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Performance of Solar Cells Fabricated on Black Multicrystalline Si by Nanowire Decoration

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Abstract— **Vertically aligned Si nanowire (NW) arrays fabricated by metal-assisted etching technique were applied to industrial sized (156 mm x 156 mm) multicrystalline Si cells as an anti-reflective (AR) medium. The NW lengths (between 0.15 to 2.2 µm) were controlled by etch duration from 5 to 50 minutes. A completely black surface could be observed, demonstrating excellent AR properties in the entire range of the solar spectrum, even without additional anti-reflective coating layer (e.g., SiN_x:H). Standard Si solar cell fabrication protocols were followed for both samples with NW arrays and to reference samples textured in standard stain etch solution. Cell parameters have been studied as a function of NW length. Results show that Si NW arrays can be used on multicrystalline Si solar cells as an AR coating. Without applying a superior passivation technique, cell conversion efficiencies are observed to normally degrade with increasing lengths of NW's, such that the highest efficiency in NW samples was resulted from the shortest NW's. It is clear that an effective passivation eliminating recombination along the NW's and optimized doping could further improve the performance of the cell. Structuring the surface of the multi-crystalline wafers with metal assisted etching is shown to be a promising alternative to presently used acid-based texturing processes.**

Index Terms—**Black Silicon, Metal Assisted Electroless Etching, Multi-c Silicon Solar Cells, Silicon NW's, Surface Texturing**

1. Introduction

At present, the crystalline Si solar cell technology overwhelmingly dominates the commercial photovoltaic (PV) market with a share of more than 85% of the total annual installation [1]. With the experience and the material availability transferred from the semiconductor industry, and reliability proven by the accumulated applications developed through the years, this technology has reached a mature state of technical development, which is required in a rapidly growing market. In recent years, the price of the PV cells and modules has drastically fallen. This development, along with the enhancements in the device performance, has made the c-Si based PV systems very competitive in many locations around the world. However, further improvements are still required if this technology is to completely replace fossil fuels.

Among many efforts currently aiming to improve the efficiency and lower the cost of PV systems, light management studies which target to reduce optical losses, and thus enhance the absorption of the solar cell, have attracted a great deal of attention in recent years [2]. Various light trapping structures have been proposed and fabricated to reduce the major optical losses caused by reflection from the front surface and transmission through the device [2-5]. Traditionally, surface texturing with wet chemical etching combined with anti-reflection coating layers (SiN_x:H) are commonly used by the industry. An improvement in the optical performance of the device is easily obtained in the visible spectrum with this technology. However, due to the optical losses in the ultraviolet (UV) and infrared (IR) regimes, a complete utilization of the solar spectrum is not achieved. This problem poses a challenge for the industry, particularly for multicrystalline solar cells for which an efficient surface texturing procedure remains unavailable. One common approach to overcome this deficiency is to design light management structures that enhance absorption through multiple reflections, increasing the optical path length, and other photonic effects. Recently, some achievements have been reported in this direction [2]. It is shown that the Si surface can be made completely black with virtually no reflection from the surface for the whole spectrum [6]. Si wafers with a surface structure having almost no reflection have been termed as black Si (b-Si) [9]. With the reported high conversion efficiency values of on monocrystalline Si, b-Si has proven to be a promising alternative to the conventional cell structures [10]. It is clear that the use of b-Si will be more important and bring greater benefits for thinner wafer thicknesses in which transmission losses will be more severe [11]. Despite being