Effects of constituents in paste on low light performances of silicon solar cells: A case study of aluminum

Takayuki Aoyama¹, Mari Aoki², Isao Sumita²,

¹Noritake Co., Limited
²Asada Mesh Co., Ltd.

Corresponding author: takayuki_aoyama@n.noritake.co.jp
Outline

- Motivation
- Approach
  - Floating contact method
  - Aim of this study
  - Experimental setup
- Results
  - I-V characteristics at low light intensities
  - Summary: low light performances
- Conclusion
Motivation

Solar cell low light performances

- Ag powder
- Glass frit
- Aluminum
- Tellurium etc.

Paste constituents

Shunts, Recombination

- Dominant losses in solar cells
- Paste constituents strongly affect.

Important for power generation in the entire life cycle of solar cells
- Shunts strongly affect [1].

How paste constituents affect?
Floating contact method

...A good method to investigate effects of paste constituents

**Standard H-pattern “grid-contact”**
- For “only” measuring cell parameters
- Paste is fixed throughout experiments

**“Floating contacts (F.C.)”**
- Electrically and geometrically isolated
- Any constituents can be used
  - Conductive ✓ Nonconductive ✓ Non-contact

Effects of F.C.

- Dark I-V
- Light intensities
- Low light performance
- Shunts, Recombination

Floating contact method

A good method to investigate effects of paste constituents

**Standard H-pattern “grid-contact”**
- For “only” measuring cell parameters
- Paste is fixed throughout experiments

**“Floating contacts (F.C.)”**
- Electrically and geometrically isolated
- Any constituents can be used
  - Conductive ✓ Nonconductive ✓ Non-contact

Effects of F.C.

- Dark I-V
- Light intensities
- Low light performance
- Shunts, Recombination
Floating contact method

Floating contact area “fraction”

Effects of F.C. can be clearly shown by the fraction change.
Aim of this study

Common known function of aluminum:

✓ Making “back surface field”
✓ Contact for p type silicon e.g.) silver/aluminum paste

Another effect of aluminum:

✓ Mitigation of shunts and recombination in silver/aluminum paste

Its effects on silver and/or glass frit in paste

Our focus:

Effects of aluminum on glass frit itself

➢ Low light performances
➢ Shunts and recombination

Experimental setup

Solar cells: n-PERT

- Grid-contact: Ag/Al paste
- SiNₓ/SiO₂
- p⁺ emitter (70Ω/sq.)
- n⁺ BSF (40Ω/sq.)
- n-type Si (156 x 156 mm²)
- Ag paste

Characterization

- Illuminated I-V measurement (1.0, 0.6, 0.2, and 0.1 sun)
- Dark I-V measurement: shunts and recombination

Floating contacts:

- No F.C.
- Ag-only paste: No glass frit
- Glass frit paste [1]:
  - Frit only
  - PbO-SiO₂-B₂O₃-ZnO
- Glass-Al paste:
  - Aluminum added glass frit paste

Light intensity affects cell parameters: $J_{sc}$, $V_{oc}$, FF, and $R_s$.

Cell parameters at low light intensity depend on paste of F.C.

- Ag-only paste affects $J_{sc}$ only.
- Glass frit paste significantly decreases Voc.
- Aluminum mitigates the Voc decrease.
Low light performances: Eff.

**Relative-Eff.**

\[
\frac{\text{Eff. with F.C.}}{\text{Eff. with no F.C.}} \text{ at each light intensity}
\]

- Glass frit drastically decreases relative-Eff., depending on at low light intensities.
- Aluminum mitigates the elevated decreasing rate.

**Causes:** Voc and FF (Rs)
Relative-$V_{oc}$: \[ \frac{V_{oc \ with \ F.C.}}{V_{oc \ with \ no \ F.C.}} \]

at each light intensity

- **Glass frit paste**:
  - Relative-$V_{oc}$ significantly decrease.
  - The decreasing rate is enlarged at the lower light intensities.

- **Glass-Al paste**:
  - Aluminum can mitigate the enlarged decreasing rate.

---

**Low light performances: Voc**
Relative-$R_s$

- Relative-$R_s$ increases with increasing the fraction.
- The increasing rate for glass frit paste increases with decreasing light intensity.
- Aluminum can mitigate the increasing rate due to glass frit paste.
Summary: low light performances

- Glass frit paste much degrade Eff. at lower light intensities, which comes from Voc and FF (Rs).
- Aluminum can mitigate the degradation.

These results come from dark I-V characteristics: shunts and recombination.

- Aluminum: mitigation of hump current
  - Shunt current, recombination current

[Graph showing current density vs. applied voltage for different pastes and conditions]
Conclusion

Effects of aluminum on glass frit for low light solar cell performances and dark I-V characteristics were investigated.

✓ Aluminum mitigates the degradation of low light performances due to glass frit by decreasing the shunts and/or recombination.

Effects of paste constituents on shunts and recombination are much important not only for solar cell performances at 1 sun, but also for the performances at low light intensity.
Thank you for your kind attention!