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

Takayuki Aoyama[1], Mari Aoki[2], Isao Sumita[2],

[1]Noritake Co., Limited

[2]Asada Mesh Co., Ltd.

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

Outline

Noritake

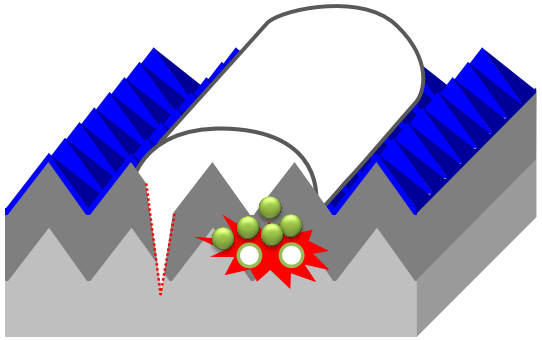
- **Motivation**
- **Approach**
  - Floating contact method
  - Aim of this study
  - Experimental setup
- **Results**
  - I-V characteristics at low light intensities
  - Summary: low light performances
- **Conclusion**

Motivation

Paste constituents

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

Shunts, Recombination



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

shunts

Solar cell low light performances

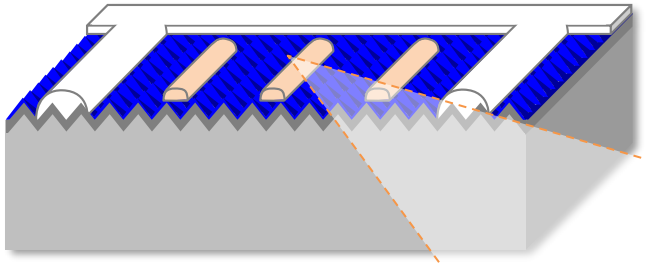
- ✓ Important for power generation in the entire life cycle of solar cells
- ✓ Shunts strongly affect [1].

How paste constituents affect ?

[1] Gabriela E. Bunea et al., in Proc. 4th WCPEC, 2006, p. 1312.

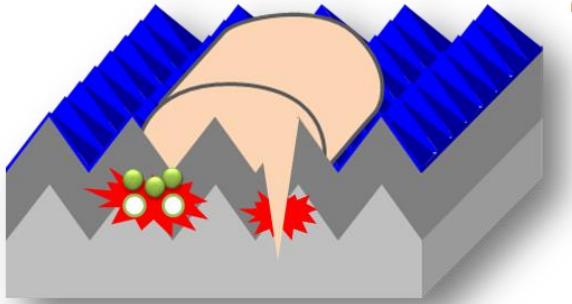
Floating contact method

…A good method to investigate effects of paste constituents



Standard H-pattern "grid-contact"

- For "only" measuring cell parameters
- Paste is fixed throughout experiments

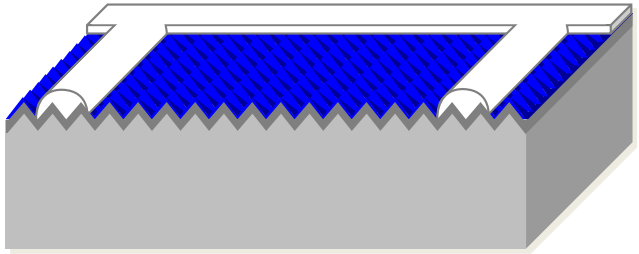


"Floating contacts (F.C.)"

- Electrically and geometrically isolated
- Any constituents can be used

✓Conductive ✓Nonconductive ✓Non-contact

Effects of F.C.

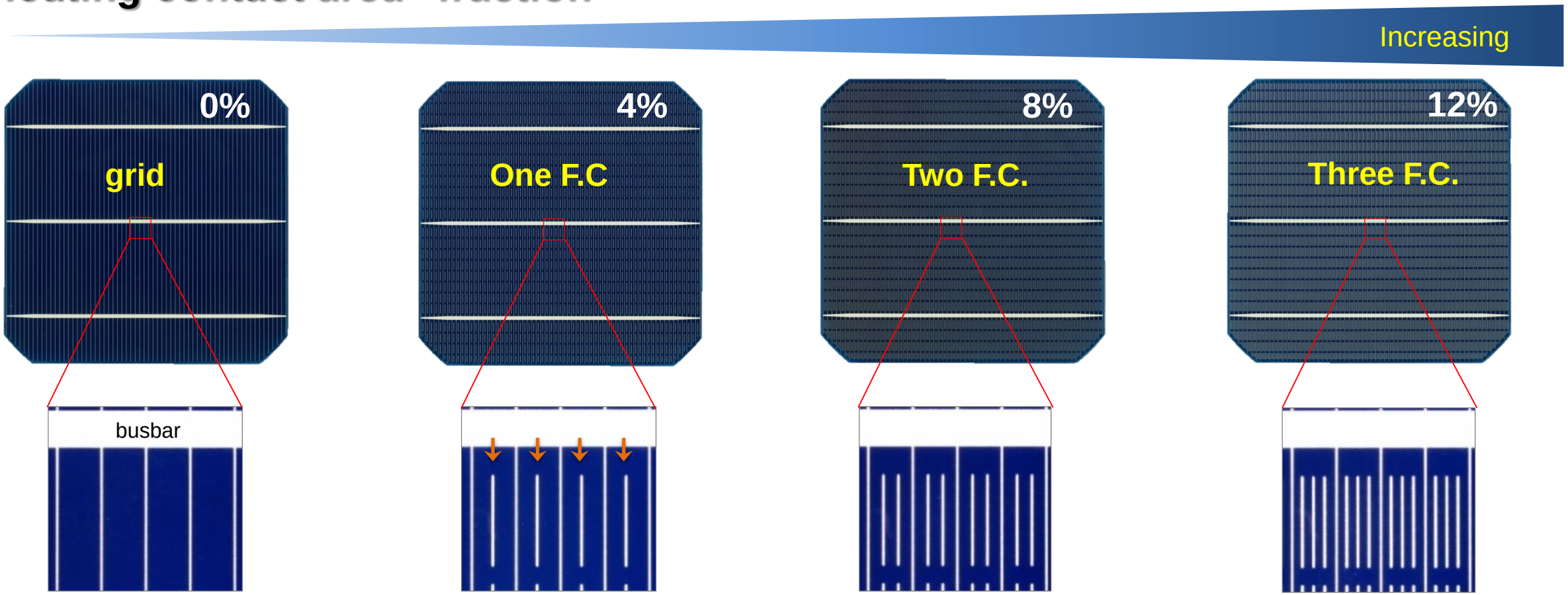


Dark I-V → Shunts, Recombination

Light intensities → Low light performance

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:

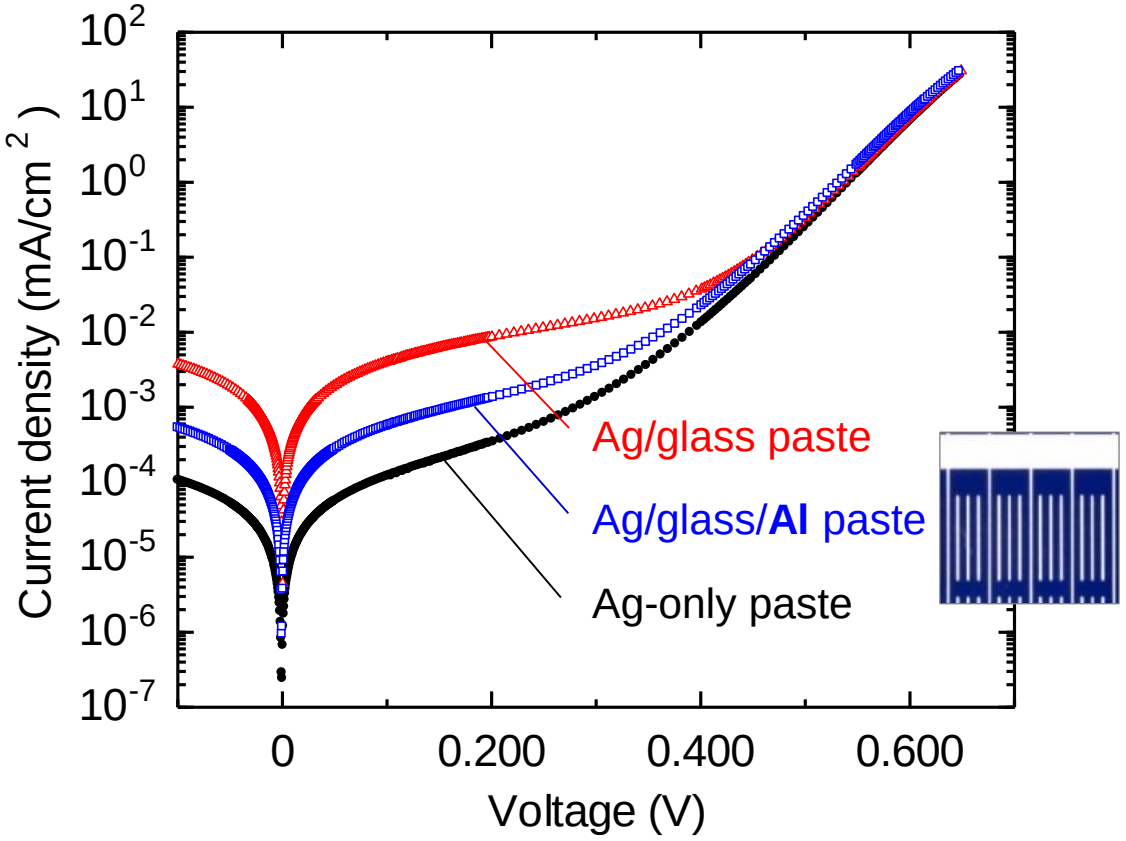
- ✓ Mitigation of shunts and recombination in silver/aluminum paste

Its effects on silver and/or glass frit in paste

Our focus:

Effects of aluminum on glass frit itself

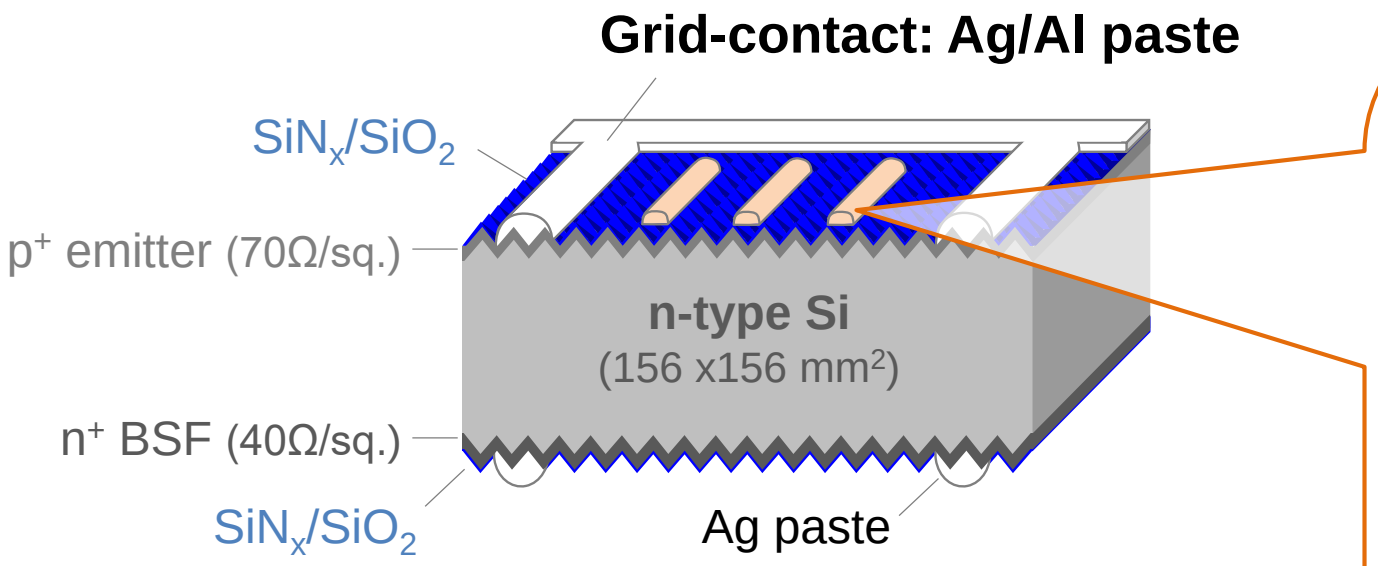
- ➢ Low light performances
- ➢ Shunts and rerombination



T. Aoyama *et al.*, *Energy Procedia*, vol. 98, pp.106, 2016

Experimental setup

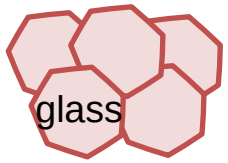
Solar cells: n-PERT



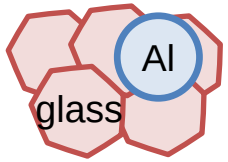
Floating contacts:

- No F.C.
- Ag-only paste:
  No glass frit

- Glass frit paste [1]:
  Frit only
  $PbO-SiO_2-B_2O_3-ZnO$



- Glass-Al paste:
  Aluminum added glass frit paste

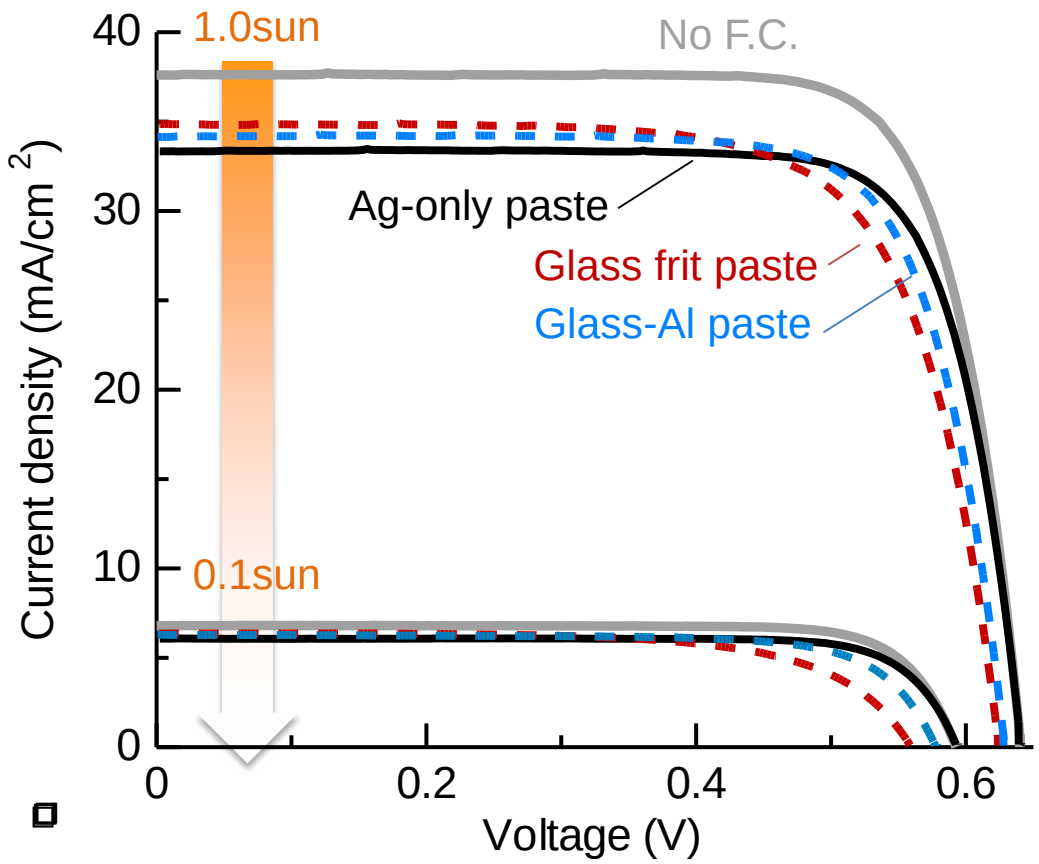


Characterization

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

[1] T. Aoyama, et al" *IEEE J. Photovolt.*, vol.7, p. 1313, 2017.

I-V curves at low light intensities



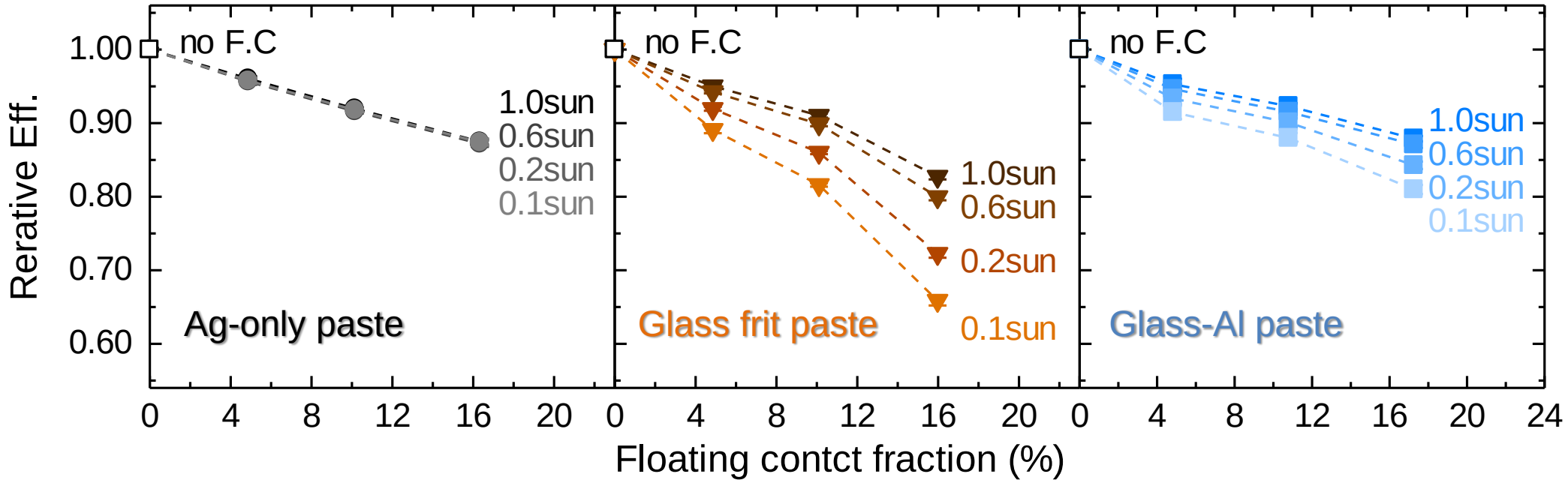
- ✓ Light intensity affects cell parameters: Jsc, Voc, FF, and Rs.
- ✓ Cell parameters at low light intensity depend on paste of F.C.

e.g.)

- Ag-only paste affects J_{sc} only.
- Glass frit paste significantly decrease Voc.
- Aluminum mitigates the Voc decrease.

Low light performances: Eff.

Relative-Eff. : $\frac{Eff.\ with\ F.C.}{Eff.\ with\ no\ F.C.}$ *at each light intensity*

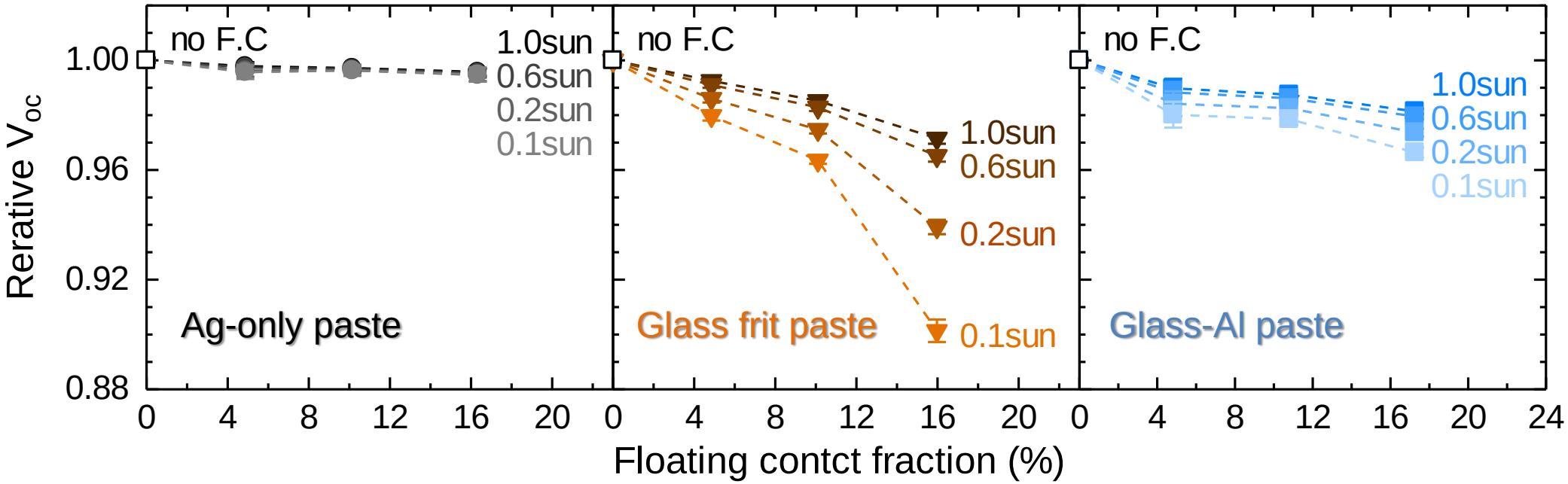


- ✓ Glass frit drastically decreases relative-Eff., depending on at low light intensities.
- ✓ Aluminum mitigates the elevated decreasing rata.

⇒ Causes: Voc and FF (Rs)

Low light performances: Voc

Relative-V_{oc} $: \frac{Voc\ \ with\ F.C.}{Voc\ with\ no\ F.C.}$ *at each light intensity*



Glass frit paste

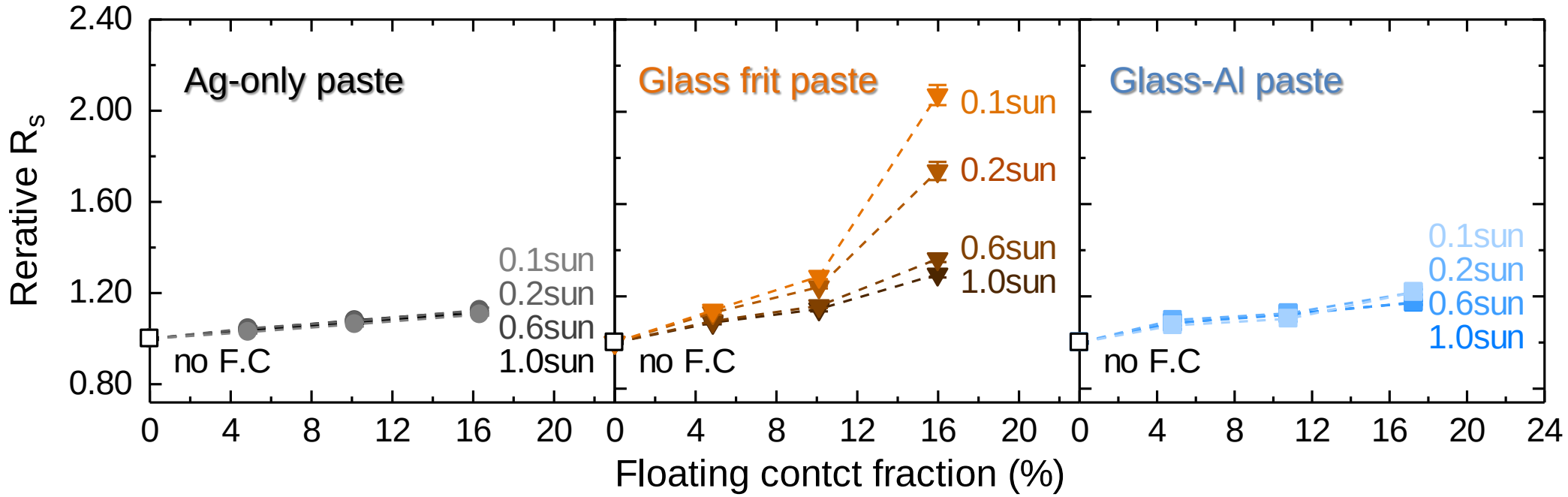
- ✓ Relative-V_{oc} significantly decrease.
- ✓ The decreasing rate is enlarged at the lower light intensities.

Glass-Al paste

- ✓ Aluminum can mitigate the enlarged decreasing rate.

Low light performances: Rs

Relative-R_s $: \frac{Rs\ \ with\ F.C.}{Rs\ with\ no\ F.C.}$ *at each light intensity*

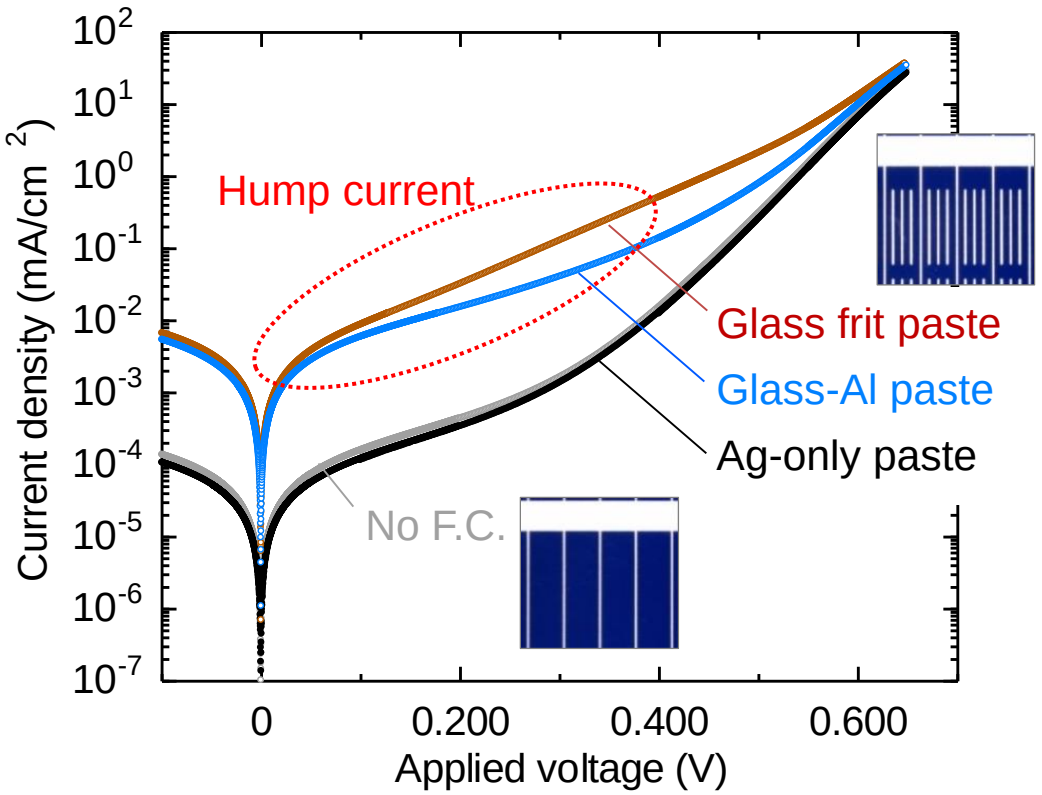


- ✓ Relative-R_s increases with increasing the fraction.
- ✓ The increasing rate for glass frit paste increases with decreasing light intensity.
- ✓ Aluminum can mitigate the increasing rate due to glass frit paste.

Summary: low light performances

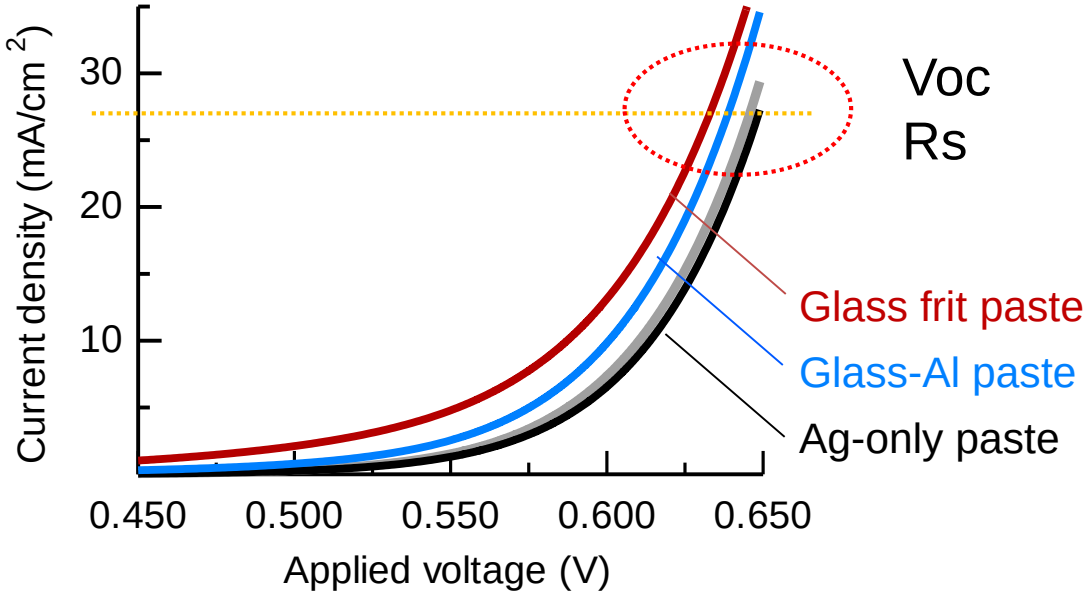
- ✓ Glass frit paste much degrade Eff. at lower light intensities, which comes from Voc and FF (Rs).
- ✓ Aluminum can mitigate the degradation.

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



✓ Aluminum: mitigattion of hump current

shunt current, recombination current



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 decraseing 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!

Noritake ASADA MESH CO.,LTD.