Fabrication of Selective Emitter Solar Cells

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ABSTRACT: A fabrication method for selective emitter solar cells was provided in this paper, and selective emitter solar cells were fabricated through this method with only one diffusion process. These solar cells were more potential than conventional BSF solar cells fabricated from the same silicon materials: their minority carrier lifetimes were much higher after oxidation, their average conversion efficiency was about 0.6 percentages higher, and their short wave spectral responses were better. All these proved that the method could be brought into industrial utilization.

KEY WORDS: Selective Emitter Solar Cell; Screen Print; One Diffusion Process

1. Introduction

Selective emitter has been proved to be an effective way to improve the conversion efficiency of solar cells [1]. Its advantages can be described as below [2]:

a) Improve the collection efficiency of light generated carriers because there are lateral junctions beneath metal contacts.

b) Reduce the contact resistance between the semiconductor and metals because those semiconductor regions under metal contacts have heavily doped.

c) Decrease front surface recombination velocity because those active semiconductor regions (non - contact regions) have lightly doped.

d) Result in good short wave spectral responses because there are thin "death layers" in those lightly doped active semiconductor regions (non - contact region).

Therefore the output performances of selective emitter solar cells are improved, so are the conversion efficiencies.

Many fabrication methods for selective emitter are available nowadays. But a simplified, effective, and low cost method is still not available for industrial practices.

In this paper, based on the usual screen printed C - Si solar cells industrial processes, and adding one process of screen printing high concentration phosphorous pastes on to wafers before diffusion, selective emitter solar cells were fabricated with only one diffusion process, and relevant tests were also given.

2. Fabrication Processes

2.1 Processes

The wafers used in the experiments were made in China. They are (100) orientation and P type mono - crystalline Cz Silicon wafers, the area is 103mm ×103mm, resistivity ranges from 0.5 to 3.0Ω·cm, doping concentration is 5×10^{15} cm^{-3} - 5×10^{16} cm^{-3}, and the thickness is about 350μm. Many conventional BSF solar cells were also fabricated from the same silicon materials. Fabrication processes of the two types of solar cells were shown in Tab. 1.

Tab. 1 Fabrication processes of the two types of solar cells

	Selective emitter solar cells	Conventional BSF solar cells
1	Texturization and chemical clean	Texturization and chemical clean
2	Screen printing high concentration phosphorous pastes onto wafers	Diffusion in $POCl_3$ ambient
3	Diffusion in $POCl_3$ ambient	Removing PSG in HF solution
4	Removing PSG in HF solution	High temperature oxidation
5	High temperature oxidation	TiO_2 deposition by APCVD
6	TiO_2 deposition by APCVD	Screen printing front and back contacts
7	Screen printing front and back contacts	Contacts co - firing
8	Contacts co - firing	Edge junctions removing by laser
9	Edge junctions removing by laser	

The diffusion process was very important. Phosphorous pastes were screen printed onto wafers before diffusion just alike metal contacts, and phosphorous concentration in the pastes were about $10^{20}cm^{-3}$. In order to form selective emitters, the total diffusion time had to be divided into two parts: t_1 and t_2, and the diffusion temperature were different in the two parts of diffusion. Here, t_1 is the time when $POCl_3$ is delivered into the diffusion furnace, and t_2 is the time when no $POCl_3$ is delivered.

2.2 Diffusion Results

After anodic oxidation and removing SiO_2 in HF solution, square resistances were measured by a four - point probe system and conduction types were also measured by a cold - hot probe system. As those regions onto which phosphorous pastes had been screen printed before diffusion were different from other regions, those regions could be defined as "printed regions" and other regions as "non - printed regions". "Printed regions" and "non - printed regions" were respectively measured during the experiments.

Tab. 2 Square resistances (Ω/ □) and conduction types (n or p) of the wafers

Removing thickness (μm)	Printed regions Ω/ □, n & p	Non - printed regions Ω/ □, n & p
0	19, n	81, n
0.043	31, n	122, n
0.086	40, n	190, n
0.129	52, n	264, n
0.172	75, n	370, n
0.215	93, n	545, n
0.258	108, n	794, n
0.301	147, n	1113, n
0.344	198, n	1425, n
0.387	267, n	65, p
0.430	397, n	46.4, p
0.473	523, n	45.8, p
0.516	788, n	45.7, p
0.559	1497, n	45.4, p
0.602	3785, n	46.3, p
0.645	150, p	46.1, p

As shown in Tab. 2, after diffusion, square resistances of the "printed regions" were about 19Ω/ □ and their diffusion depths were about 0.60μm, and square resistances of the "non - printed regions" were about 81Ω/ □ and their diffusion depths were about 0.34μm. But those data in Tab. 2 were not very precise, because "printed regions" and "non - printed regions" interacted during measurement, there must be some errors in the results. But the differences of "printed regions" and "non - printed regions" were very clear in Tab. 2. So, selective emitters had been obtained.

3. Measurement and Test

3.1 Minority Carrier Lifetimes

The minority lifetimes of semi finished solar cells were measured after diffusion process and oxidation process by a method of quasi steady state photoconductor (QSSPC), and data were shown in Tab. 3. The instrument was the WCT - 100 lifetime tester of the American Sinton Consulting Company.

Tab. 3 Lifetimes of the two types of semi finished solar cells

Cell types	samples	After diffusion (μs)	After oxidation (μs)
Selective solar cells	S1	14.36	26.72
	S2	14.41	28.91
Conventional BSF solar cells	C1	11.95	15.94
	C2	12.04	16.47
	C3	11.58	16.98

As shown in Tab. 3, the minority lifetimes of selective emitter solar cells were much higher than that of conventional BSF solar cells. This implied that the performances of selective emitter solar cells were better than that of conventional BSF solar cells.

3.2 Spectral Responses

Spectral responses of the two types of solar cells were measured. As shown in Fig. 1, the spectral response of selective emitter solar cells was better than that of conventional BSF solar cells when wavelength ≤750 nm.

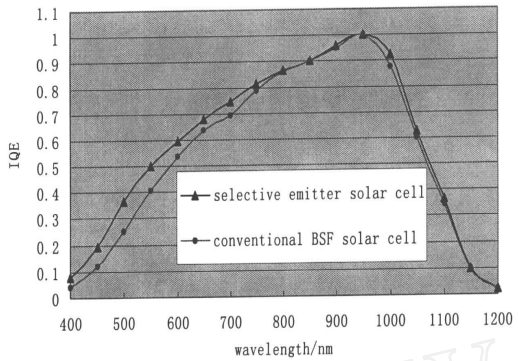

Fig. 1 Spectral responses of the two types of solar cells

3.3 Electricity Parameters

Electricity parameters of the two types of solar cells were measured, and data were shown in Tab. 4 and Tab. 5. Their average results were shown in Tab. 6.

As shown in Tab. 4 and Tab. 5 and Tab. 6, the performances of selective emitter solar cells were better than that of conventional BSF solar cells, and the average conversion efficiency of selective solar cells was about 0.6 percentages higher than that of conventional BSF solar cells.

Tab. 4 Electricity parameters of conventional BSF solar cells

samples	V_{oc} (mV)	J_{sc} (mA/cm^2)	F. F. (%)	EFF. (%)
c1	593	29.86	76.5	13.6
c2	595	29.82	78.1	13.9
c3	595	29.86	76.9	13.7
c4	595	29.47	77.3	13.5
c5	598	29.69	75.5	13.4

Tab. 5 Electricity parameters of selective emitter solar cells

samples	V_{oc} (mV)	J_{sc} (mA/cm^2)	F. F. (%)	EFF. (%)
s1	602	30.38	76.4	14.0
s2	603	30.71	77.6	14.4
s3	603	30.60	77.7	14.3
s4	602	30.36	77.6	14.2
s5	602	30.53	77.1	14.2
s6	600	30.24	78.0	14.2
s7	603	30.62	77.3	14.3
s8	603	30.40	78.0	14.3

Tab. 6 Averages of the electricity parameters of the two types of solar cells

Cell types	V_{oc} (mV)	J_{sc} (mA/cm^2)	F. F. (%)	EFF. (%)
Conventional BSF solar cells	595.2	29.74	76.86	13.62
Selective emitter solar cells	602.3	30.48	77.46	14.24
Differences	7.1	0.74	0.6	0.62

4. Discussion

Higher minority lifetimes and better short wave spectral responses indicated that there are less recombination and lower front surface recombination velocity in front diffusion layers of selective emitter solar cells than in conventional BSF solar cells. This was because the active regions (non-contacts regions) of selective emitter solar cells had lightly doped. Larger fill factors are because the regions beneath metal contacts in selective emitter solar cells had heavily doped. Higher open circuit voltages and higher short circuit currents are because the lateral junctions beneath metal contacts contribute to the collection of light generated carriers. In the experiments, the highest conversion efficiency was not more than 15%, this was because that the substrate wafers are not very good.

5. Conclusion

Selective emitter solar cells could be fabricated by the above-mentioned method. And there is only one more process in the fabrication method than an usual industrial method, that is screen printing high concentration phosphorous pastes on to wafers before diffusion, therefore, without much more complexities and with some economic advantages, the fabrication method could be brought into industrial utilization.

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选择性发射极太阳电池的制作*

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摘　要: 文章提供了一种一次扩散制作选择性发射极太阳电池的方法,并利用该方法制作了选择性发射极太阳电池。这种方法所制得的选择性发射极太阳电池比用同种硅材料制得的常规 BSF 太阳电池具有较大的优势:在氧化工艺后,其少子寿命比常规 BSF 太阳电池的高,其平均光电转换效率也高出 0.6 个百分点左右,而其短波段的光谱响应优于常规 BSF 太阳电池。最后指出了这种方法可以实现选择性发射极硅太阳电池的工业化生产。

关　键　词: 选择性发射极太阳电池;丝网印刷;一次扩散

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