6th Metallization Workshop, Konstanz, Germany, 2016

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

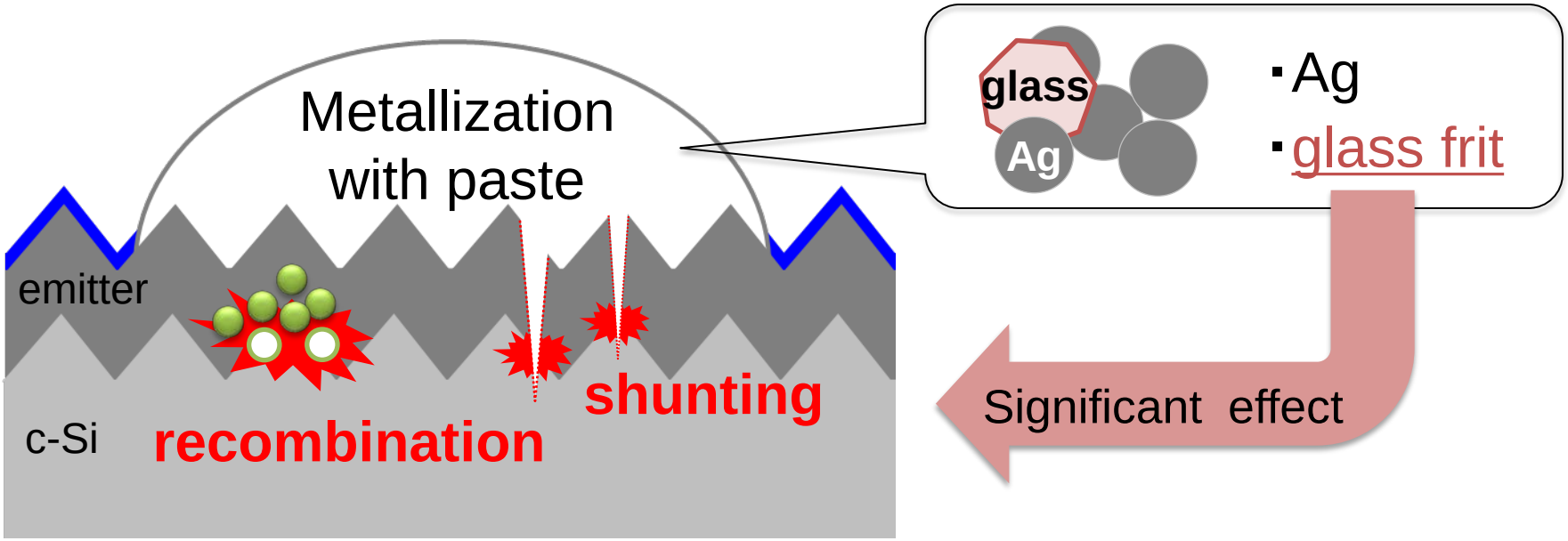
- Electrical losses … V_{oc}, R_{sh}, J_{02}
- Interface morphology between contact and Si wafer

Conclusion

Problems in metallization with paste

Screen-printing with conductive paste

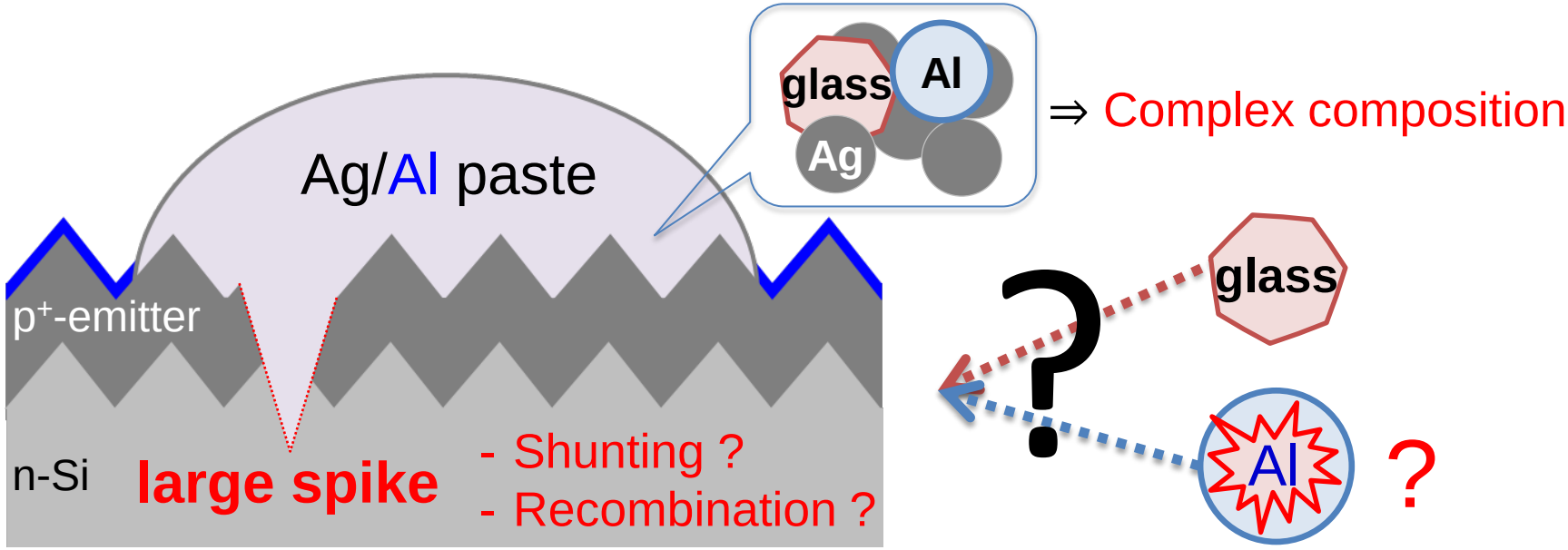
-simple process and cheaper cost



…Loss in V_{oc} ⇒ Severe limit of cell efficiency !

Problems in Ag/Al metallization

Ag/Al paste : Al addition ⇒ “Good” contact to p^+-emitter

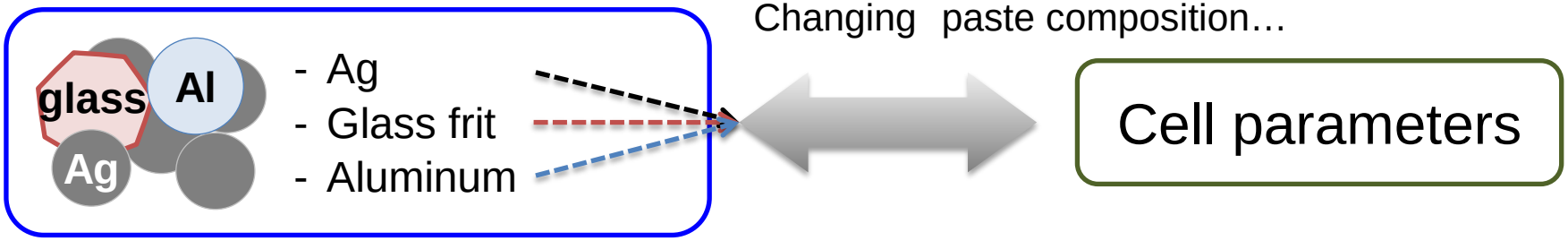


It’s still a big question how glass frit and aluminum affect ?

The purpose of our study…

To elucidate the specific effects of Al

Conventional evaluation for pastes



= Complex system

Indirect method

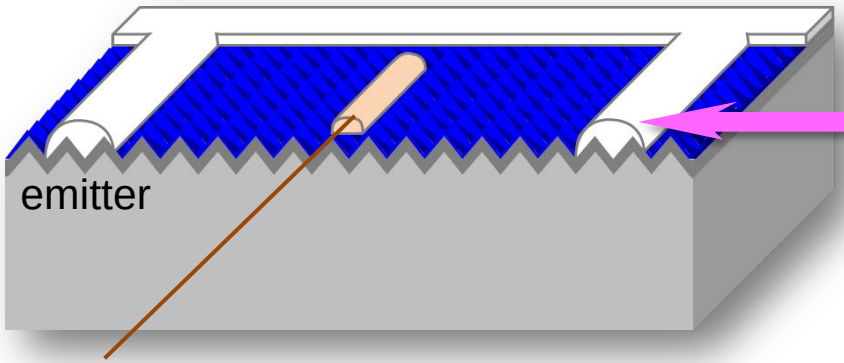
to evaluate respective effects of materials in paste

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

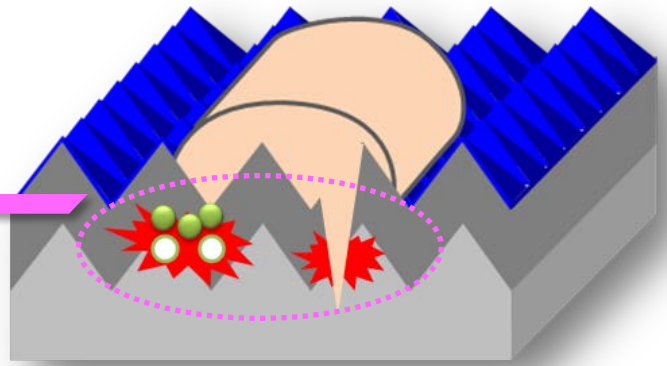
How can we elucidate "specific" effects of Al ?

“Floating contact method”

Standard H-pattern grid-contact



detected

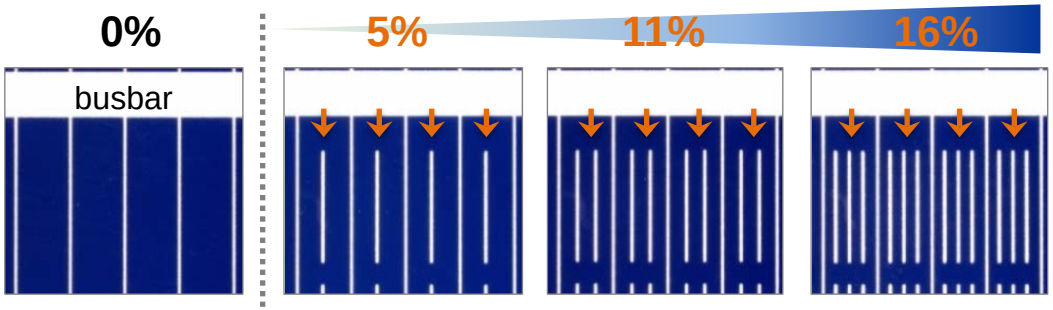


- Shunting
- Carrier recombination

Floating contacts

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

Floating contact “fraction”…



Advantages

- Conductive ✓
- **Nonconductive** ✓
- **Non-contact** ✓

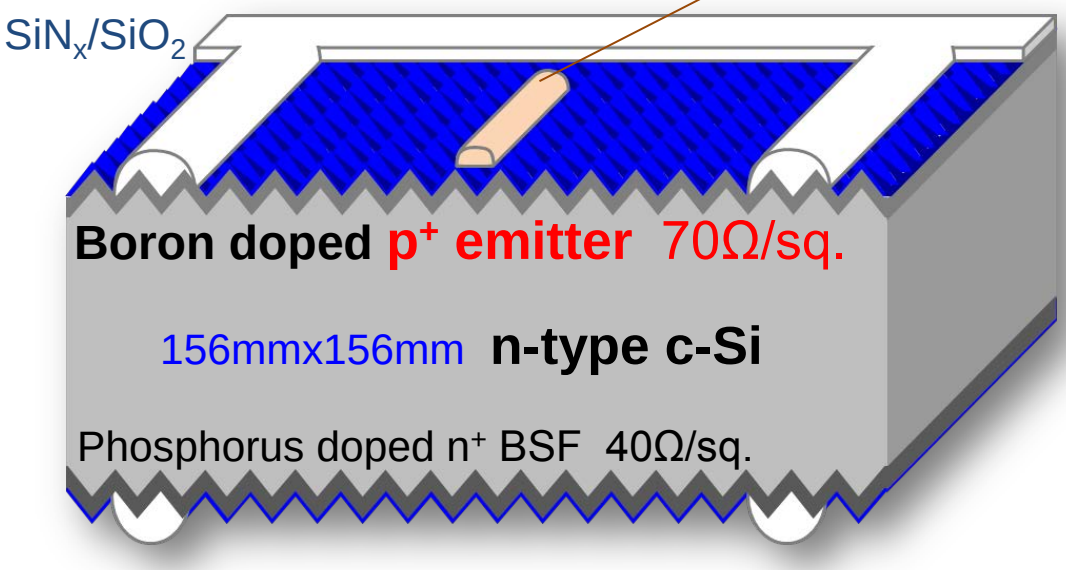
…Al less Ag past to p^+-emitter

R. Hoenig, Ph. D. dissertation, 2014.

Test pastes

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

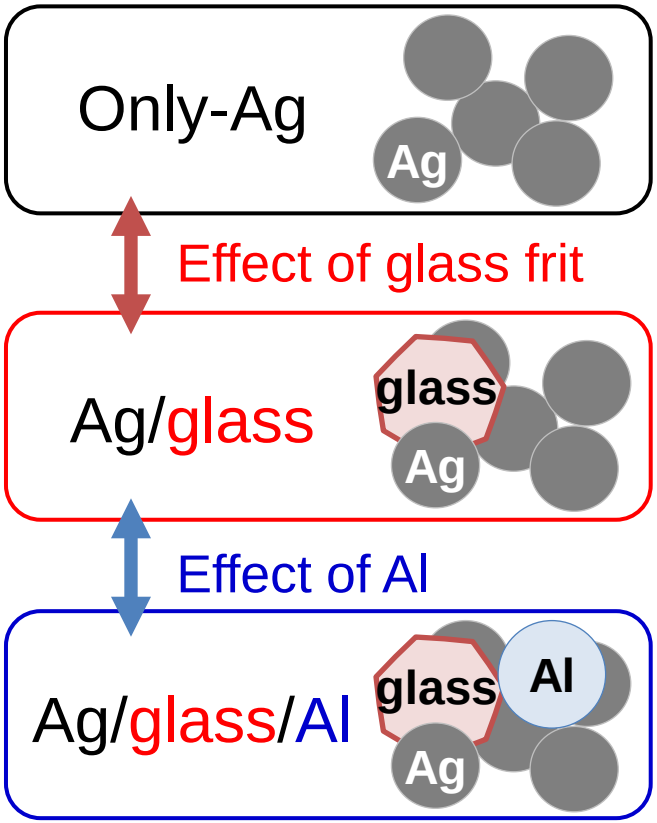
H-pattern grid contact:
Ag/Al paste



Standard Ag paste

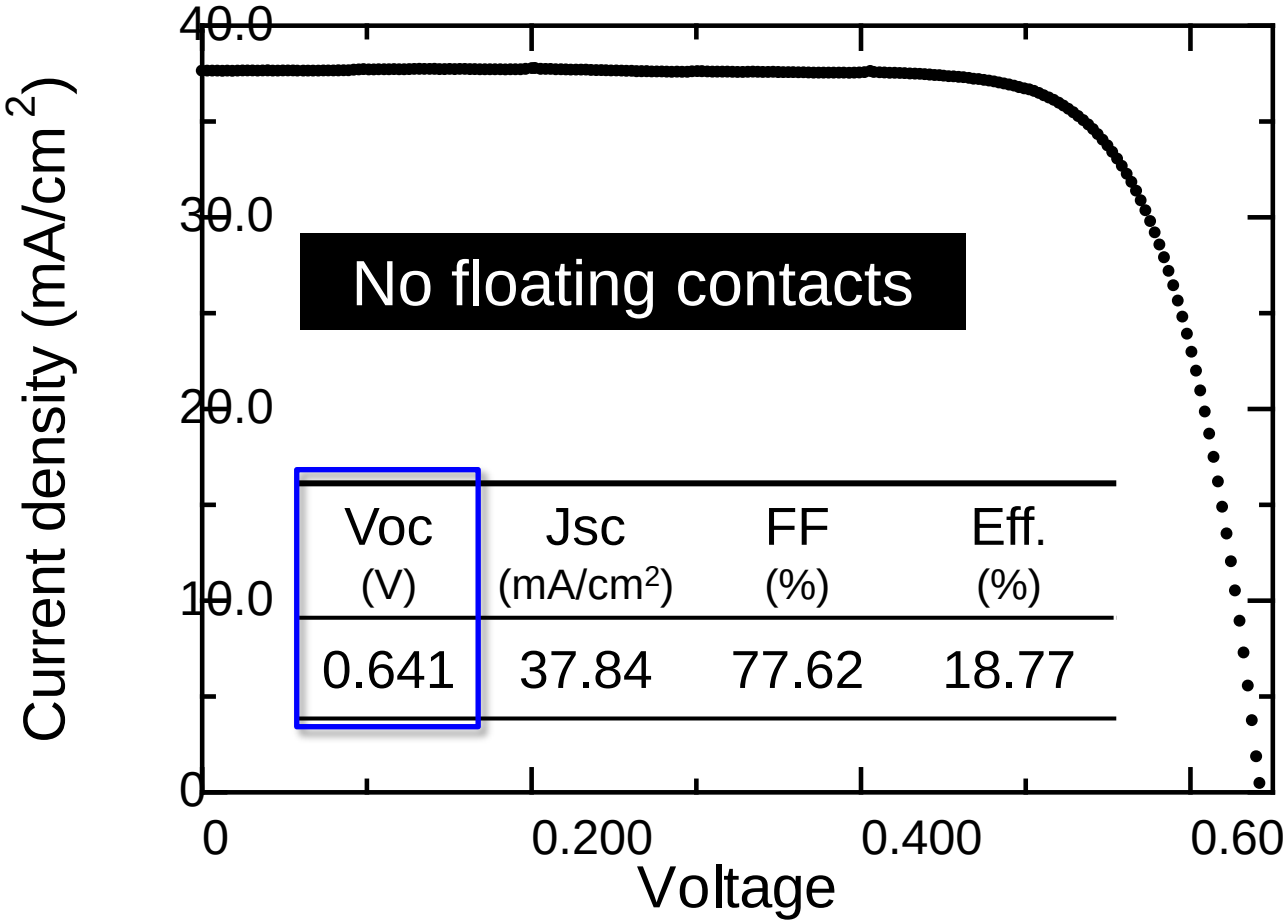
Floating contacts:

Three test pastes

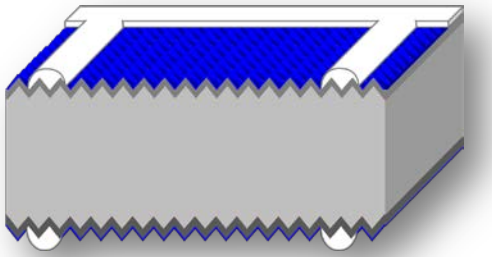


Glass frit: $PbO\text{-}SiO_2\text{-}B_2O_3\text{-}ZnO$

Cell properties without floating contact

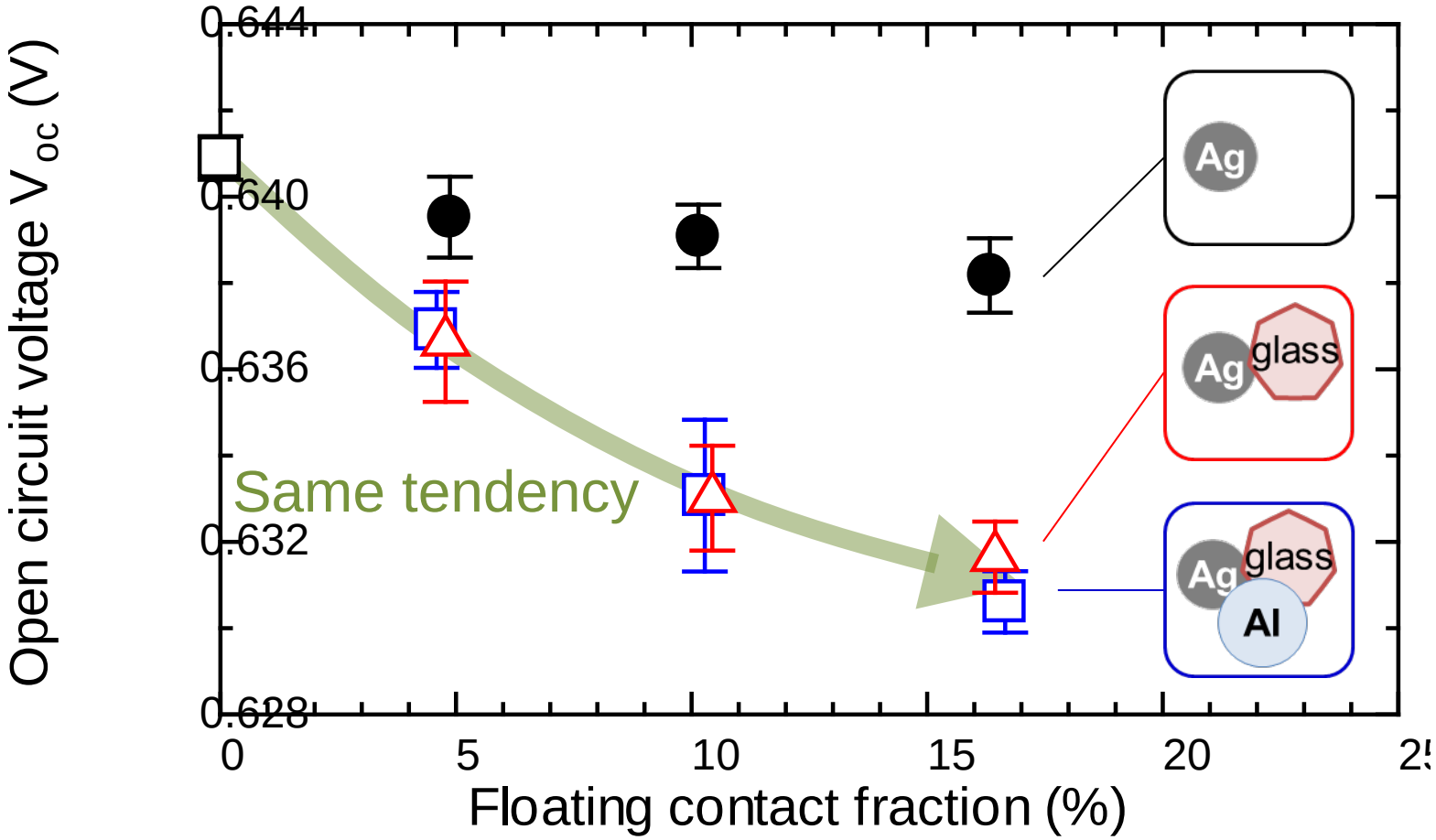


Voc (V)	Jsc (mA/cm^2)	FF (%)	Eff. (%)
0.641	37.84	77.62	18.77



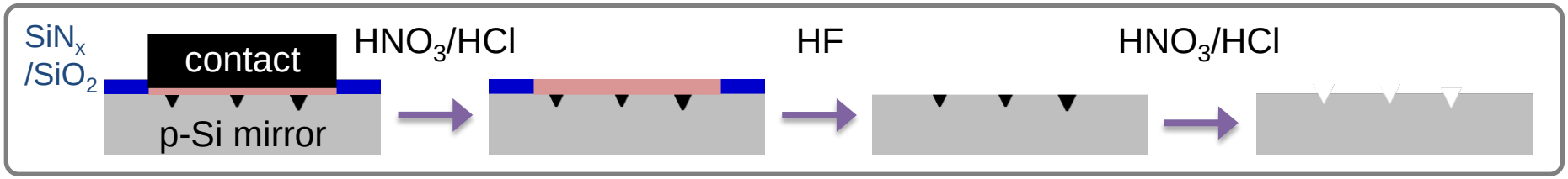
- The cell parameters are good enough to evaluate the effects of floating contacts.

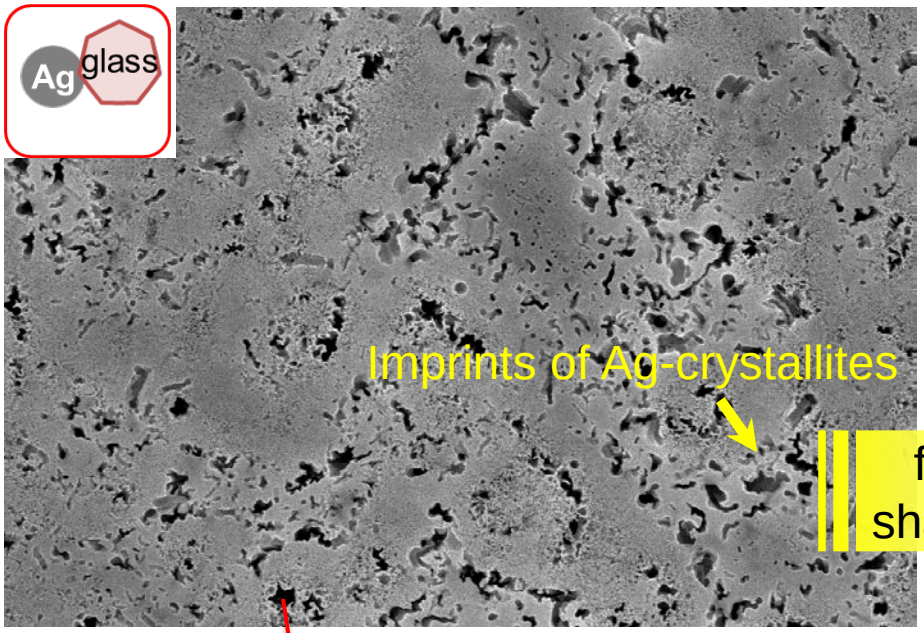
Open circuit voltage, V_{oc}



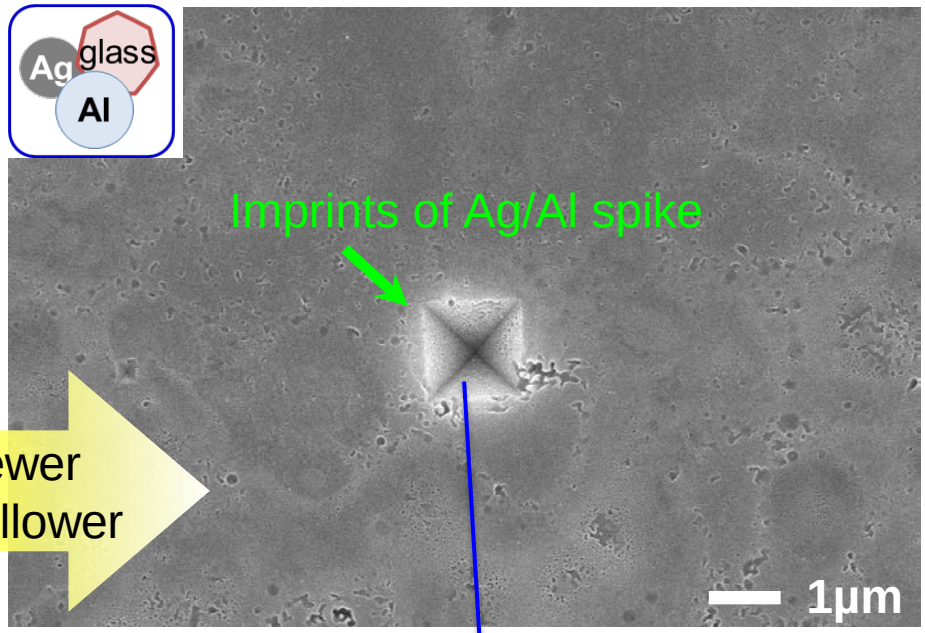
- Conductive paste causes loss in V_{oc} in n-type solar cells even if the paste does not contain aluminum

Interface morphology underneath contact



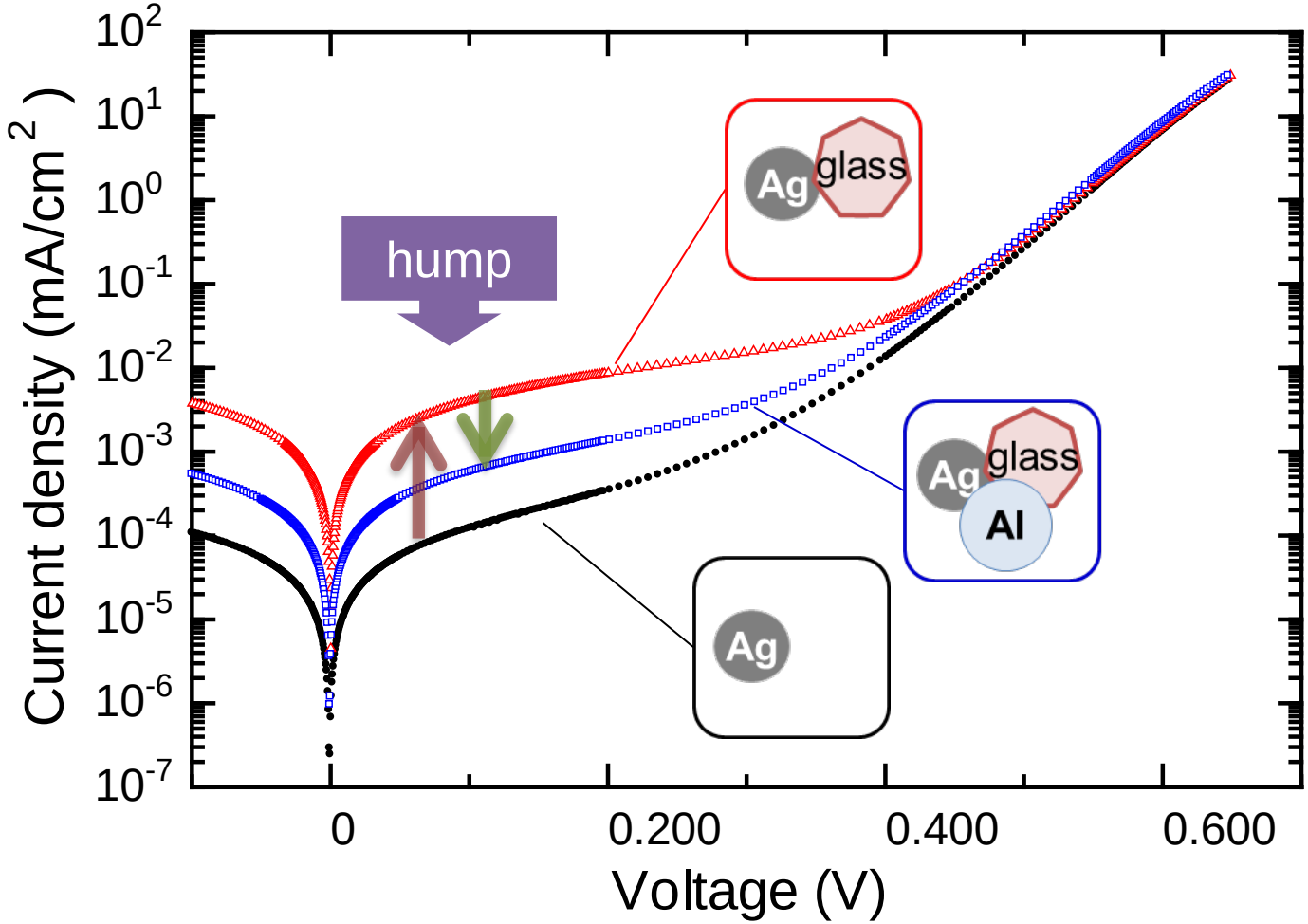


fewer
shallower



- Al mitigates generation of Ag-crystallites and their growth
- Adding Al causes forming the large spike

Dark IV curves

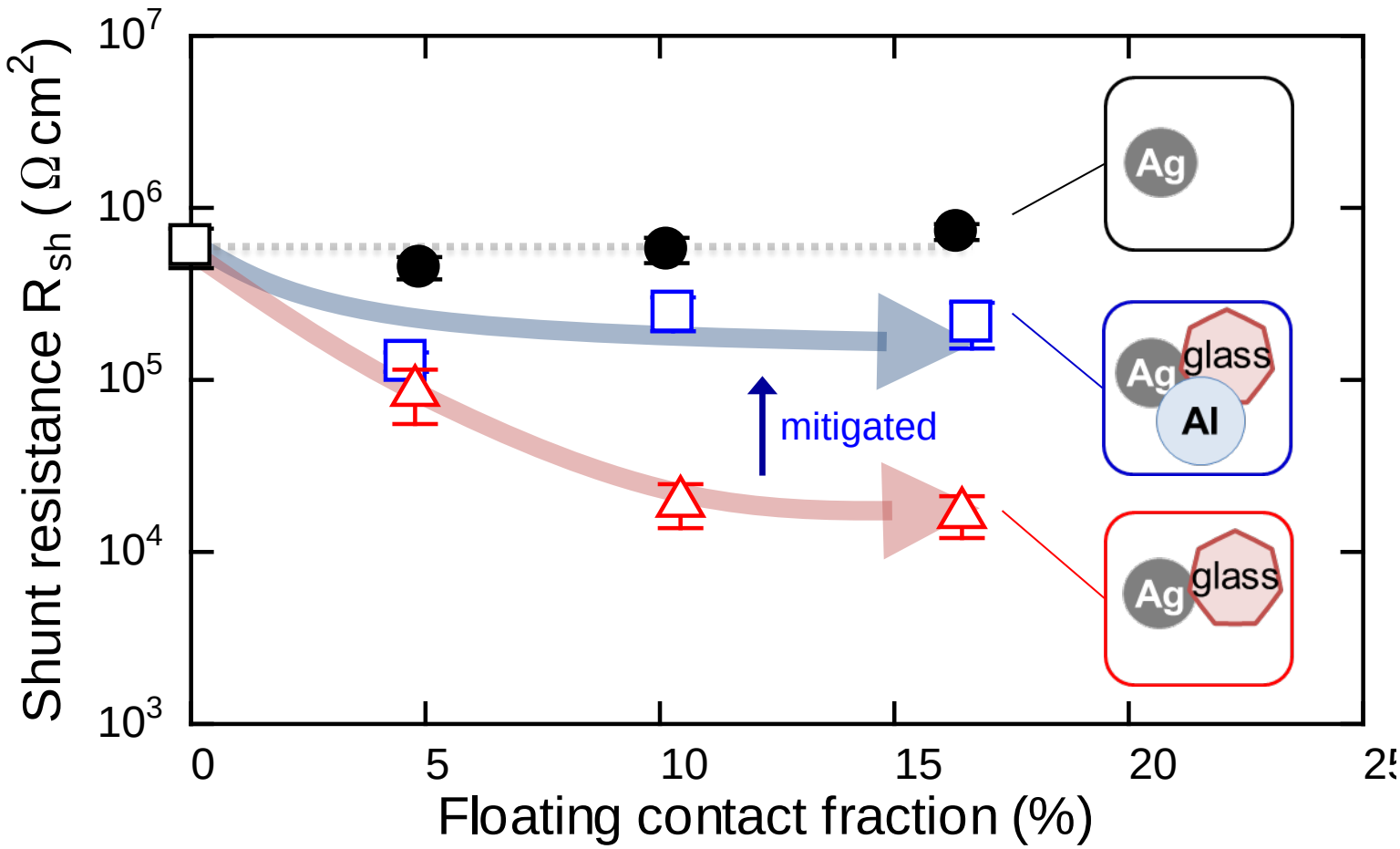


Fraction:16%

- Al mitigates the current increase at low voltage range.

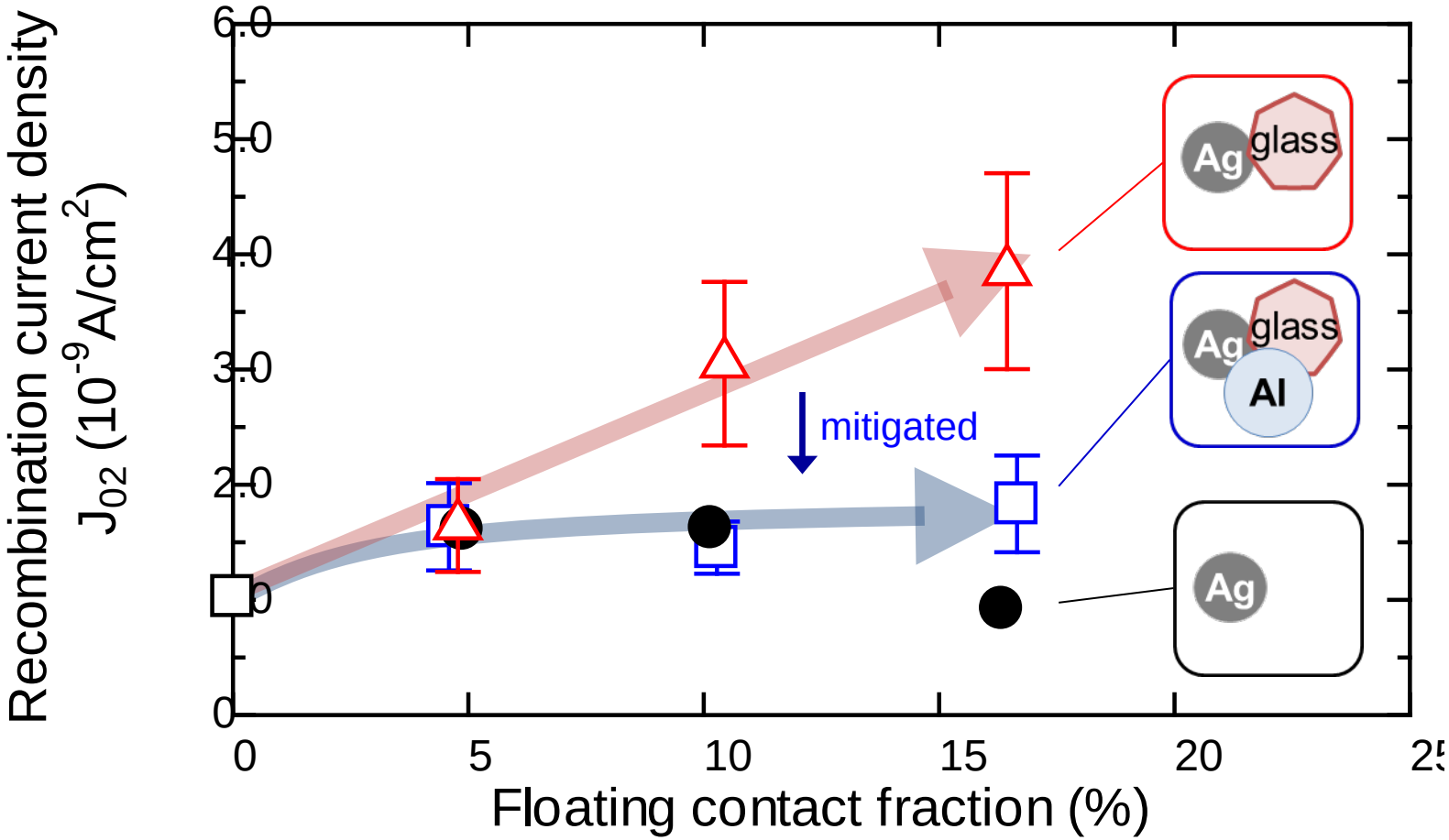
Numerical fitting with the two-diode model ⇒ R_{sh}, J_{02}

Shunt resistance, R_{sh}



- Al in Ag/Al paste does not induce significant shunting

Recombination current, J_{02}

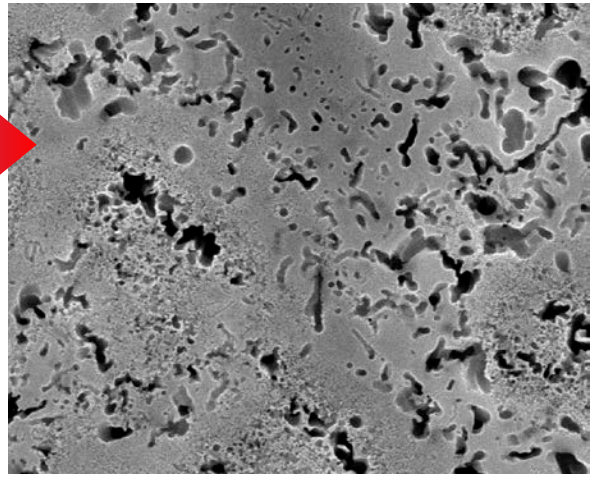


- Al mitigates the increase of recombination current

Al effects on p^+-emitter

R_{sh}, J_{02}

degraded

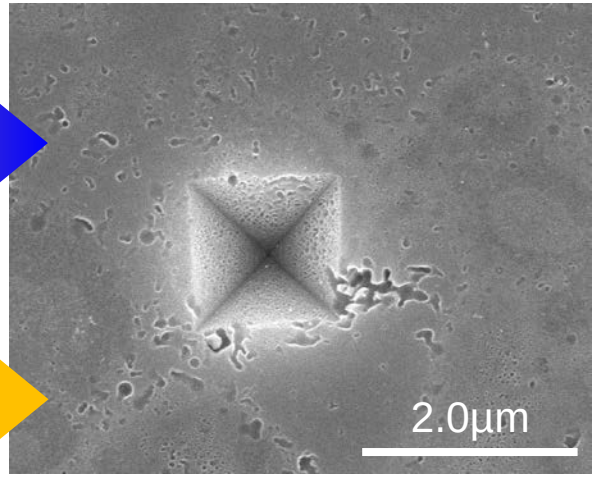


R_{sh}, J_{02}

mitigated

Ag-crystallite

fewer
shallower



- 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!

MEIJI UNIVERSITY Noritake

PHOTOVOLTAIC SPECIALISTS CONFERENCE 43rd IEEE Portland, OR • June 5-10, 2016

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

Takayuki Aoyama, Mari Aoki, Isao Sumita, Yasushi Yoshino, Yoshio Ohshita, Atsushi Ogura

"A Study on the Evaluation Method of Glass Frit Paste for Crystalline Silicon Solar Cells"

Mari Aoki, Takayuki Aoyama, Isao Sumita, Yasushi Yoshino, Atsushi Ogura, Yoshio Ohshita