Effect of Aluminum in Metallization Paste on the Electrical Losses in Bifacial N-type Crystalline Silicon Solar Cells

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**Outline**

- **Motivation**
  - Problems in metallization with paste
  - In the case of Ag/Al metallization for n-type solar cells
  - Conventional evaluation for pastes

- **Evaluation method**
  - “Floating contact method”

- **Test pastes**
  - Homemade three test pastes

- **Aluminum effects on n-type solar cells**
  - Electrical losses ... $V_{oc}$, $R_{sh}$, $J_{02}$
  - Interface morphology between contact and Si wafer

- **Conclusion**
Problems in metallization with paste

Screen-printing with conductive paste

- simple process and cheaper cost

...Loss in $V_{oc}$ ⇒ Severe limit of cell efficiency!
Problems in Ag/Al metallization

Ag/Al paste: \textit{Al} addition $\Rightarrow$ “Good” contact to $p^+$-emitter

- Shunting?
- Recombination?

$\Rightarrow$ Complex composition

It’s still a big question how glass frit and aluminum affect?

The purpose of our study...

\textbf{To elucidate the specific effects of Al}
Conventional evaluation for pastes

= Complex system

Indirect method
to evaluate respective effects of materials in paste

The conventional method cannot divide effects of glass frit and Al on cell parameters, accurately.

How can we elucidate “specific” effects of Al?
“Floating contact method”

Standard H-pattern grid-contact

Floating contacts

- electrically and geometrically isolated from grid-contact
- effects on an emitter

Floating contact “fraction”...

- Conductive ✓
- Nonconductive ✓
- Non-contact ✓

...Al less Ag past to p⁺-emitter

Advantages

0% 5% 11% 16%

Test pastes

- To elucidate specific effects of aluminum on p⁺-emitter

Floating contacts:

Three test pastes

1. Only-Ag
2. Ag/glass
3. Ag/glass/Al

Glass frit: PbO-SiO₂-B₂O₃-ZnO

H-pattern grid contact:
Ag/Al paste

Boron doped p⁺ emitter 70Ω/sq.
156mmx156mm n-type c-Si
Phosphorus doped n⁺ BSF 40Ω/sq.

Standard Ag paste

Effect of glass frit
Effect of Al
The cell parameters are good enough to evaluate the effects of floating contacts.
Conductive paste causes loss in $V_{oc}$ in n-type solar cells even if the paste does not contain aluminum.
Al mitigates generation of Ag-crystallites and their growth
Adding Al causes forming the large spike

- Shunting? , Recombination?
- Fewer shallower
Al mitigates the current increase at low voltage range.

Numerical fitting with the two-diode model \( \Rightarrow R_{sh}, J_{02} \)
Al in Ag/Al paste does not induce significant shunting
Recombination current, $J_{02}$

Al mitigates the increase of recombination current
The Al effects on Ag-crystallite mitigates the decrease of $R_{sh}$ and the increase of $J_{02}$.

The large spikes do not induce the significant electrical losses.
Conclusion

“Specific” effects of Al on $p^+$-emitter can be elucidated by using the “floating contact method” with the homemade test pastes.

- Conductive paste causes loss in $V_{oc}$ in n-type solar cells even if the paste does not contain Al.
- Al in Ag/Al paste mitigates shunting of pn junction and carrier recombination on $p^+$-emitter by mitigating generation of Ag-crystallite and their growth.
- The big metallic spikes underneath Ag/Al paste do not induce significant shunting of pn junction and carrier recombination.

The “floating contact method” have big advantages for elucidating respective effects of paste component on cell parameters.
Thank you for your attention!

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