

Oki Engineering Co., Ltd.

**QUALITY EVALUATION
TECHNIQUES OF
SOLAR CELL MODULE**

Daisuke MURAHARA

**Oki Engineering Co., Ltd.
Hikawadai Nerima-ku, Tokyo JAPAN**

Purpose

- **To improve the reliability of the photovoltaic systems, we developed the process diagnostic system of the solar cell module.**
- **This technique is effective for both of the solar cell module manufacturer and the user.**

Outline

- **Introduction**
- **Evaluation Method**
- **Evaluation Results**
 - Assembly Inspection
 - Cell Part Inspection
- **Summary**

Introduction

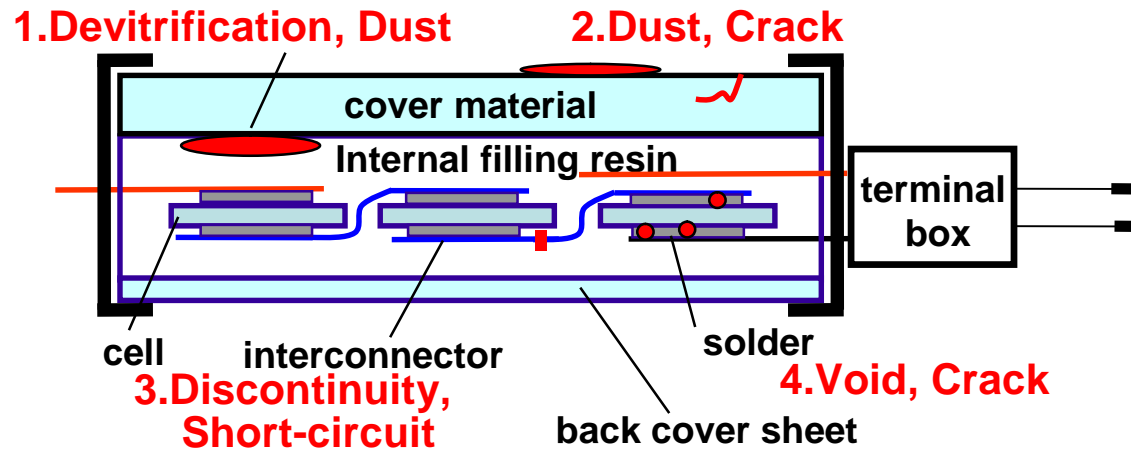
- **Necessity of Quality Evaluation Techniques for Solar Cell Module**

- Photovoltaic power systems spread rapidly and number of solar panel suppliers increases, but the approach to the reliability and quality evaluations are not so much moving ahead.
- If an eco-friendly solar cell breaks down in a short term and the exchange is necessary, it is consequentially bad for the environment.
- If the solar battery that exists in the electric power line where high reliability is demanded breaks down, it has a serious influence on our life.

- **Development of Quality Evaluation Techniques for solar Cell Module**

- We have developed a process diagnostic system for photovoltaic system based on standard methods already developed for LSI and MEMS technologies.
- This techniques become effective tools for the solar cell module manufacturer to confirm the quality of conformance and benchmark their photovoltaic products with those from other companies.

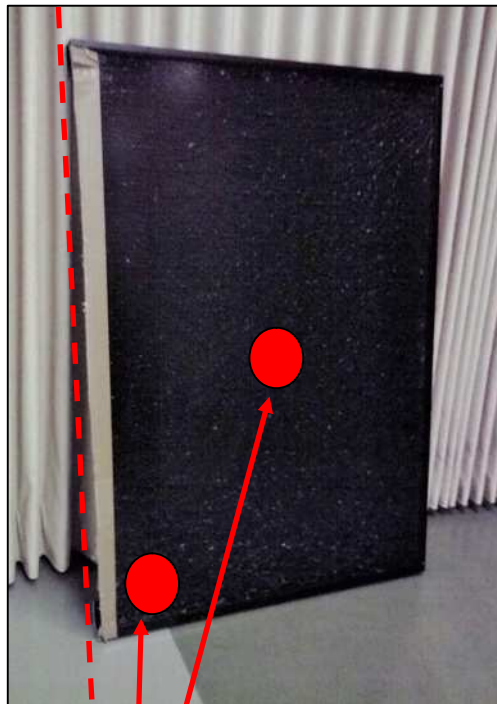
Evaluation Method: Inspection Items (assembly inspection)



Inspection item	Equipment	Subject of inspection	Detected defect factor	Factor No.
External visual inspection	OM	Protective material, Filler, Power supply line, Interconnector, Soldered joint part	Devitrification, Dust, Abnormaly sealing, Crack, Discontinuity, Short-circuit	1,2,3,4
X-ray inspection	X-ray	Terminal connector box, Interconnector, Soldered joint part	Dust, Discontinuity, Short-circuit, Abnormaly sealing, Void, Crack	1,3,4
Cross-sectional OM inspection	OM	Protective material, Filler, Layer structure, Interconnector, Soldered joint part, Cell	Abnormal structure, Uniformity (film thickness), Dust, Crack, Discontinuity, Short-circuit, Void	1,2,3,4

OM : Optical Microscope

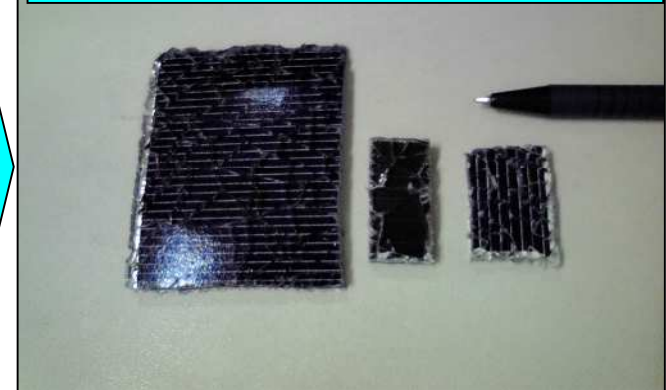
Evaluation Method: Sample Preparation (Module Cutting)



Cover glass break into many pieces.
Board material is used for maintain
the shape.



Fragment sample is used for
inspection.



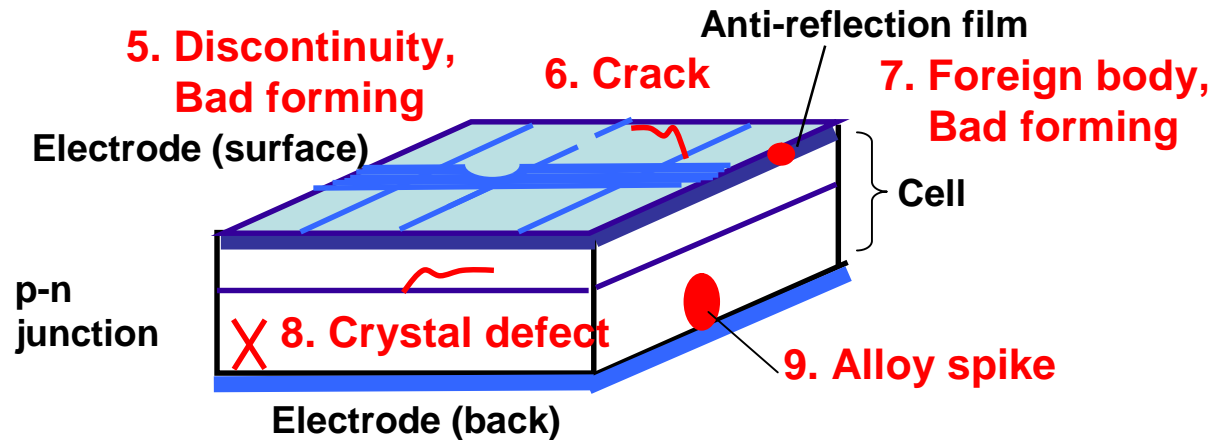
1st step
(electric rim saw with diamond blade)

2nd step
(diamond band saw)

Inspect at least
two points



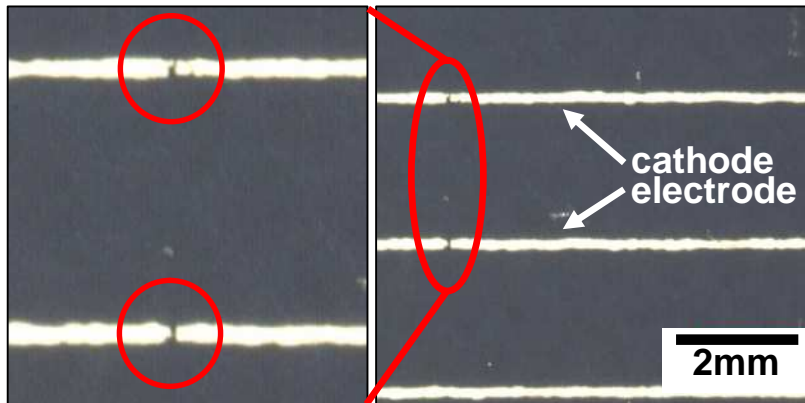
Evaluation Method: Inspection Items (Cell Part Inspection)



Inspection item	Equipment	Subject of inspection	Detected defect factor	Factor No.
Surface OM inspection	OM	Electrode (surface, back), Anti-reflection coating, Cell	Discontinuity, Bad forming, Crack, Scratch, Dust	5,6,7
Surface SEM inspection	SEM	Electrode (surface, back), Anti-reflection coating, Cell	Bad forming (texture), Discontinuity, Crack, Scratch, Dust	5,6,7
Cross-sectional SEM inspection	SEM	Electrode (surface, back), Anti-reflection coating, Cell (p-n junction)	Bad forming (texture, uniformity), Dust, Crystal defect, Alloy spike	5,6,7,8,9
Cross-sectional TEM inspection	TEM	Electrode (surface, back), Anti-reflection coating, Cell (p-n junction)	Bad forming (texture, uniformity), Dust, Crystal defect, Alloy spike	5,6,7,8,9

OM : Optical Microscope SEM : Scanning Electron Microscope
TEM : Transmission Electron Microscope

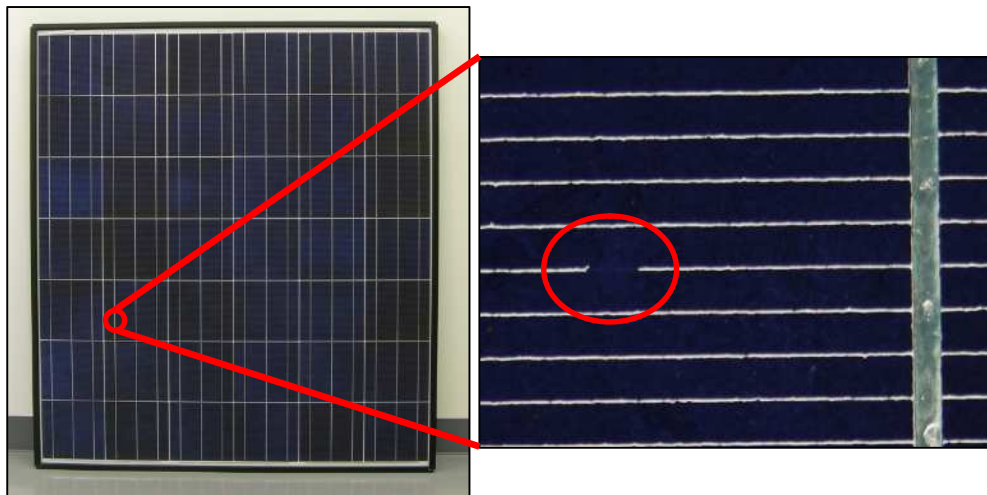
Evaluation Results (Assembly Inspection): External Visual Inspection (Silicon Type)



Discontinuity of cathode electrode
(mono Si type)



State of the outside joint
(poly Si type)



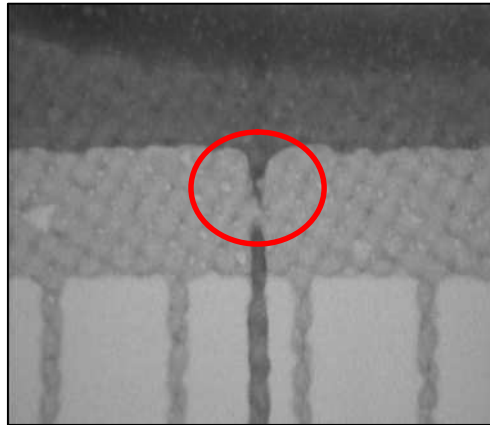
Discontinuity of cathode electrode
(poly Si type)



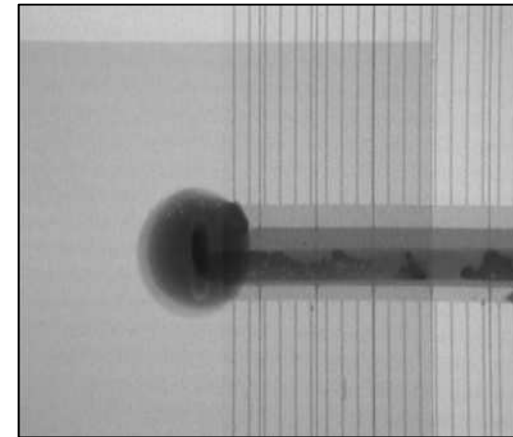
Filling state of resin in the terminal box
(poly Si type)

If the defect density is high, it cannot be disregarded and may be the dominant factor controlling the performance.

Evaluation Results (Assembly Inspection): X-ray Inspection (Silicon Type)

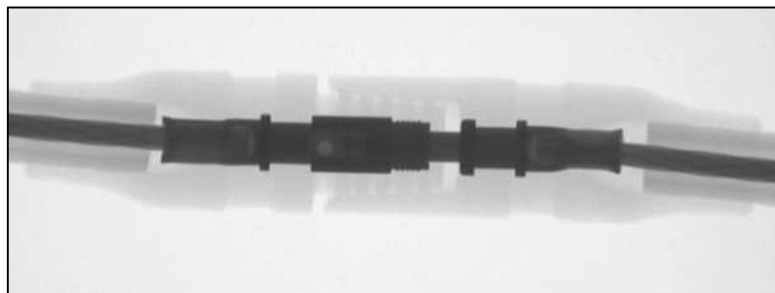


**Discontinuity of cathode electrode
(mono Si type)**

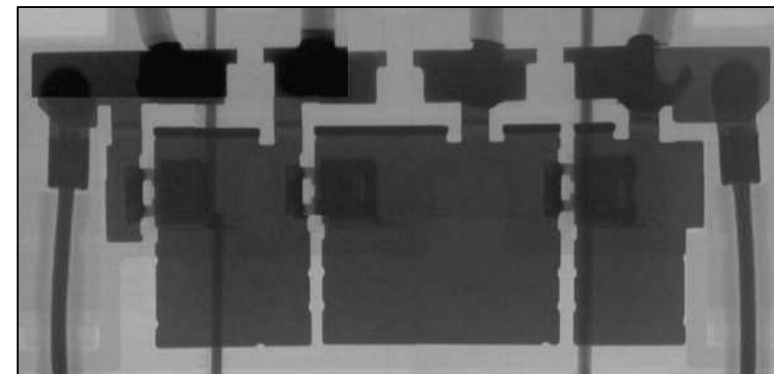


**Irregularity at the solder of
interconnector**

If the connection is already compromised from the beginning, there is a possibility that a discontinuity may occur with age and lifetime deterioration.



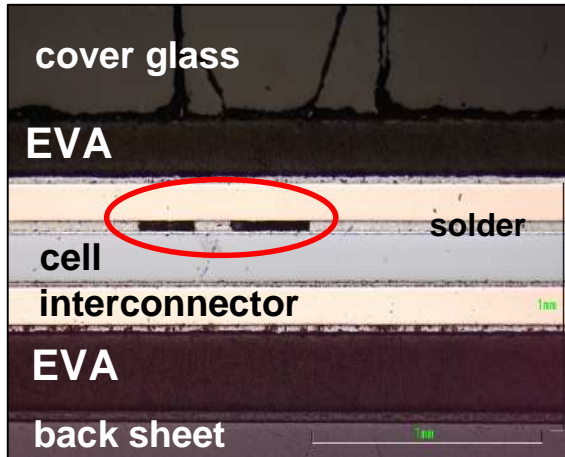
**Engagement condition of the outside joint
(poly Si type)**



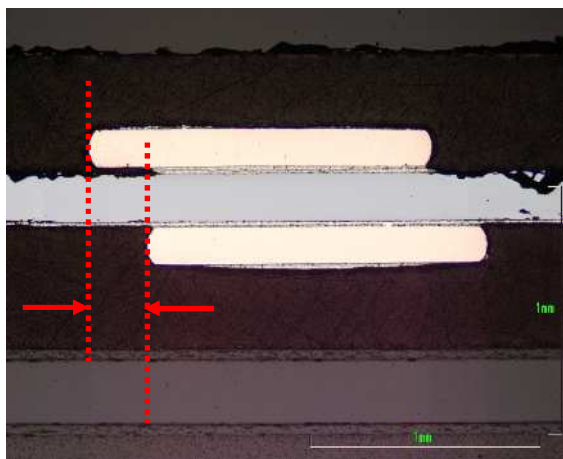
**Inside condition of the terminal box
(poly Si type)**

Evaluation Results (Assembly Inspection): Cross-sectional OM Inspection (Silicon Type)

Mono Si type

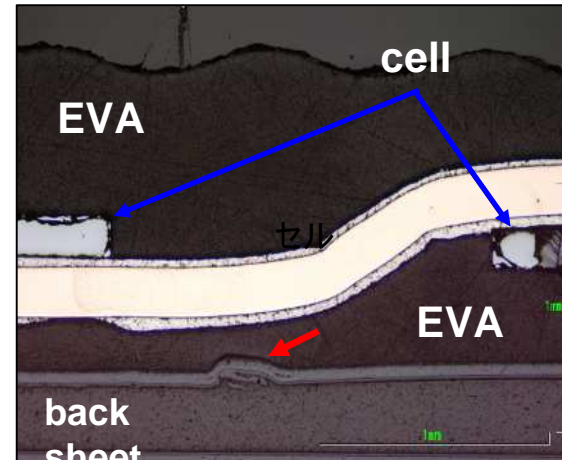


**Vertical direction
(Solder void of interconnector)**

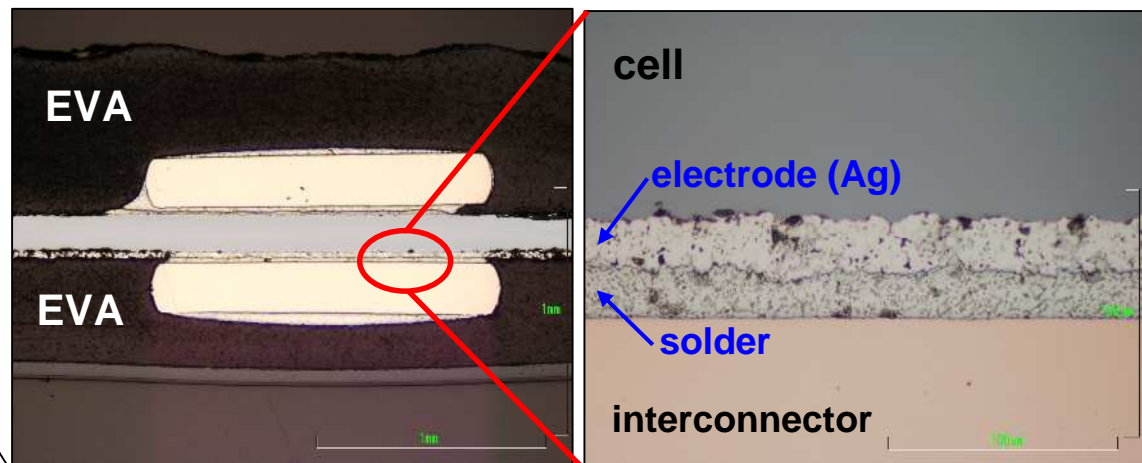


**Horizontal direction
(Irregularity of the alignment)**

Poly Si type

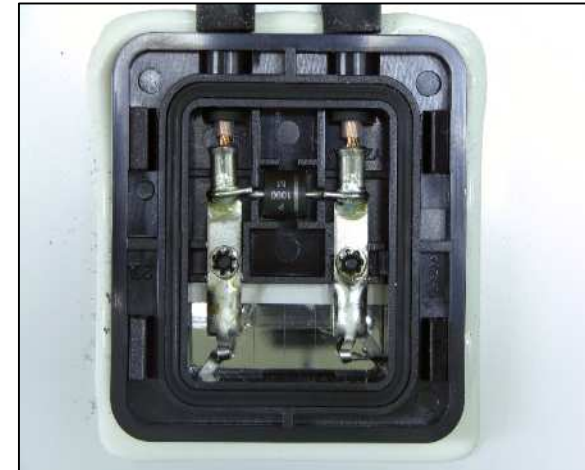
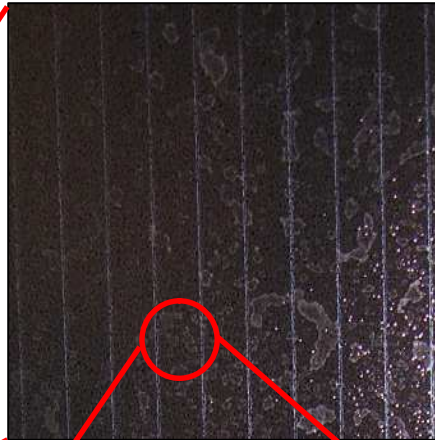
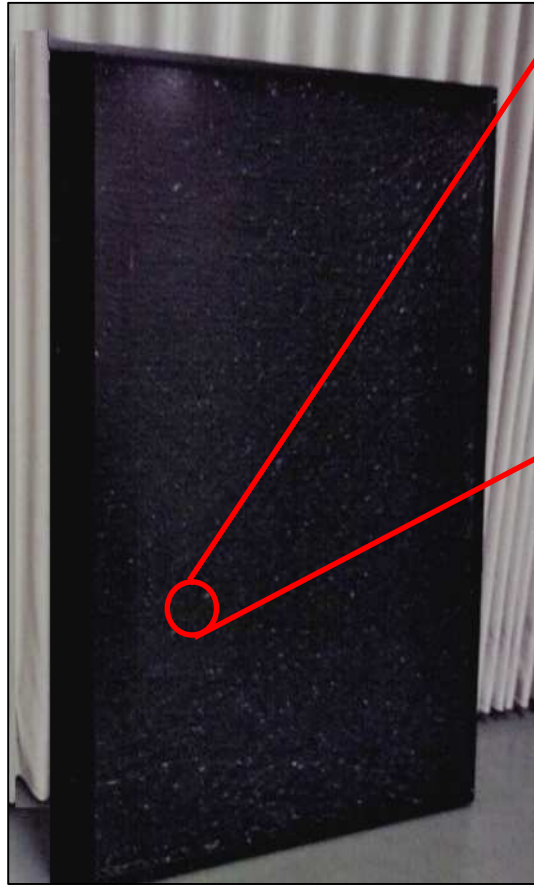


**Vertical direction
(Ununiformity of back sheet)**



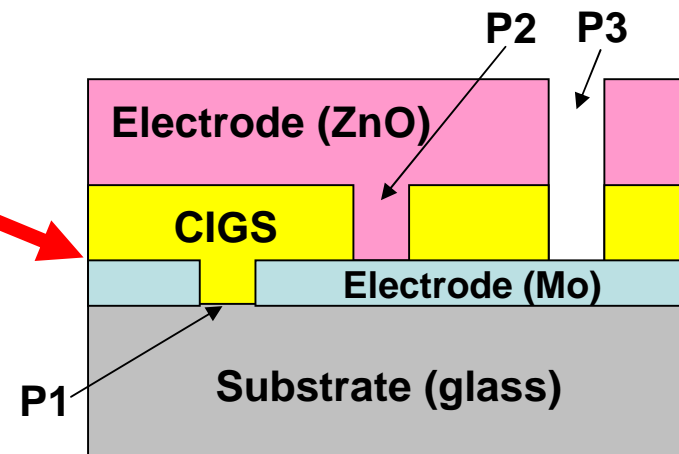
Horizontal direction

Evaluation Results (Assembly Inspection): External Visual Inspection (CIGS Type)



Inside condition of the terminal box

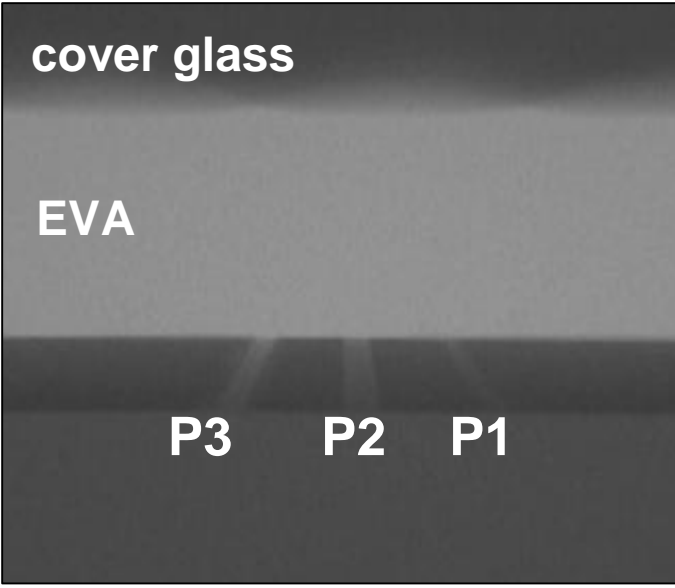
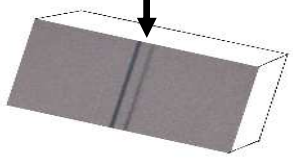
No defects are observed



Evaluation Results (Assembly Inspection): X-ray Inspection (CIGS Type)

P1-P3 part

X-ray



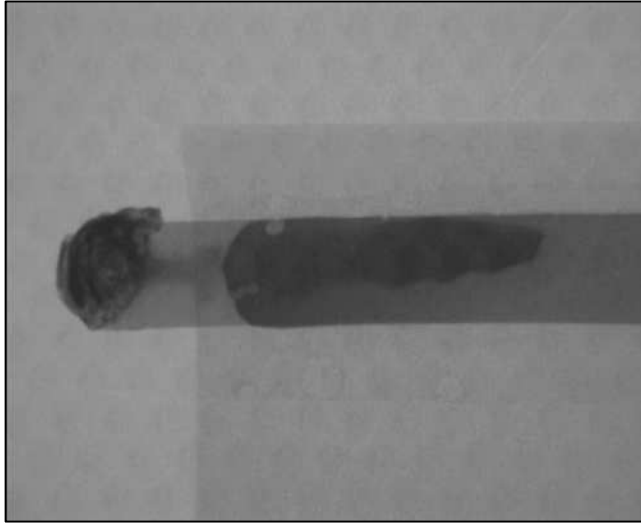
cover glass

EVA

P3 P2 P1

No defects are observed
It is important to inspect the state of the thin film before the EVA is removed.

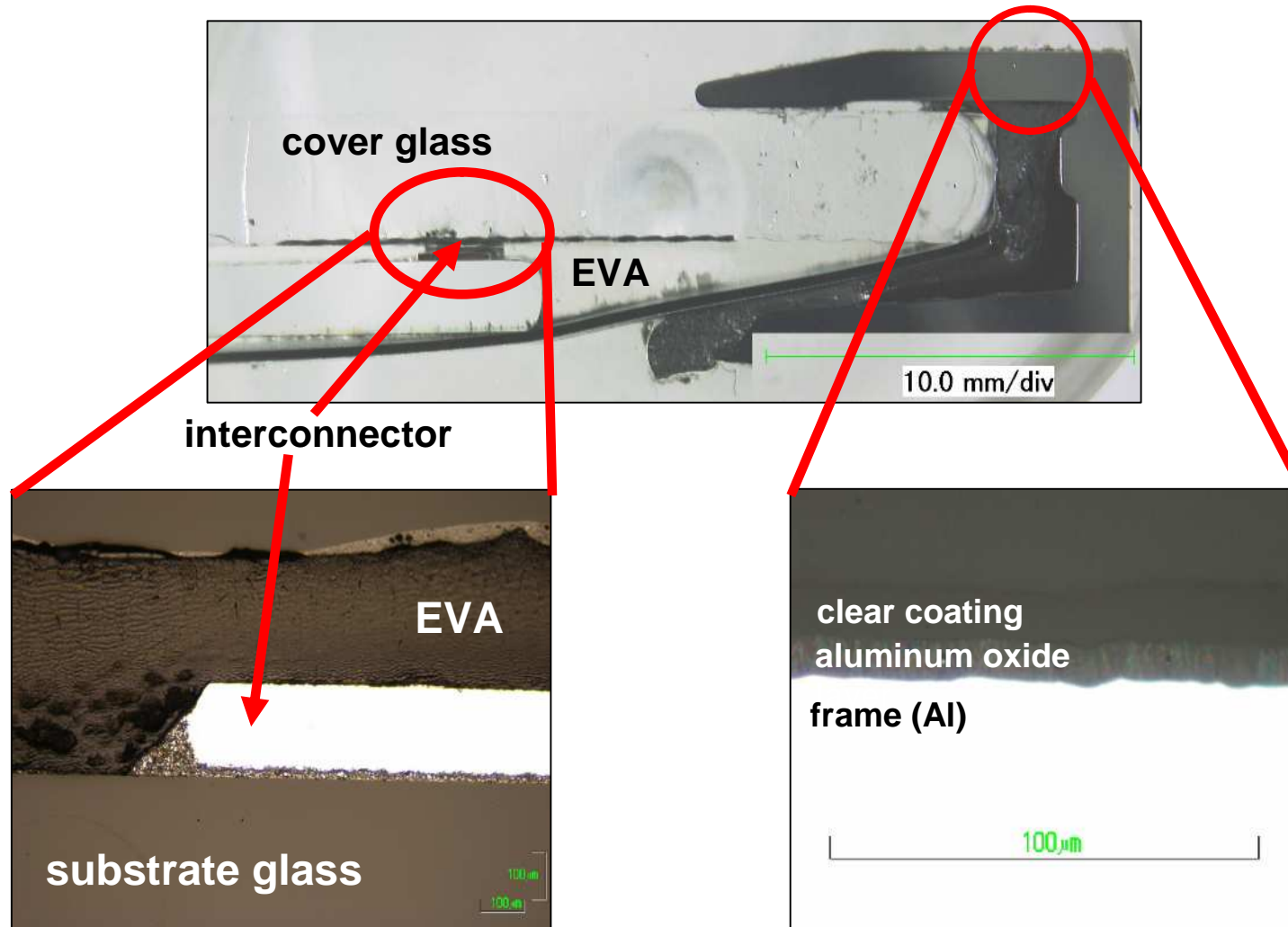
Interconnector



Irregularity of the solder is observed

If the connection is already compromised from the beginning, there is a possibility that a discontinuity may occur with age and lifetime deterioration.

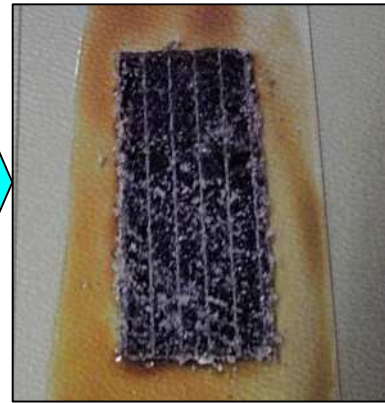
Evaluation Results (Assembly Inspection): Cross-sectional OM Inspection (CIGS Type)



No defects are observed

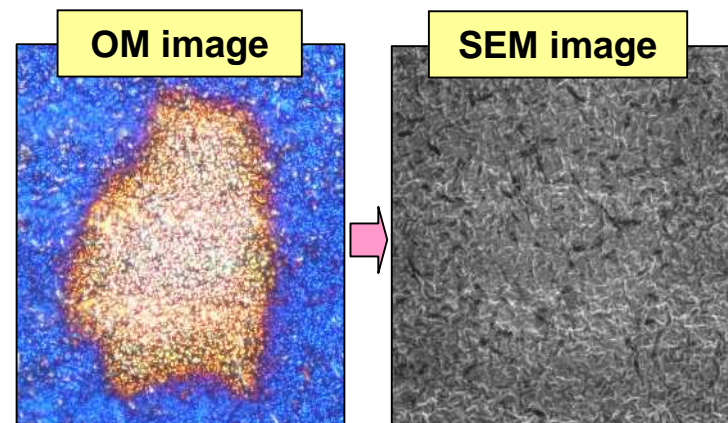
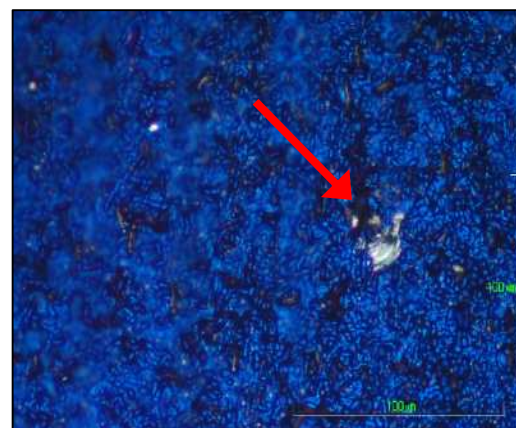
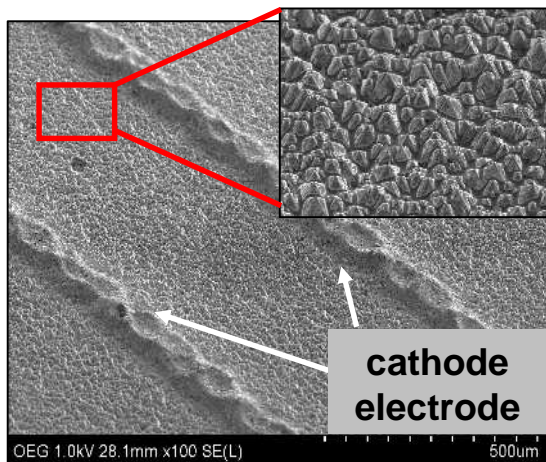
Evaluation Results (Cell Part Inspection): Surface OM and SEM Inspection (Silicon Type)

Chemical stability of EVA (Ethylene Vinyl Acetate) used as an internal resin is high



EVA and covered glass were cut off by passing a thin Nichrome wire.

EVA on the surface of the cell was removed by mechanically pulling it off.



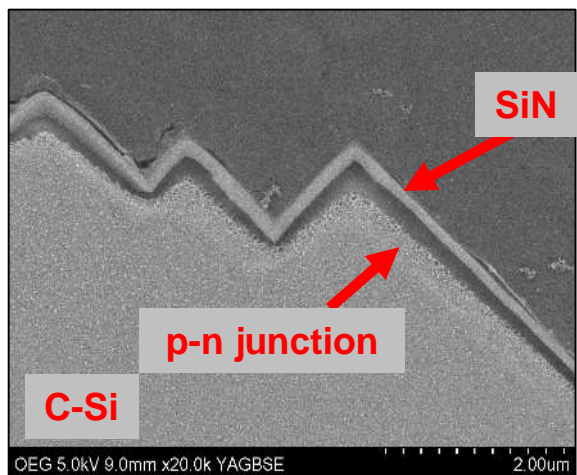
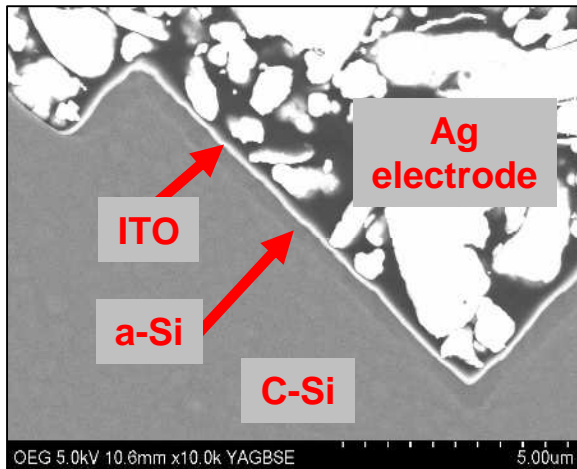
Surface of the cell (mono Si type)

Crack at the cell surface (poly Si type)

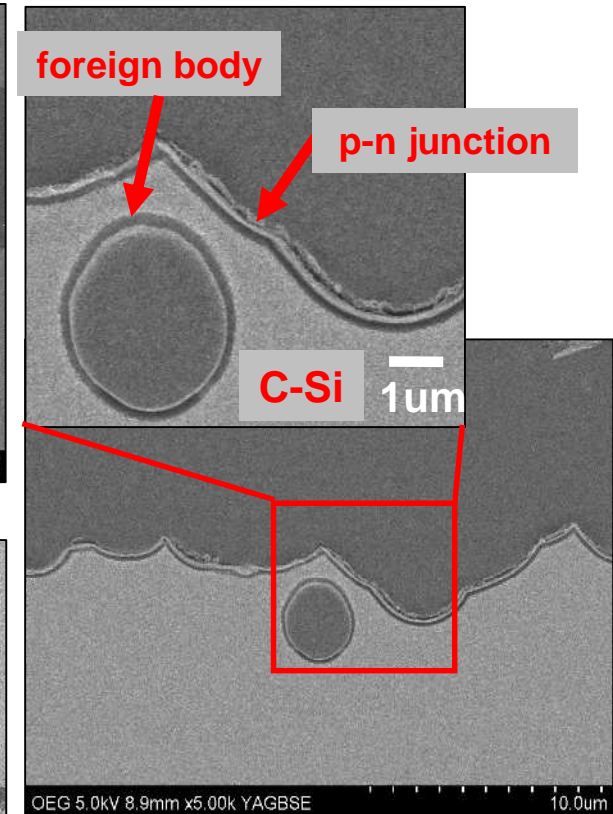
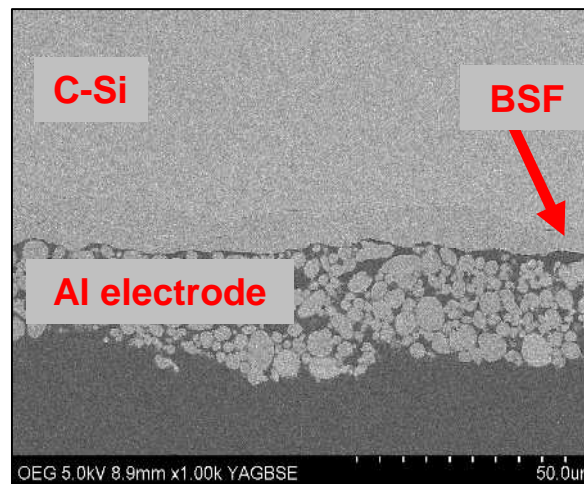
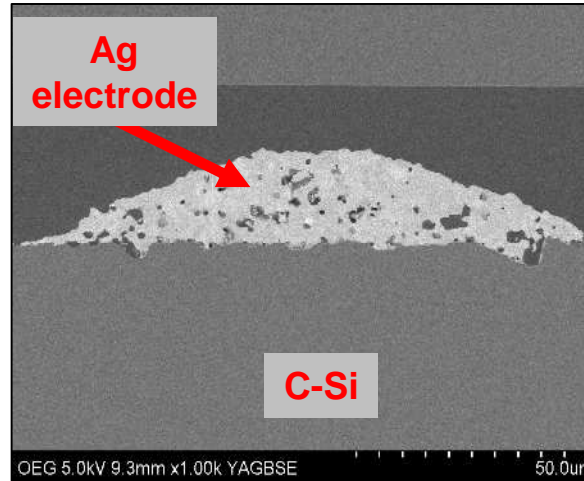
Discoloration at the cell surface (poly Si type)

Evaluation Results (Cell Part Inspection): Cross-sectional SEM Inspection (Silicon Type)

Mono Si type



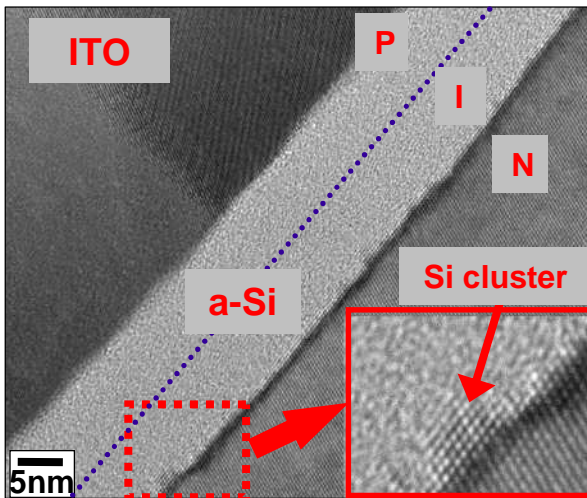
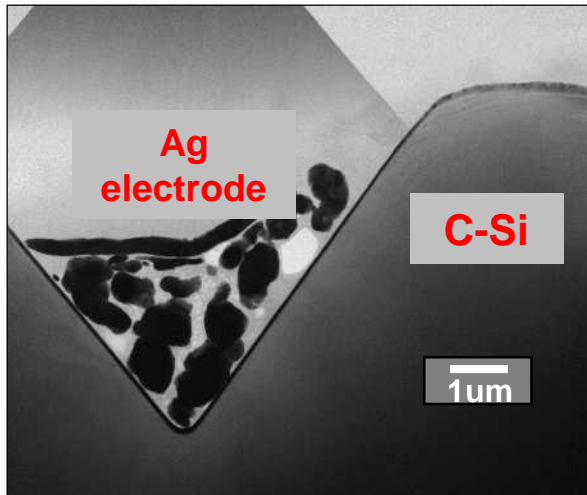
Poly Si type



Foreign body is observed

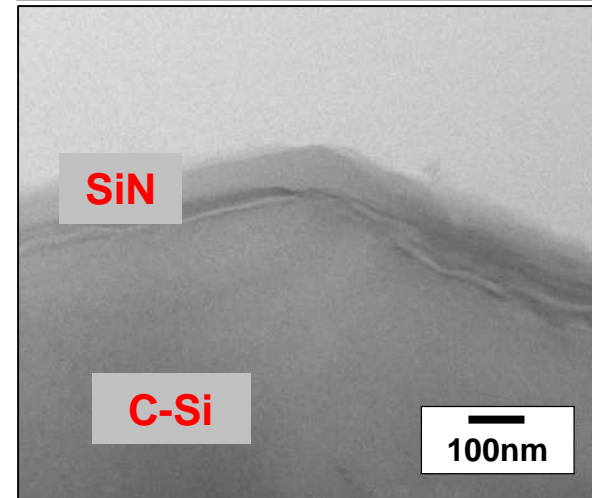
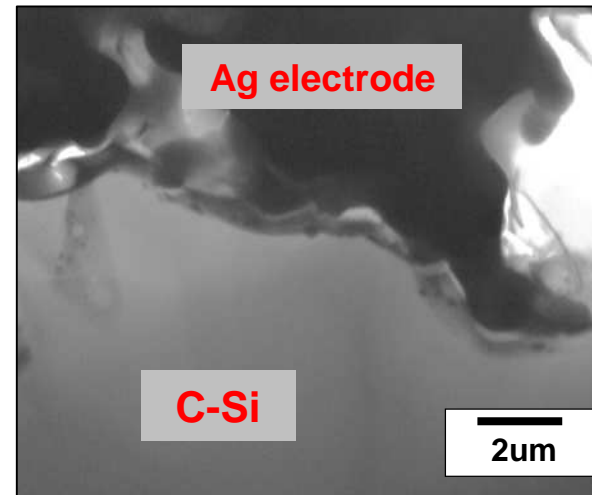
Evaluation Results (Cell Part Inspection): Cross-sectional TEM Inspection (Silicon Type)

Mono Si type



Si cluster is observed

Poly Si type



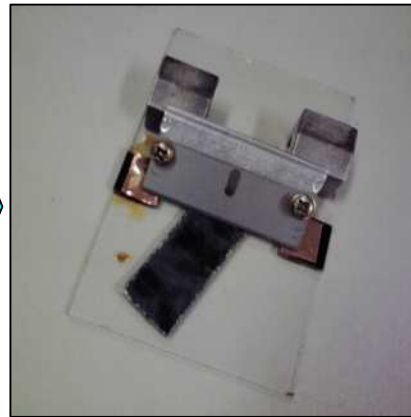
No defects are observed

Evaluation Results (Cell Part Inspection): Surface OM Inspection (CIGS Type)

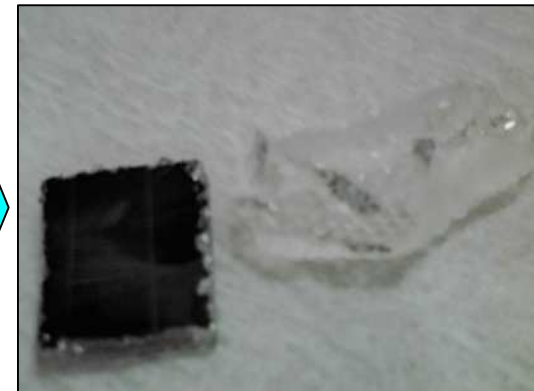
The thin film structure is destroyed easily by stress of EVA peeling.



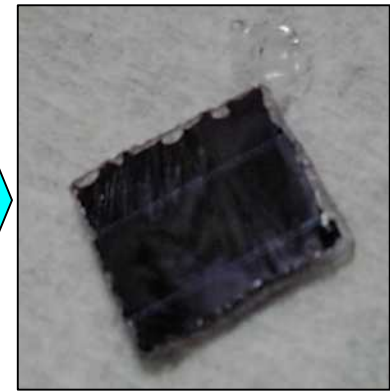
EVA is softened by organic solvent



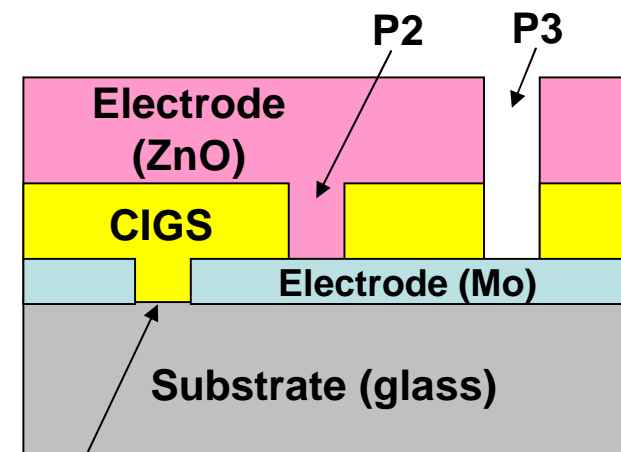
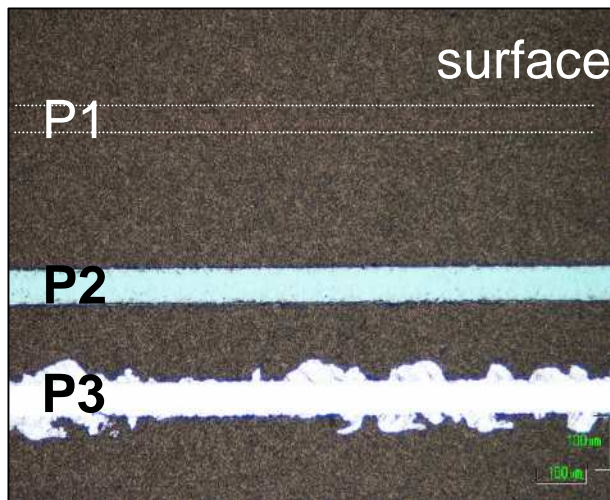
surface EVA is excised with the razor



excised EVA



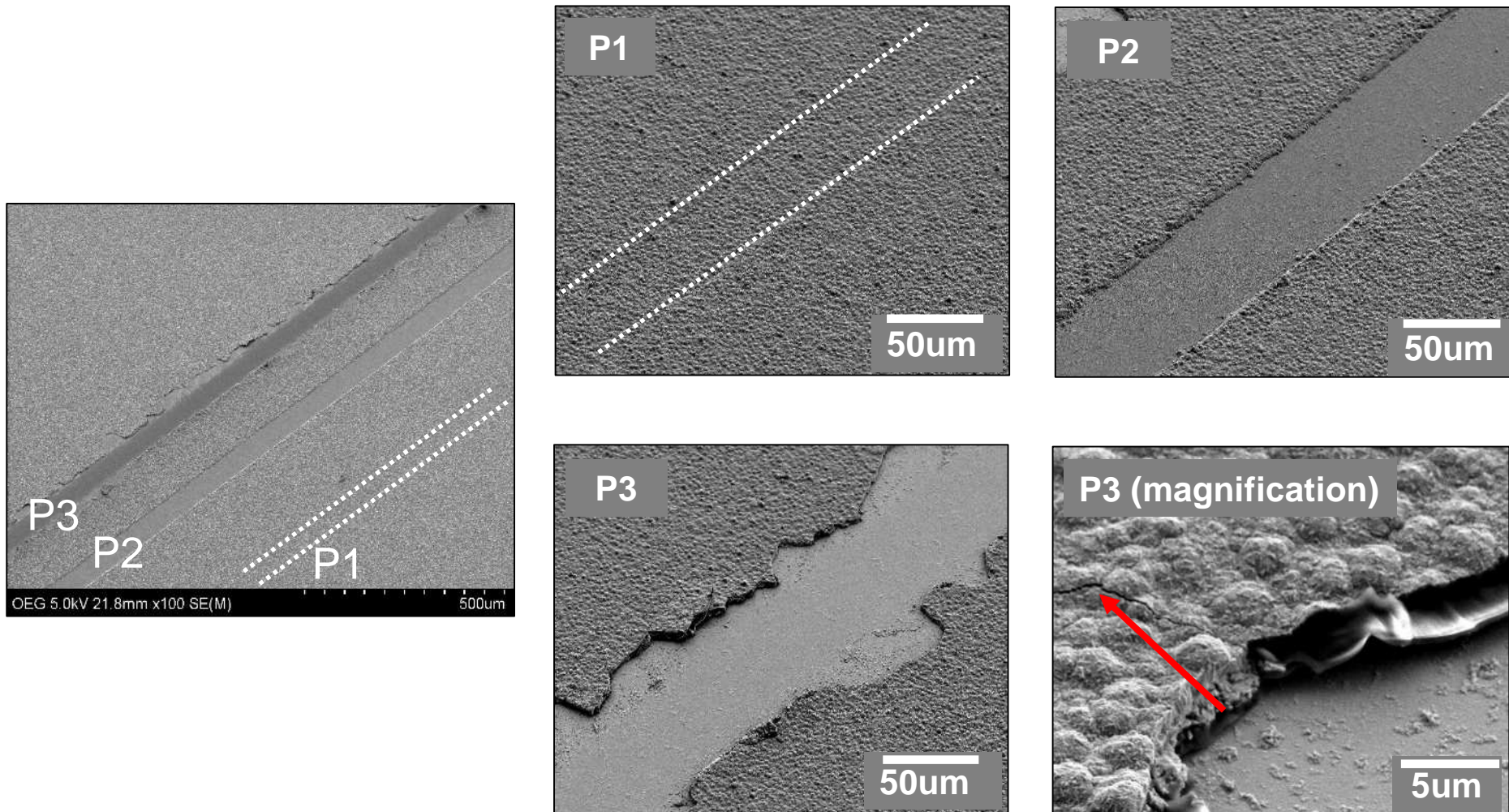
repeats



No defects are observed

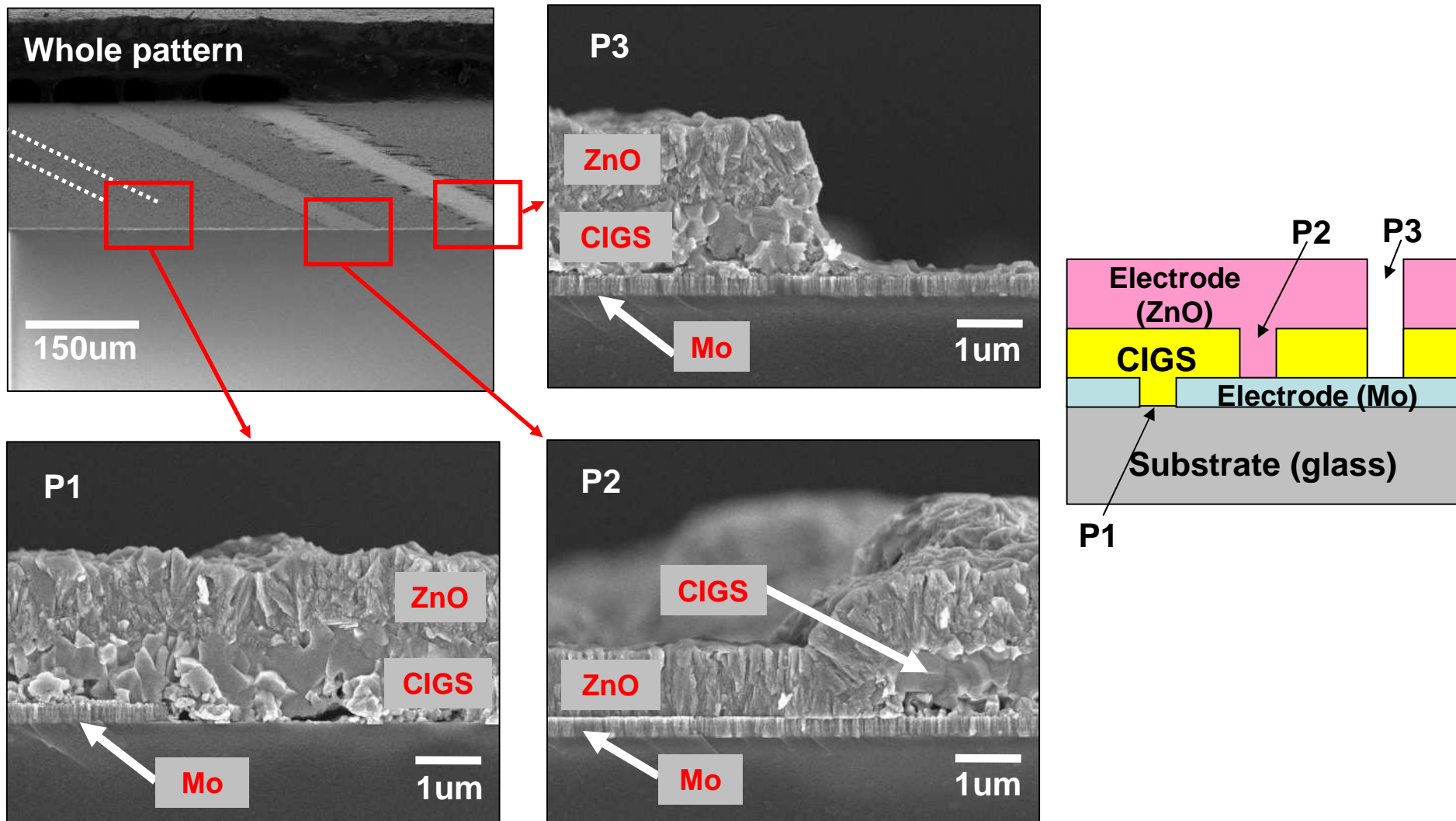
P1

Evaluation Results (Cell Part Inspection): Surface SEM Inspection (CIGS Type)



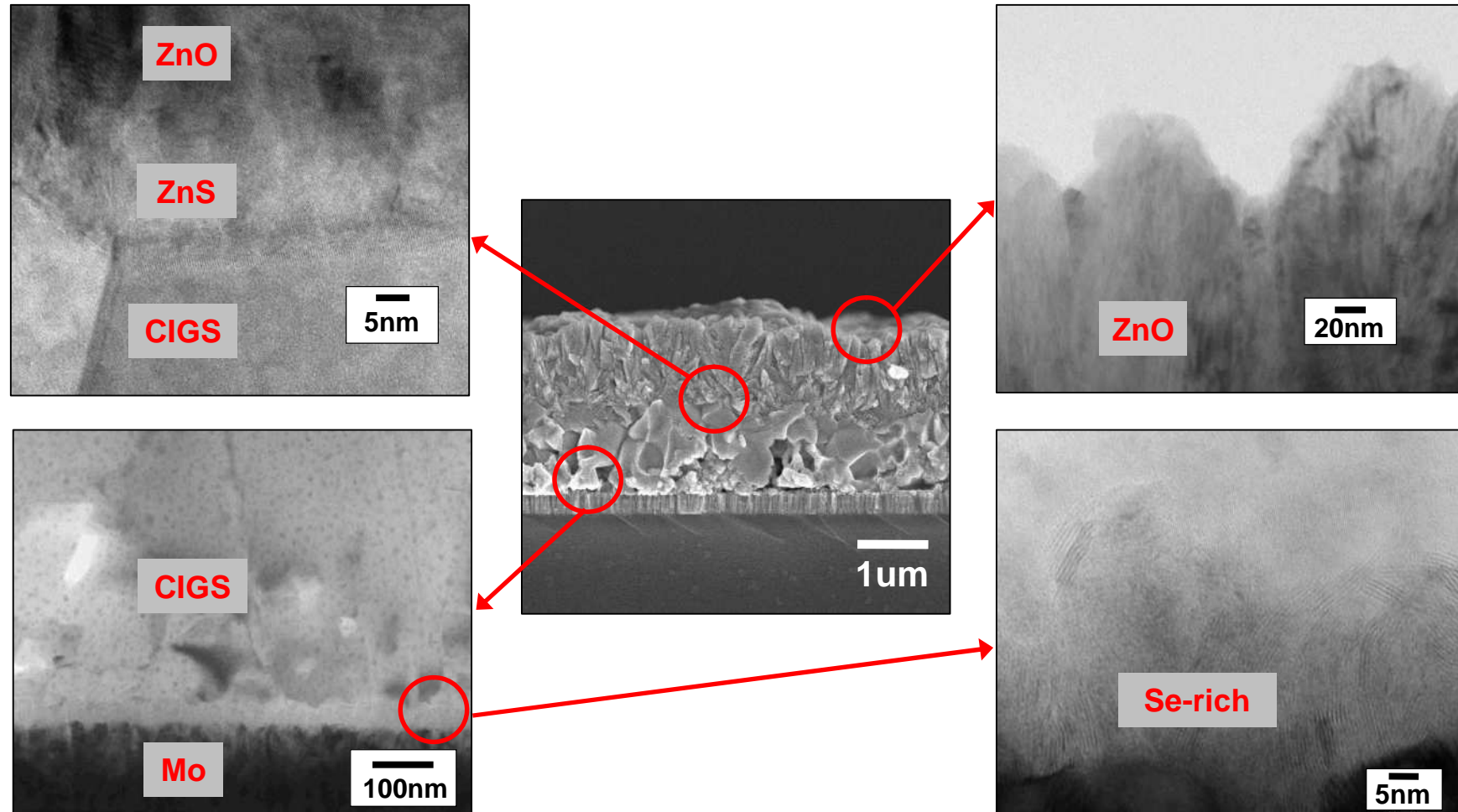
**Minute crack was observed at P3
(no influence on the quality)**

Evaluation Results (Cell Part Inspection): Cross-sectional SEM Inspection (CIGS Type)



No defects are observed

Evaluation Results (Cell Part Inspection): Cross-sectional TEM Inspection (CIGS Type)



No defects are observed

Summary

- We developed evaluation techniques for solar cell modules, and also confirmed the ability to detect various defects associated with other items of inspection.

Result Lists of Inspection

Inspection Items	Silicon type			CIGS type
	Monocrystalline Silicon type	HIT type	Polycrystalline Silicon type	
External visual inspection	■	▲	▲	○
X-ray inspection	■	○	○	■
Cross-sectional OM inspection	■	○	■	○
Surface OM inspection	○	○	○	■
Surface SEM inspection	○	○	○	○
Cross-sectional SEM inspection	○	○	■	○
Cross-sectional TEM inspection	○	■	○	○
○ :No defects ■ :Negligible defect that doesn't become problem on reliability ▲ :Defect with possibility to influence on reliability ✕ :Serious defect to which breakdown of module is expected				

- The conforming article analysis techniques of the solar cell module were proven as effective means of the quality evaluation.