HIGH THROUGHPUT IN-LINE ACIDIC TEXTURISATION AND EDGE ISOLATION: AN INDUSTRIAL REALITY

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ABSTRACT: The University of Konstanz and RENA have developed processes and systems for inline acidic texturing and wet edge isolation. Both have shown good results in the lab under industrial conditions with large amounts of wafers. The purpose of this work is to verify the suitability of both processes for industrial application in terms of process stability. The results shown in this paper were gathered from mc-Si and Cz-Si solar cells on systems running in three-shift production with a capacity of 1800 wafers/h for 156 mm square wafers. The cells were processed with inline acidic texturing, inline oxide etching and wet edge isolation, using conventional phosphor diffusion, silicon nitride deposition and screen-printing processes. Both processes showed good results, reliability and stability. The optimization of the parameters allowed for bath life times of 150.000 wafers for the acidic texture and 1.500.000 wafers with the edge isolation process.

Keywords: Texturisation - 1, Edge isolation - 2, Manufacturing and processing - 3.

1 INTRODUCTION

In the past years a fast shift towards inline wet processing of solar cells has taken place. Two key processes for this development are the acidic texturing and inline edge isolation processes [1-3]. Acidic etching allows a sufficient saw damage removal in a much shorter time than with an alkaline solution, making this process ideal for inline processing. Most important, acidic etching also allows for texturing not only on mc-Si but also on Cz-Si cells, thus allowing a lower reflection and a higher J_{sc} compared to cells with alkaline saw damage etching.

The inline edge isolation avoids the stacking of cells and thus drastically simplifies the process flow. Moreover, the process allows the integration of the edge isolation and P-glass removal processes in one single inline tool, thus making the process flow even more efficient. The process ensures the electrical separation of the emitter by etching away the doped layer on the complete back side of the wafer. This way, no Al-BSF is any more required to compensate the parasitic doping on the back side of the cell. This eases the implementation of cell concepts using e.g. a passivated back side instead of an Al-BSF.

Both processes have already shown positive results on lab scale. The purpose of this work was to confirm the performance and verify the stability of the processes under mass production conditions.

2 EXPERIMENTAL SETTINGS

All the following results were produced using a standard industrial cell process: saw damage etching, diffusion, edge isolation, P-glass removal, silicon nitride deposition, printing, and firing. Saw damage removal was either carried out by alkaline etching or by acidic texturisation performed on RENA InTex tools. The reference groups for the edge isolation and P-glass removal processes were etched in stacks using plasma etching and batch type equipment. The inline edge isolation was performed on RENA InOxSide tools together with the P-glass removal.

Some data presented in this paper originate from experiments carried out on a lab scale or results gained from industrial production lines working under experimental conditions to guarantee a better control of the process environment. These trials were typically run with neighbouring wafers. Most of the results, however, were gathered from running production lines with a capacity of 1800 wafers/h. In this case, the wafers used were mostly not neighboured but coming from stacks of comparable quality, which still allows reliable comparison due to the very large amount of wafers used.

3 ACIDIC TEXTURING OF CZ-SI MATERIAL

The acidic texturing process is not dependent on the orientation of the crystal structure of the silicon. Therefore it allows the processing of both mc-Si and Cz-Si cells. However, the surface structure created by the acidic texturing process does not achieve such a good reflection and light trapping as random pyramids and therefore leads to a lower current than the KOH/IPA process.

Though, both lab and production results show the acidic process as a promising alternative to the alkaline texture process.

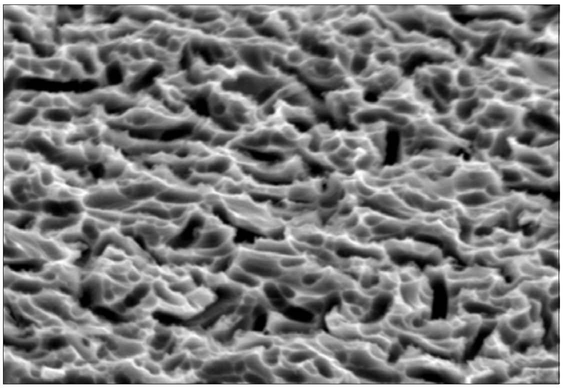

Figure 1: Surface of an acidic textured wafer.

3.1 Lab scale experiments

125 mm semi-square neighbouring Cz-wafers were processed at the University of Konstanz (UKON) using both alkaline and acidic texturing. The same comparative experiments were also carried out at a manufacturer’s site except for the acidic texturing step that was performed at UKON. The results of both experiments are summarised in tables 1 and 2.

Table 1: Comparison of alkaline texturing (40 cells) and acidic texturing (80 cells) at cell level. Cell processing carried out at UKON.

Texturing		FF %	J_{sc} mA/cm²	V_{oc} mV	Eff. %
KOH/IPA	mean	74.8	35.5	618.1	16.4
	s.d.	1.2	0.2	1.5	0.3
InTex	mean	76.2	34.1	621.8	16.2
	s.d.	0.5	0.1	1.0	0.1
Absolute difference		1.4	-1.4	3.6	-0.2
Relative difference		1.9%	-3.9%	0.6%	-1.6%

Table 2: Comparison of alkaline texturing and acidic texturing (InTex) at cell level (100 cells each group) and at module level (72 cells each group). Cell processing carried out at a manufacturer’s site.

	FF %	J_{sc} mA/cm²	V_{oc} mV	Eff. %
Relative difference at cell level	2.0%	-4.7%	1.0%	-1.5%
Relative difference at module level	1.6%	-1.5%	0.8%	0.8%

Both experiments show very similar behaviour at cell level with a clear loss in current with the acidic textured cells. However, after encapsulation, the difference in current becomes less significant. On the other hand, the higher specific surface of the acidic textured cells allows for a better contact which is the probable cause of the higher FF with the acidic textured cells. Unlike the lower current, this influence remains also under glass. This way, the acidic textured cells show a slightly higher efficiency than the reference group.

3.2 Production data

Table 3 shows production data on 125 mm semi-square Cz-cells with acidic texturing using a 60 Ohm/sq emitter. The data demonstrate a very satisfactory production level.

Table 3: Production level with acidic texturing (InTex) on Cz-Si material (4.100 cells).

	FF %	Jsc mA/cm²	Voc mV	Eff. %
InTex	77.7	34.1	616	16.3

4 ACIDIC TEXTURING OF MC-SI MATERIAL

4.1 Semi-industrial scale experiments

Table 4 exhibits a comparison between alkaline saw damage etching and acidic texturing, carried out on an industrial production line under experimental conditions.

Table 4: Comparison of cell results for alkaline etched (2.000 cells) and acidic textured (1.000 cells) 156 mm square mc-Si wafers from the same ingots from three different wafer manufacturers with different qualities;
a) 50 Ohm/sq emitter, b) 60 Ohm/sq emitter.

	FF %	J_{sc} mA/cm²	V_{oc} mV	Eff. %	R_s mΩ	R_{sh} Ω
Alk. etching a)	76.6	31.9	607.4	14.9	4.4	56
InTex b)	76.8	32.9	605.6	15.3	3.5	58
Abs. difference	0.2	1.0	-1.8	0.4	-0.9	2

The results show a satisfactory increase in current and good suitability of the acidic textured cells for a 60 Ohm/sq emitter. The two maximum peaks in the efficiency distribution shown in Figure 2 are caused by the different materials used for the experiment. The best cells reached an efficiency of 16.1%.

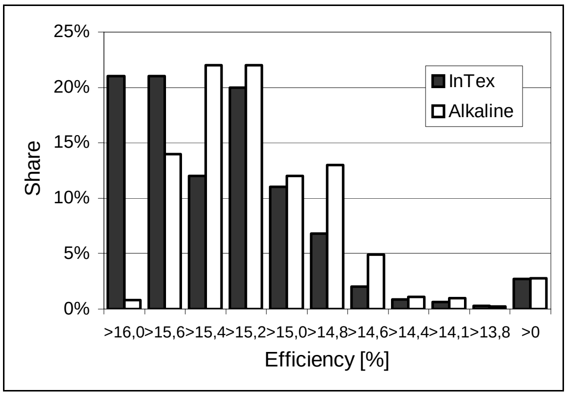

Figure 2: Comparison of cell results for alkaline etched (1.000) and acidic textured (1.000) 156 mm square mc-Si wafers out of the same ingots from three different wafer manufacturers with different qualities.

4.2 Production data

Also the production data presented in table 5 show a comparable gain in efficiency with the acidic etching process.

Table 5: Cell results for alkaline etched (42.100 cells) and acidic textured (45.500 cells) 156 mm square mc-Si wafers. Comparable material in both groups.

	FF %	Jsc mA/cm²	Voc mV	Eff. %
Alkaline etching	77.9	31.0	613	14.8
InTex	78.6	31.6	616	15.2
Abs. difference	0.7	0.6	3	0.4

The lower increase in current but higher gain in FF than in the preceding results are related to the intrinsic characteristics of the different silicon material but lead to a comparable raise in efficiency of 0.4%.

The increase in voltage is unexpected for an acidic texturing process but can be explained by the advanced metal cleaning implemented in the RENA InTex equipment. Again the improvement in fill factor is caused by the better contact on the acidic textured surface.

5 INLINE EDGE ISOLATION

The function of the inline edge isolation process is illustrated in Figure 3. The cells are transported on the surface of an etching bath in such a way, that only the back side of the wafers is wetted. This way, the emitter is completely removed from the back side of the wafer, thus electrically separating both sides of the cell. Accurate fluid and process control allow for leaving the top side of the cell dry while the back side is being etched, making sure that the emitter is not damaged.

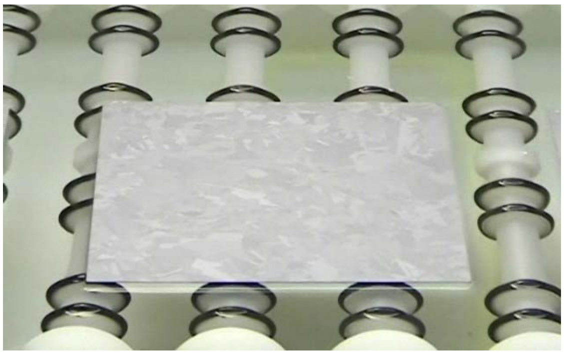

Figure 3: Function of the InOxSide process.

Tables 6 to 8 show the results obtained in production on mc-Si and Cz-Si acidic textured wafers.

Table 6: Cell results for plasma etching (1.000 cells) and wet chemical edge isolation (1.000 cells) of acidic textured 156 mm square mc-Si neighbouring wafers from three different wafer manufacturers with different qualities.

Edge isolation	FF %	J_{sc} mA/cm²	V_{oc} mV	Eff. %	R_s mΩ	R_{sh} Ω
Plasma etching	76.1	33.05	605.4	15.2	3.8	31.3
InOxSide	76.8	32.9	605.6	15.3	3.5	57.7
Abs. difference	0.7	-0.15	0.2	0.1	-0.3	26.4

Table 7: Cell results for plasma etching (4.000 cells) and wet chemical edge isolation (4.000 cells) of acidic textured 156 mm square mc-Si neighbouring wafers from the same ingots.

Edge isolation	FF %	J_{sc} mA/cm²	V_{oc} mV	Eff. %
Plasma etching	77.3	32.5	605	15.2
InOxSide	77.4	32.9	606	15.4
Abs. difference	0.1	0.3	1	0.2

Table 8: Cell results for plasma etching (16.000 cells) and wet chemical edge isolation (2.400 cells) of acidic textured 156 mm square Cz-Si wafers. Comparable material in both groups.

Edge isolation	FF %	J_{sc} mA/cm²	V_{oc} mV	Eff. %
Plasma etching	74.6	34.8	611	15.9
InOxSide	74.9	35.2	614	16.2
Abs. difference	0.3	0.4	3	0.3

All comparisons show an increase in efficiency with the InOxSide process resulting from a better edge isolation performance and therefore better fill factor. The achievable gain in FF and the possible gain in current are mainly dependent on the settings and performance of the reference plasma edge isolation process.

Combining inline acidic texturing with edge isolation a short current density of 35.2 mA/cm² was achieved.

Table 9 shows a lab scale comparison on alkaline etched Cz-Si wafers. With a shunt resistance of 110 Ω on 125 mm semi square cells, the InOxSide system reaches an average isolation performance of over 17 kΩcm.

Table 9: Cell results for plasma etching (100 cells) and wet chemical edge isolation (100 cells) of acidic textured 125 mm semi-square neighbouring Cz-wafers. Processing at manufacturer's site except InOxSide step at UKON.

Edge isolation	FF %	J_{sc} mA/cm²	V_{oc} mV	Eff. %	R_s mΩ	R_{sh} Ω
Plasma etching	73.6	34.82	613.0	15.7	7.9	30
InOxSide	74.8	34.57	611.3	15.8	7.7	110
Abs. difference	1.1	-0.26	-1.7	0.1	-0.2	80

6 PROCESS STABILITY

Figure 4 monitors the etch depth during the acidic texturing process over a complete bath lifetime.

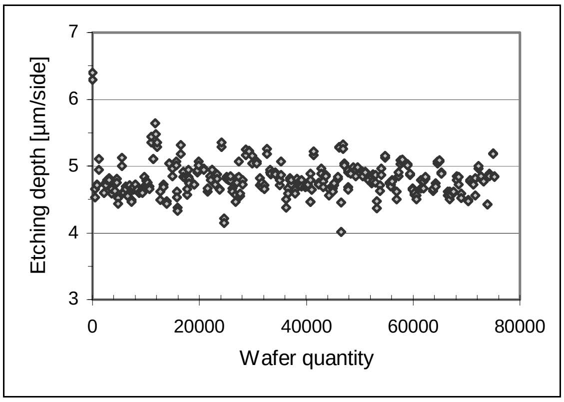

Figure 4: Etching depth in acidic texturing of mc-Si wafers.

Results verify an excellent stability over several days of processing up to a lifetime of 75.000 cells.
Table 10 summarises the achieved bath lifetimes and chemical consumption for both the acidic texturing and edge isolation processes.

Table 10: Bath lifetime and chemical consumption for acidic texturing (InTex) and edge isolation (InOxSide).

Process	Number of etched wafers over bath lifetime	Acid consumption per wafer (156 mm square)
InTex	150.000	12 ml
InOxSide	1.500.000	1 ml

In both cases accurate temperature control and replenishment settings allow for high bath life times. This has a major positive influence on the equipment uptime and is a proof for the high stability of the process: the edge isolation process can be run over several weeks without need for a bath change.

7 CONCLUSION

The inline acidic texturing was successfully implemented with 60 Ohm/sq emitters. It also shows very satisfactory performance on Cz-Si material.
The inline edge isolation process exhibited outstanding process results on acidic textured material and also promising results on alkaline textured Cz-Si cells achieving shunt resistances over 17 kΩcm². Combining inline acidic texturing with edge isolation current densities as high as 35.2 mA/cm² were reached.

Moreover, both processes show excellent process stability, achieving bath lifetimes of 150.000 and 1.500.000 cells for the acidic texturing and inline edge isolation, respectively. This in conjunction with low chemical consumption of the processes makes them highly suitable for industrial three-shift high throughput applications.

8 REFERENCES

[1] A. Hauser et al., Proc. 3rd WCPEC, Osaka 2003.
[2] A. Hauser et al., 19th EU PVSEC, Paris 2004.
[3] F. Delahaye et al., 19th EU PVSEC, Paris 2004.