Renewable Energy Research Center

Development of high efficiency PERC cell

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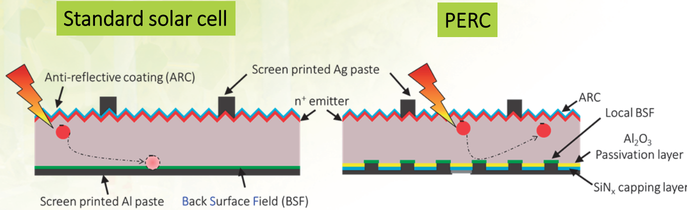
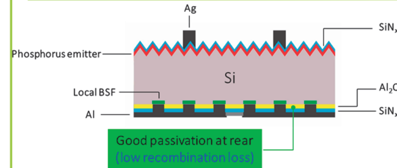
1. Passivated Emitter Rear Cell (PERC)



PERC technology

The concept of advanced silicon-based solar cells with a dielectric passivation layer at the rear of the cell is one of the most promising structures for changing the conventional cell into a more-efficient passivated emitter rear contact (PERC) cell. The presence of a passivation layer at the rear of the cell permits low surface-recombination velocities, a steadier flow of electrons, and an improved performance. Consequently, excellent rear-surface passivation is essential, and is one of the most important issues in improving the efficiency of PERC structures.

2. Excellent rear-surface passivation (How to?)



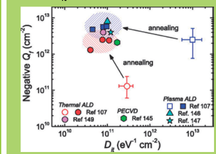
AlO_x

Surface passivation technology
1. Atomic layer deposition or ALD (In-house)
2. Reactive sputtering (SCREEN Company)

SiN_x

Surface passivation technology
1. PECVD (In-house)

Influence of annealing on the Q_f and D_{it} at temp. of 400C. [1]



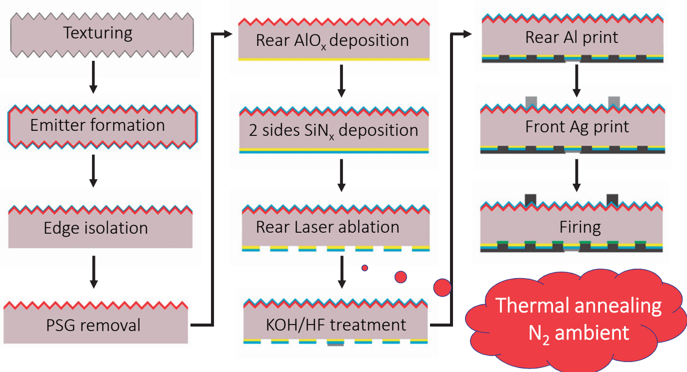
Post-deposition annealing (PDA) is essential to activate the chemical and field-effect passivation mechanisms of Al_2O_3 on the Si surface.

Objective

To clarify the effects of PDA on surface passivation of ALD Al_2O_3 films for Si-based PERC solar cells. A possible mechanism underlying the effect of thermal annealing on electrical activity is discussed, particularly in terms of field-effect passivation based on the flat-band voltage shift, an understanding of which is necessary to achieve further improvements in PERC technology.

[1] Dingemans G, and Kessels WMM. J. Vac. Sci. Technol. A 2012; 30: 040802.

3. PERC cell processing

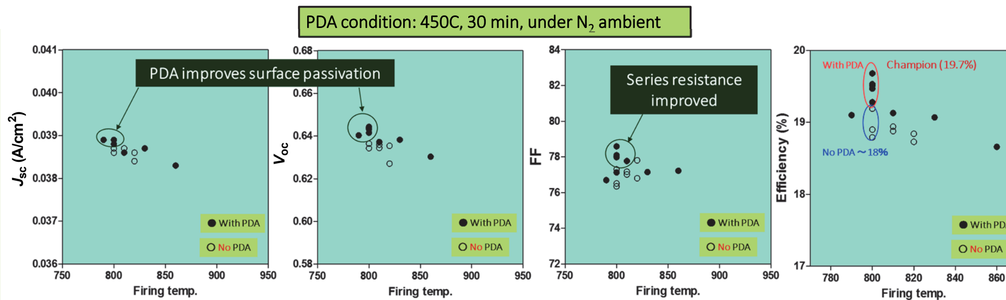


4. Experimental details

- CZ-Si (156 mm × 156 mm × 200 µm), 2.3 to 2.9 Ω·cm
- AlO_x passivation technologies
  - ALD (20 nm)
  - Deposition temperature: 200C
- Post-deposition annealing (PDA) temperature
  - 450C, 650 C
- PECVD-SiN_x films
  - deposition temp. at 450 C
  - Reflective index = 2.1
  - 190 nm thick at rear, 80 nm thick at front
- Thermal treatment conditions
  - Under N_2 ambient
  - 450C for 30 min

5. Results and discussion (Effect of PDA on surface passivation and PERC cell performance)

PDA condition: 450C, 30 min, under N_2 ambient

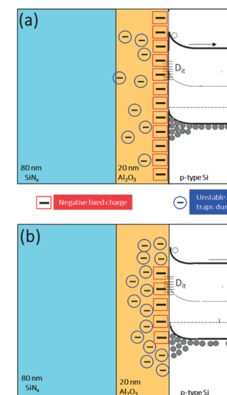


- PDA process improves surface passivation, as indicated by J_{sc} as well V_{oc} values.
- FF value increased upon PDA applied, indicating that series resistance is improved.
- A suitable firing temperature is about 800C, and cell performance decreases as increasing firing temperatures.
- A PDA for 30 min at 450 C under N_2 was required to obtain a high level of surface passivation for ALD-Al_2O_3 films, owing to local reconstruction of the Al_2O_3, and the consequent increase in the density of negative fixed charges (Q_f) at the interface [2, 3].

[2] Joonwichien S. *et al.*, Energy Procedia (2016).To be published
[3] Hoex B. *et al.*, Appl. Phys. Lett. 2006; 89: 042112.

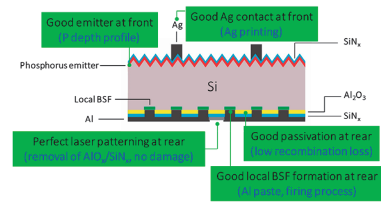
6. Possible mechanism

Ideal schematic illustrations of the surface band diagrams of p-type silicon with (a) PDA, and (b) without PDA. [2]



A possible mechanism: thermal annealing under certain conditions is crucial for full activation of field-effect passivation; this is directly related to the formation of a negative fixed charges, which can assist in repelling electrons in the conduction band (p-type). When accompanied by a strong hole-accumulation layer at the valence band, a reduction in the surface-recombination velocity can occur.

7. Rooms for improvement



8. Summary

- We investigated the effects of PDA on the performance of PERC cells in order to improve the quality of surface passivation.
- It is found that PERC cell performance is improved after introducing to PDA under dry N_2 annealing, accorded to the full activation of field-effect passivation, resulting in a lower surface recombination velocity, which can be realized with increased J_{sc} and V_{oc} values.
- It is assumed that the more negatively charged traps originating from the steam are created in the ALD-Al_2O_3 films giving rise to an upward more in band bending.
- These results suggest that consideration of thermal annealing process is crucial for improving the quality of passivation stacks at rear side and is then high performance of PERC cell.