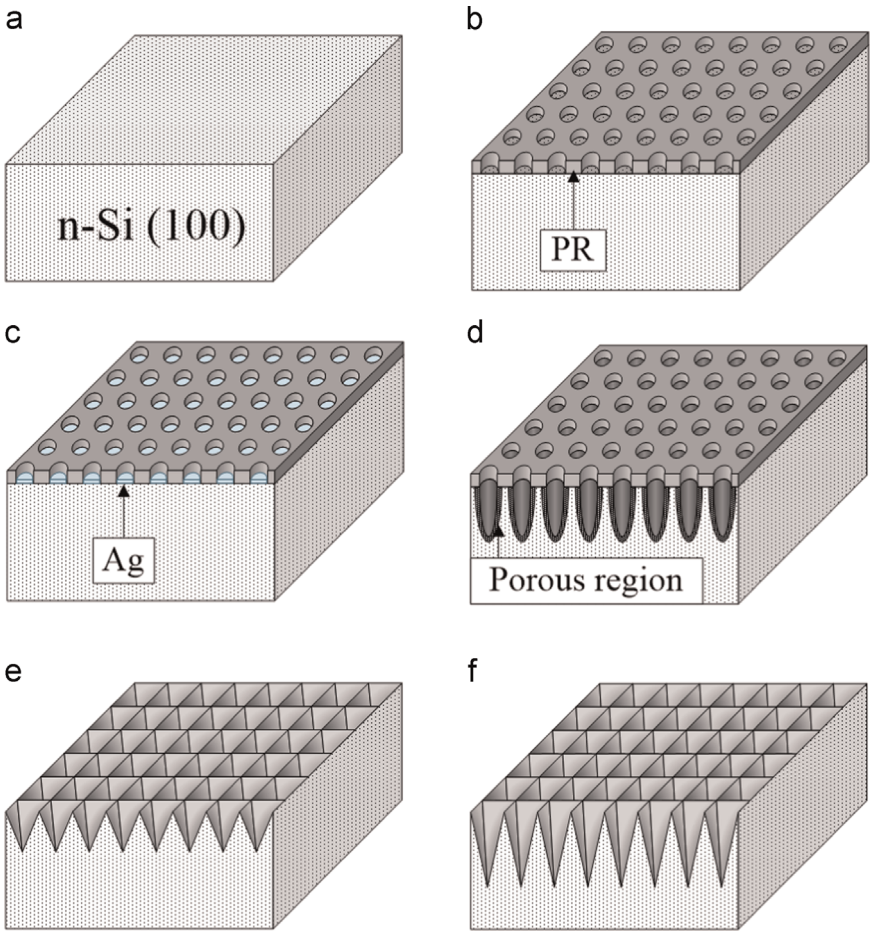

Fig. 1. Processing steps for the funnel shaped structures with metal assisted chemical etching: (a) silicon wafer; (b) photoresist (PR) pattern; (c) deposition of Ag by electrolysis metal deposition; (d) metal assisted chemical etching; (e) funnel shaped structures; and (f) deep funnel shaped structures.

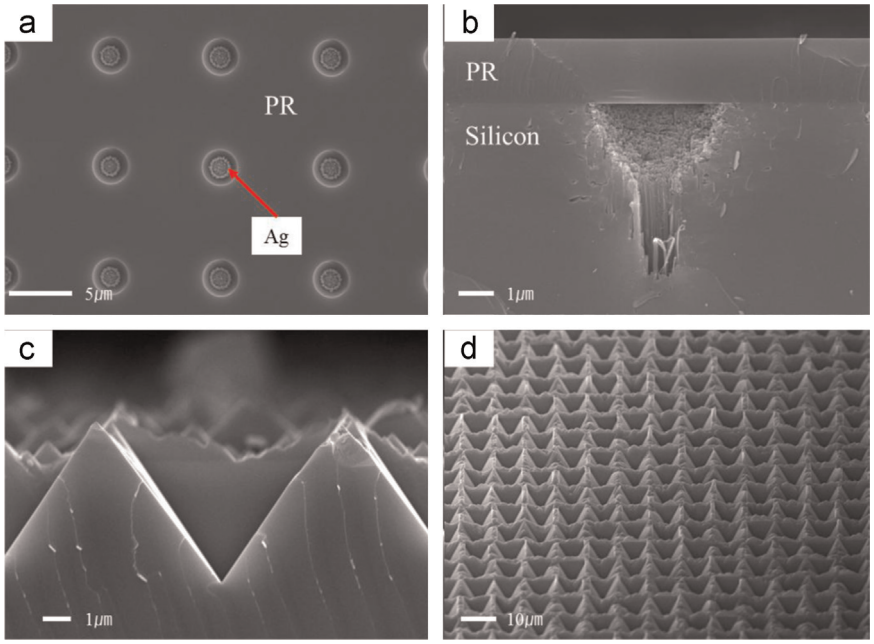

Fig. 2. SEM images for funnel shaped structure process: (a) photoresist pattern and Ag deposit; (b) metal assisted chemical etching; (c) cross section view; and (d) tilted view of funnel shaped structures.