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High Efficiency Passivated Emitter Rear Contact Solar Cells with Diamond Wire Saw Multi-crystalline Silicon wafers

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Abstract

During recent years, diamond wire sawn (DWS) multicrystalline silicon (mc-Si) wafers have been widely used to reduce the production costs; however, these wafers need additional process treatments such as reactive ion etching (RIE) or metal-catalysed chemical etching (MCCE) to form a surface with relatively low reflectivity. Although the absolute power conversion efficiency of the solar cell could be improved by 0.3-0.5% through the introduction of such surface treatments, the production costs would also be increased. In this study, an improved production-scale acidic texturization with additives is used to texture the surfaces of DWS mc-Si wafers, giving a similar weighted averaged reflectance (WAR) of 19.69% as slurry-cut wafers. The effect of the texturization process on the surface morphology, WAR and performance of the DWS mc-Si cells is discussed.

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Keywords: Diamond wire saw; Silicon solar cell; Texturization; PERC; PV module

1. Introduction

Diamond wire saw technique is known to introduce saw marks on the wafer surface after wafer slicing [1]. These saw marks will affect the subsequent texturization step, which will have significant impact on the light absorption loss and lower the solar cell efficiency [2]. Cao *et al*. demonstrated metal catalyzed chemical etching (MCCE) to texture diamond wire sawn multicrystalline Si wafers [3]. MCCE and an extra alkaline treatment has been proven as

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an efficient way to fabricate high-efficiency black mc-Si solar cells, whereas it is limited by production capacity and the cost due to the complicated process. MCCE can produce high aspect ratio surface which can reduce WAR to 10% or below, but an extra treatment process is needed which increases production costs. The energy conversion efficiency could be comparable to that of solar cells fabricated on slurry sawn wafers. Lippold *et al*. used sulfuric acid, nitric acid and hydrofluoric acid mixtures as texturization solution to adjust the etching speed [4]. Chen *et al.* used vapor blast etching method to remove the saw marks on the wafer surface [5]. Sand blasting can provide a textured surface which is similar to slurry sawn wafers, whereas micro-cracks may be induced during the sand blasting process. In this study, we modify the production texturization process with additives to texture the DWS wafers to achieve low WAR. These textured DWS wafers are used subsequently to fabricate mc-Si PERC cells to evaluate the effect of the improved texturization process on the cell efficiency.

2. Experiment

Texturization is an important step in Si solar cell fabrication. Not only can it remove the surface damage layer caused by wafer slicing, texturization step can increase the light absorption by reducing the light reflection on the wafer surface. However, different wafer slicing conditions will lead to different surface morphology and weighted average reflectance (WAR). Two types of wafer sources with different slicing condition are measured by WAR-D8 and the results are shown in Fig. 1. The acidic etching ability will influence the variation of surface condition in as-cut stage. It should be highlighted that the initial ratio of amorphous region to crystalline region of the DWS wafers are higher in wafer source B than wafer source A. Since the amorphous region on the DWS wafer will provide more defects from the initialization of texturization process in acidic solution, we have selected wafer source A in this study.

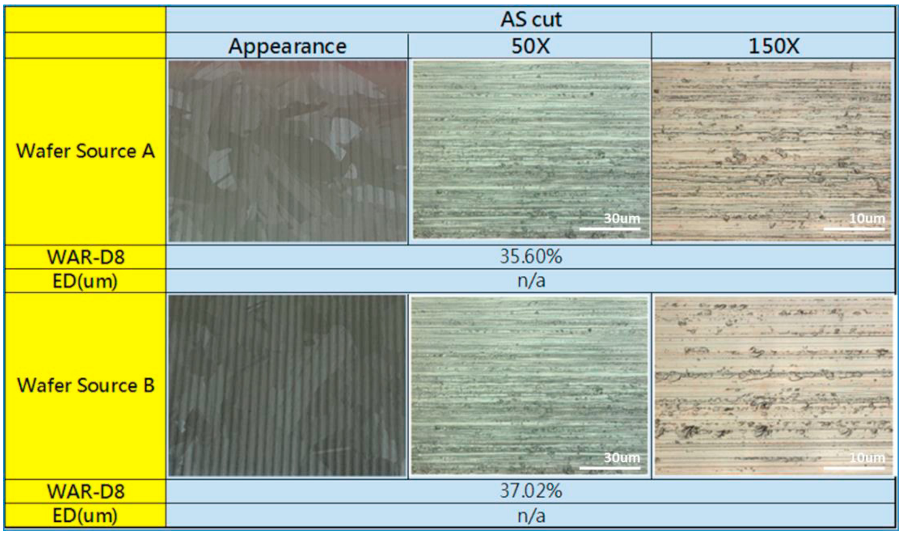

Fig. 1. Two types of slicing condition of DWS multi wafer.

Two types of texturization conditions were used in this study, namely Type-1 and Type-2. Type-1 was used for traditional acidic texturization solution which was composed of HNO_3 and HF solution (ratio of HNO_3 : HF = 3 : 1). Type-2 is composed of an optimized ratio of HNO_3 and HF with extra additives. The surface morphology of the textured surface was analyzed using the WAR, and the WAR results will be used to monitor light trapping ability of the two acidic etching process. Etching depth was also calculated to determine the thickness of the silicon lost from each side of the DWS wafer.

Subsequently, two types of mc-Si solar cells are fabricated in this study. Firstly, Al-BSF mc-Si solar cells are fabricated to evaluate the optimal etching depth using Type-2 acidic texturization solution. Mc-Si PERC cells are later fabricated as illustrated by process flow in Fig. 2. The n-type phosphorus doped emitter was formed on the front