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Potential process design and control for solar cell lean production in future

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ABSTRACT

In this paper, the correlation between wafer quality and cell efficiency was studied to identify the key impact factors, such as effective lifetime, impurities and defects. Standard (STD, 2.94E21atoms/cm^3) and lightly doped emitter (LDE, 1.08E21atoms/cm^3) diffusion were investigated for different qualities wafers. For high impurities wafer, cell efficiency of STD diffusion is 0.44%_abs higher than that of LDE diffusion due to the better gettering by bulk lifetime and iron concentration measurement; for high defect wafer, cell efficiency of STD and LDE are similar; for good wafer (high lifetime, low defect and low impurities), LDE diffusion is better than STD with 0.08%_abs higher cell efficiency due to the better blue wavelength response by using IQE measurement, which should be higher if optimizing firing condition for Fill Factor improvement. Therefore, the possible wafer sorting provides opportunities to design and control different cell process for different incoming wafers to enable the best possible output in a lean production in future.

1. Introduction

As the Photovoltaic (PV) industrial growing, new production lines were installed dramatically, resulting in vast excess capacity and falling returns on capital. Most of PV companies have negative return; cost reduction and quality improvement are the keys to make profit and stand better competitive position in future.

These new changes force cell manufacturers, especially those in mainland China, to adjust their extensive type of production to a lean one with better process design and control to be more competitive in both quality and cost. The progress in wafer sorting, such as the utilization of inline photoluminescence (PL) tools, allows cell manufacturers to group their incoming wafers into different categories based on their effective lifetime, impurities, defects, resistivity and other qualities. Intensive study in the past has proved that these wafer qualities have great impacts on the final cell efficiency [1–6]. There is chance to tune the cell process, e.g. diffusion, to reduce or minimize the negative impacts caused by wafer qualities [7–9]. Therefore, the possible wafer sorting provides opportunities to design and control different cell process for different incoming wafers to enable the best possible output in a lean production in future.

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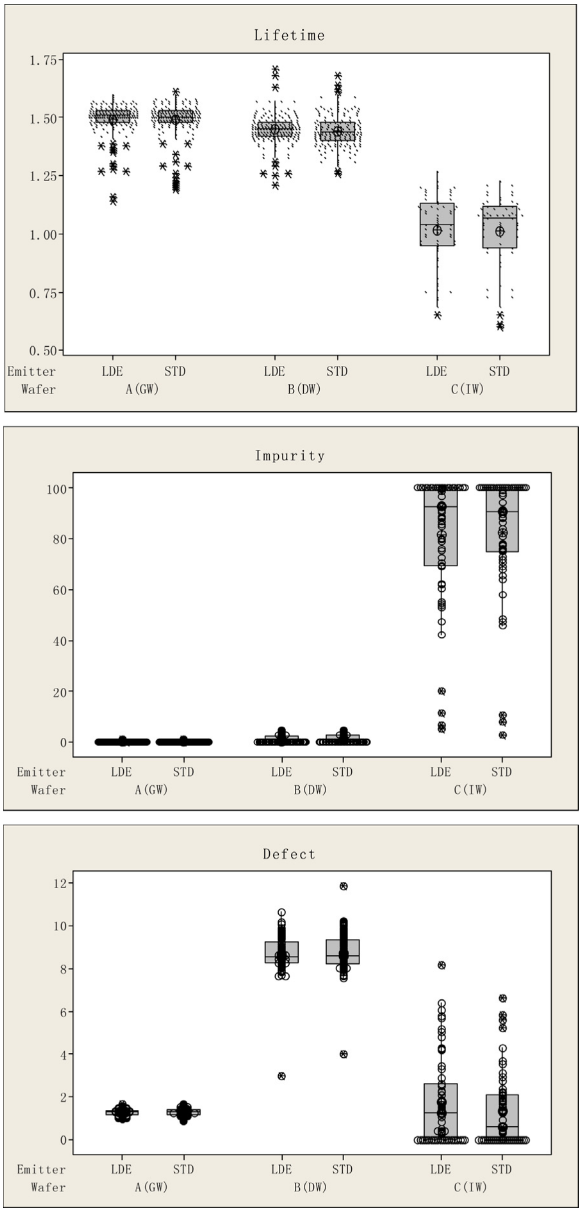

Fig. 1. The lifetime, impurity and defect distribution of test wafers.

In this paper, the correlation between wafer quality and cell efficiency was studied to identify the key impact factors, such as effective lifetime, impurities and defects. Different cell processes, e.g. diffusion, were then designed for incoming wafers with different qualities to maximize their power output. In this case, cell manufacturers could use different diffusion recipes to cater different incoming wafers with consideration of production throughput, wafer qualities and output distribution.

2. Experimental details

All samples were processed on boron doped multi-crystalline Si wafers, acquired from commercial production which uses directional solidification in a quartz crucible and consequent wire sawing. The size and thickness of the wafers are 156*156 mm (a pseudo-square) and $180 \pm 20\,\mu$m, respectively. For the reasons of better comparison, neighboring wafers were selected and divided into different sets according to the qualities, including lifetime, impurities and defects as shown in Fig. 1 and the typical wafer qualities were shown in Fig. 2 using PL. Yellow color represents impurity and blue color represent defect (mainly dislocation). Good wafer (GW) means high lifetime, low impurities and low defects; Impurity wafer (IW)