Effect of Aging on Discharge Tolerance of Grouted Solar Array Panels Confirmed by Simulated Space Environment

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Outline

1. Back ground
2. Purpose
3. Aging test
4. Primary arc test
5. Secondary arc test
6. Summary

1. Background

Recent Satellites become・・・

larger
smart
high-power

⇨

Discharge on solar array

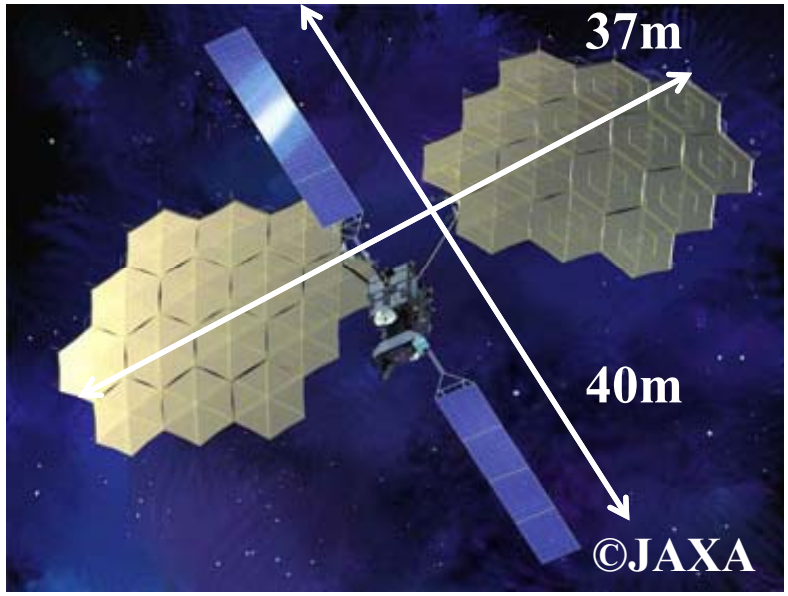
⇨

Power loss

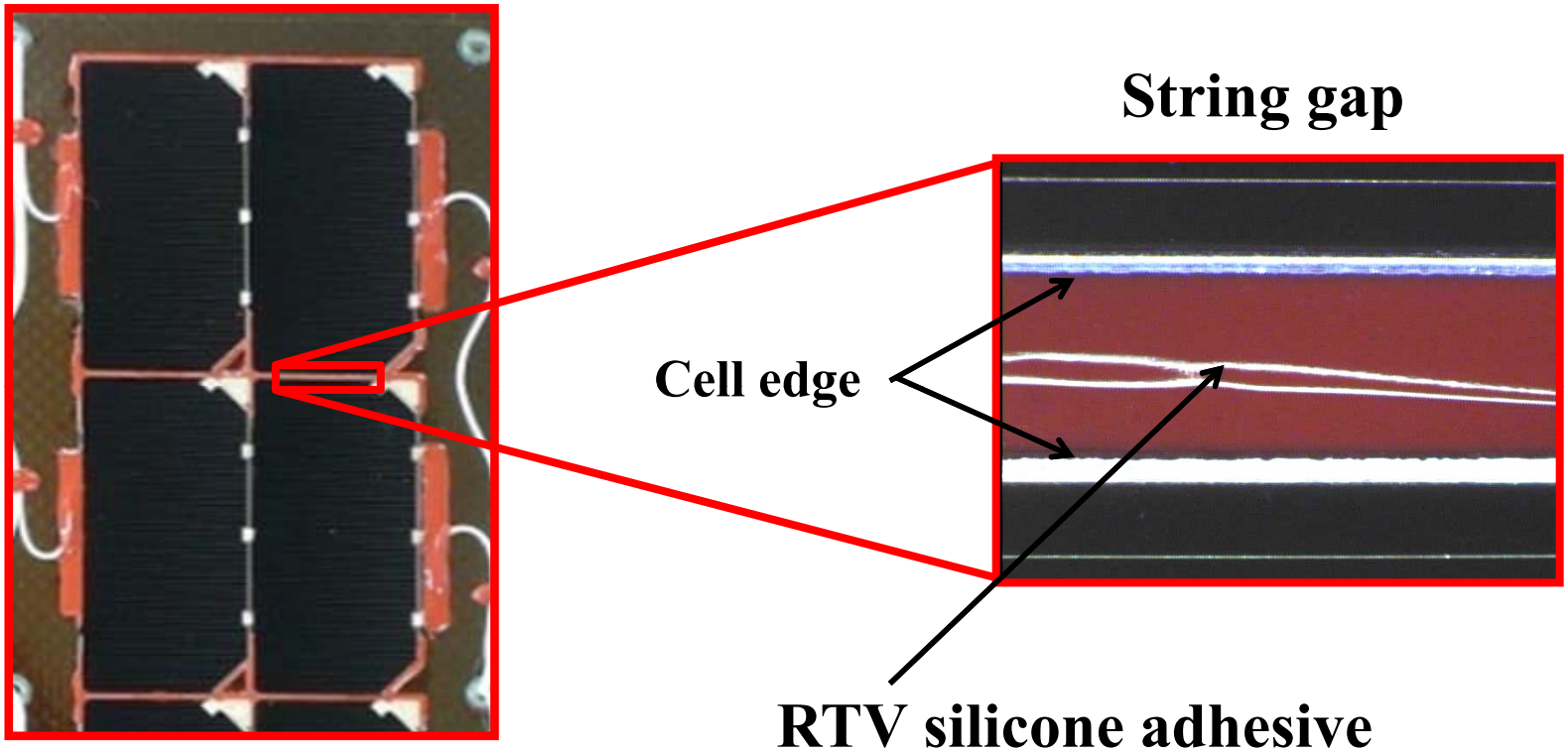
◆ETS-VIII

(Engineering test satellite)

- One of largest geostationary satellites (37m × 40m)
- Mission:
  Improve mobile communication, development of technologies for a multimedia broadcasting system, etc.
- Bus voltage: 50V → 100V



Grouting



Effect of aging on Discharge Tolerance of Grouted Solar Array Panels is unclear

2. Purpose

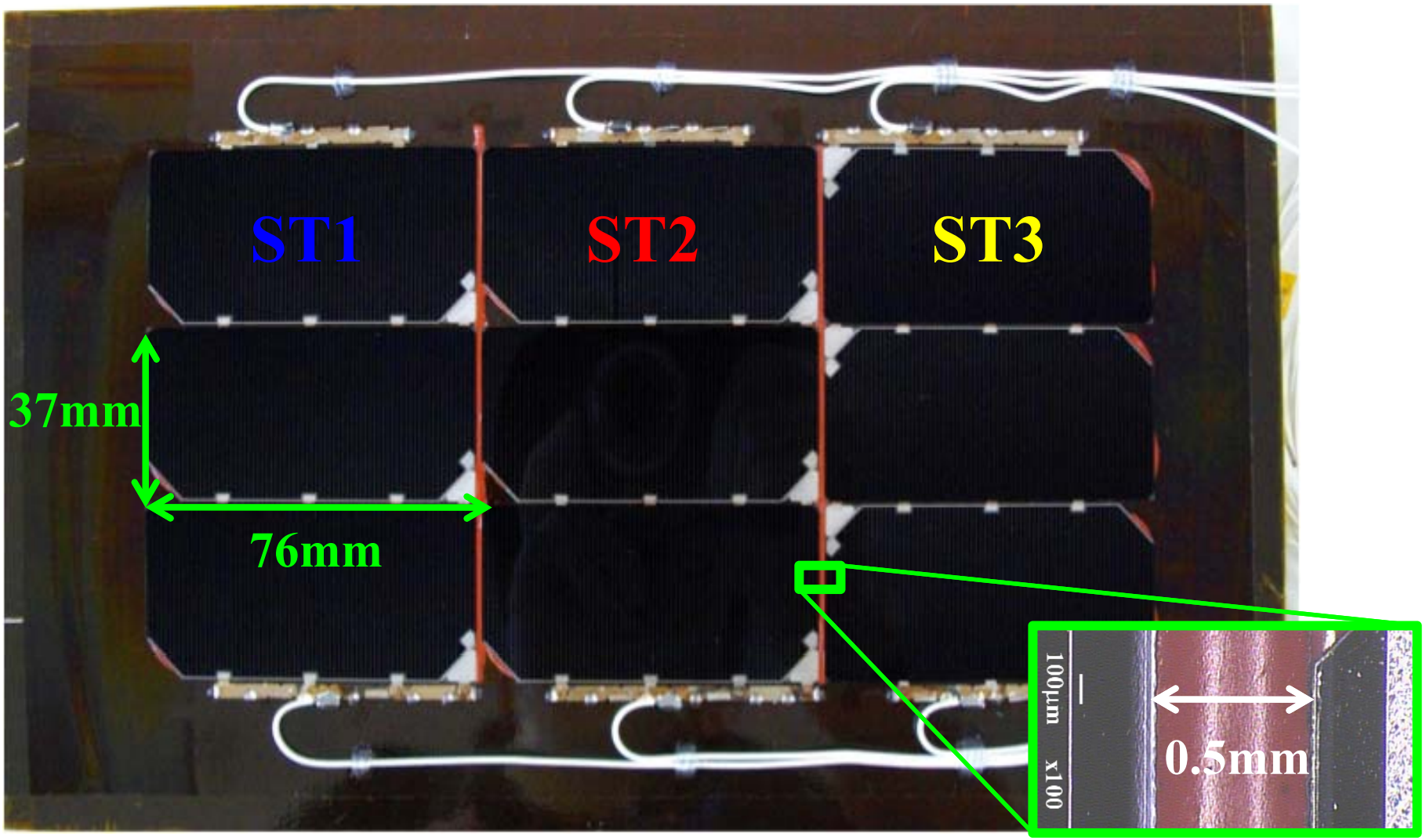
Evaluate discharge tolerance of grouted solar array panel after aging tests.

- **Aging tests against 3 coupon (Equivalent to 10 years)**
  - **Proton irradiation**
  - **Electron irradiation**
  - **Thermal cycling**

    ⇨ **2 coupons were sent to ONERA and NASA**

- **Arc test in round robin style**
  - **Primary arc test**
  - **Secondary arc test**

Test coupon



Test flow

:Grouting

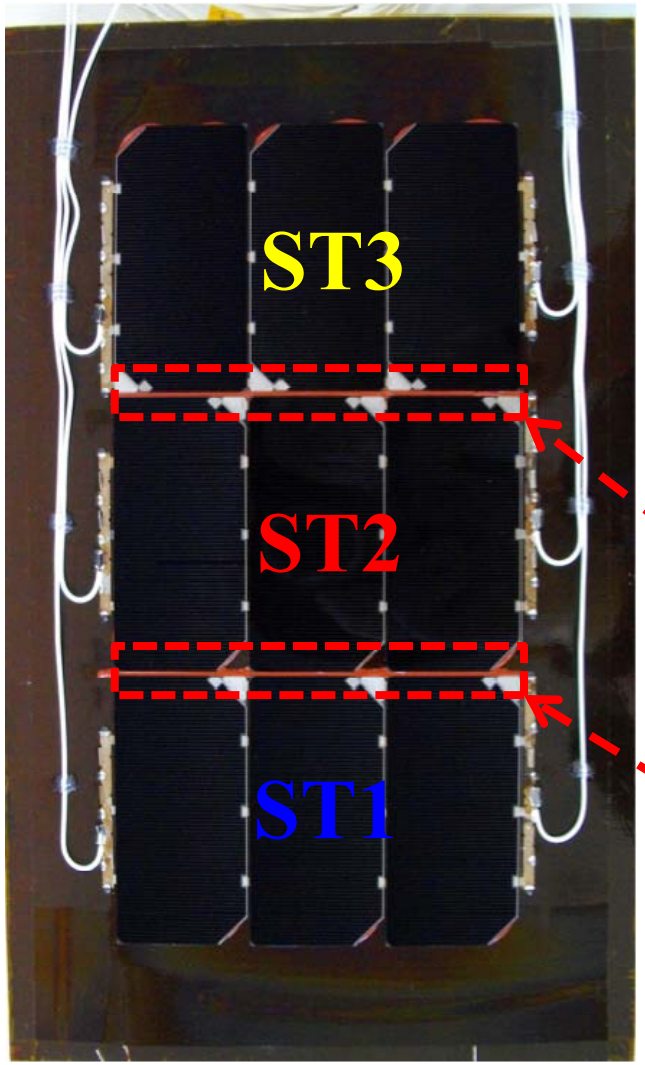
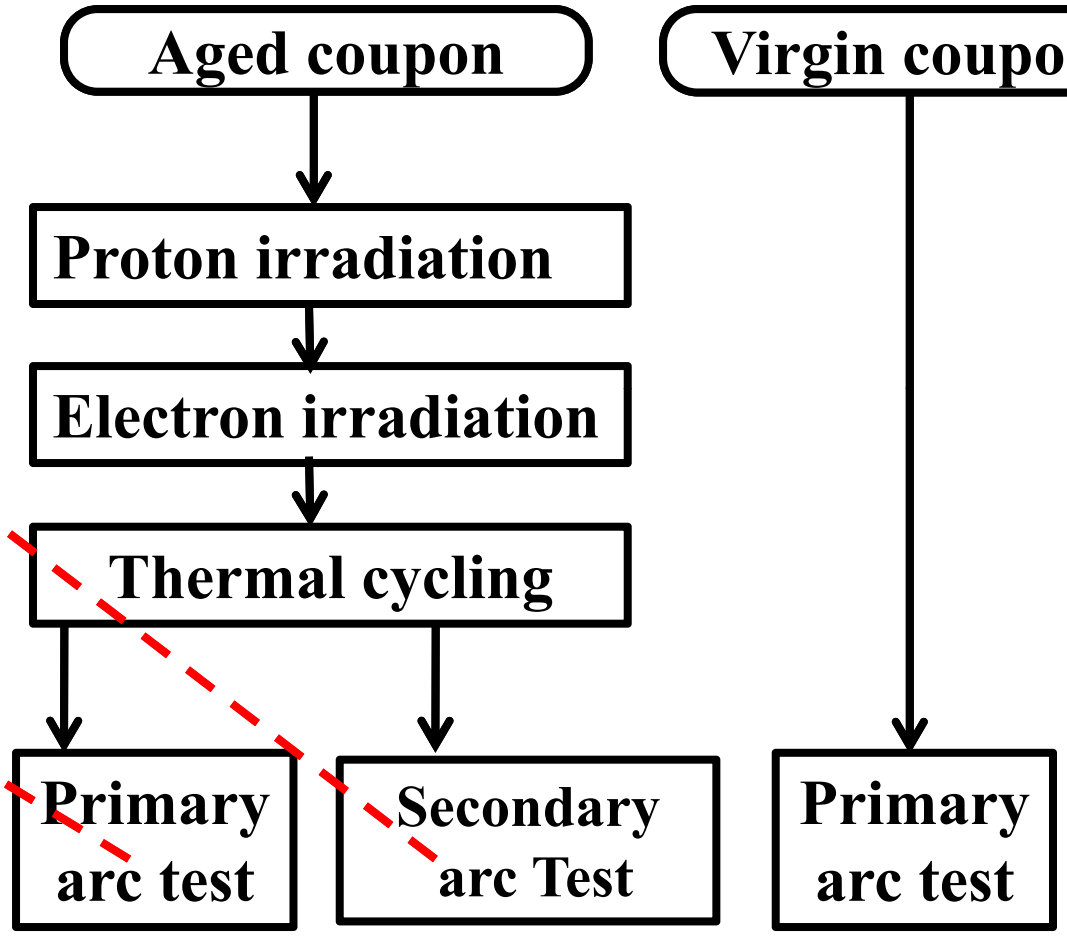
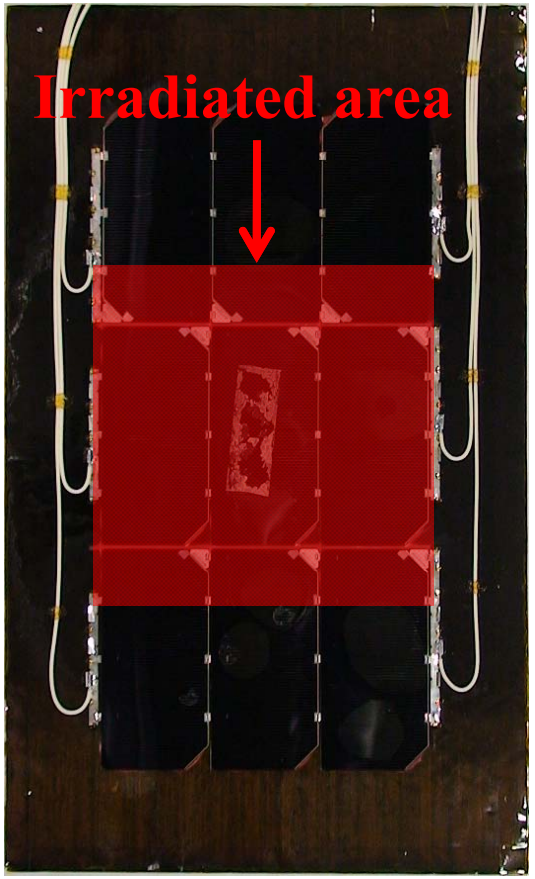


Photo of a test coupon



3. Aging test

Proton irradiation condition



Area :10cm×10cm

Energy :10MeV

Flux :1.25 × 10^9 p/cm^2· s

Fluence :10^{12} p/cm^2

Fluence distribution of Proton was uniform on irradiated area.

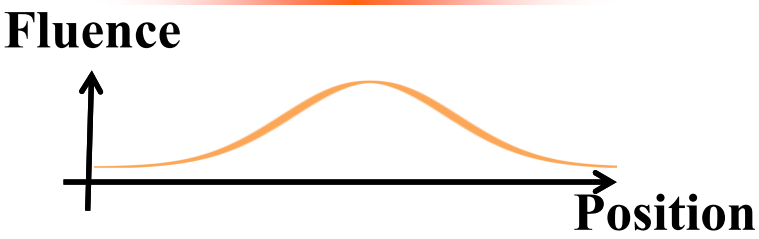
Electron irradiation condition

Area : All

Energy :1MeV

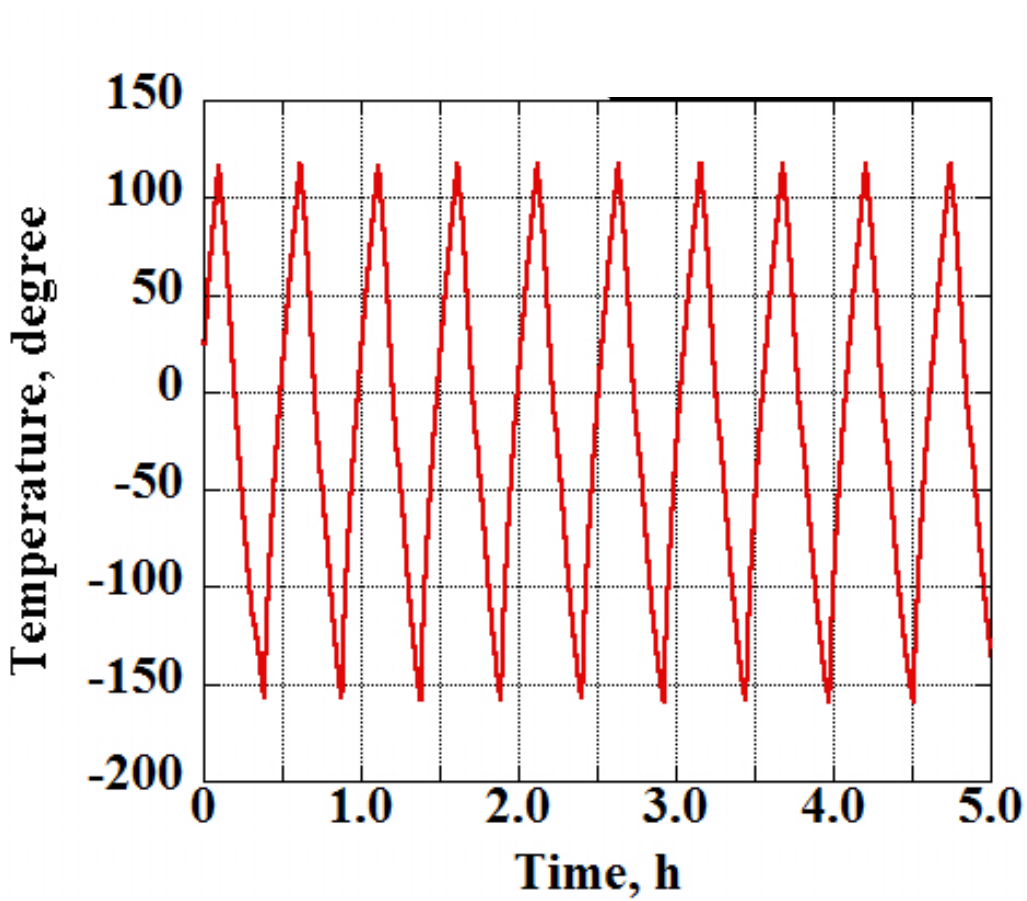
Flux :5×10^{11} p/cm^2· s

Fluence : Up to 10^{16} e/cm^2



Fluence distribution of electron was not uniform.

Thermal cycling condition



Controlled temperature profile

Max : 100℃

Min : -150℃

Period : 1 hour/cycle

Cycle no. : 1000

Visual examination result (1/2)

● :Crack

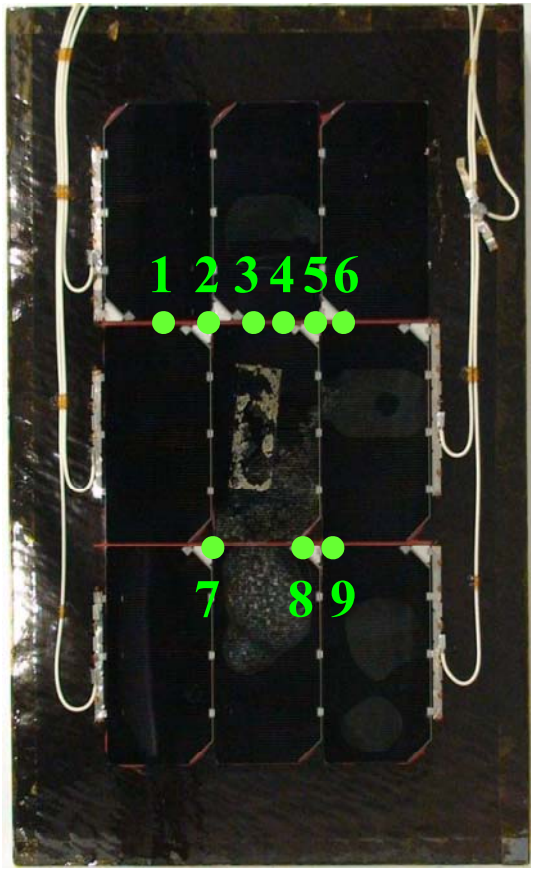
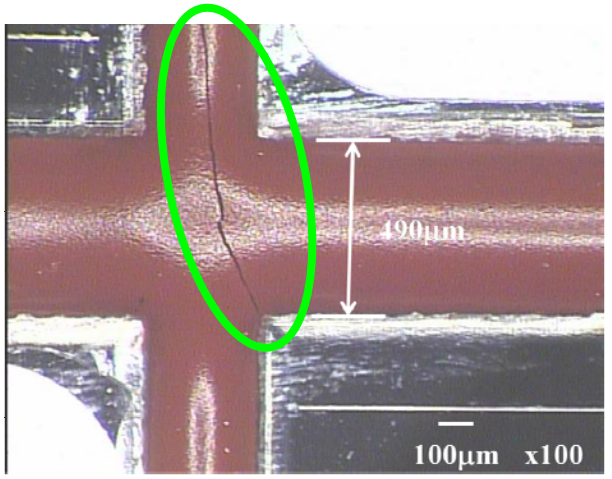
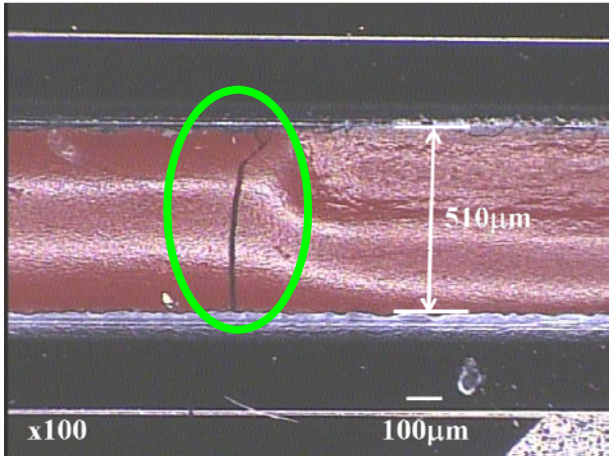


Photo of test coupon after simulated space environment test



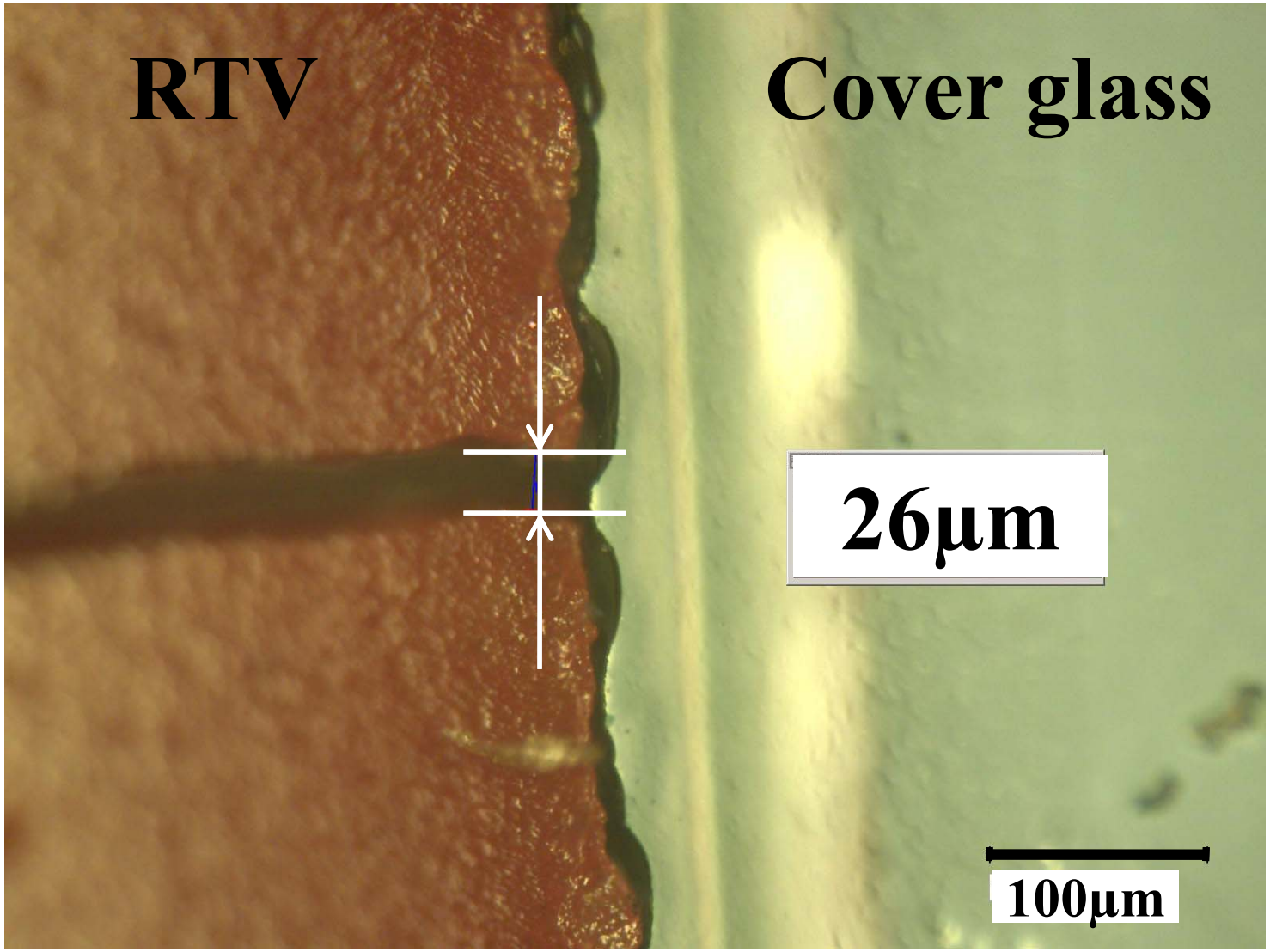
Microscope picture of crack 2



Microscope picture of crack 4

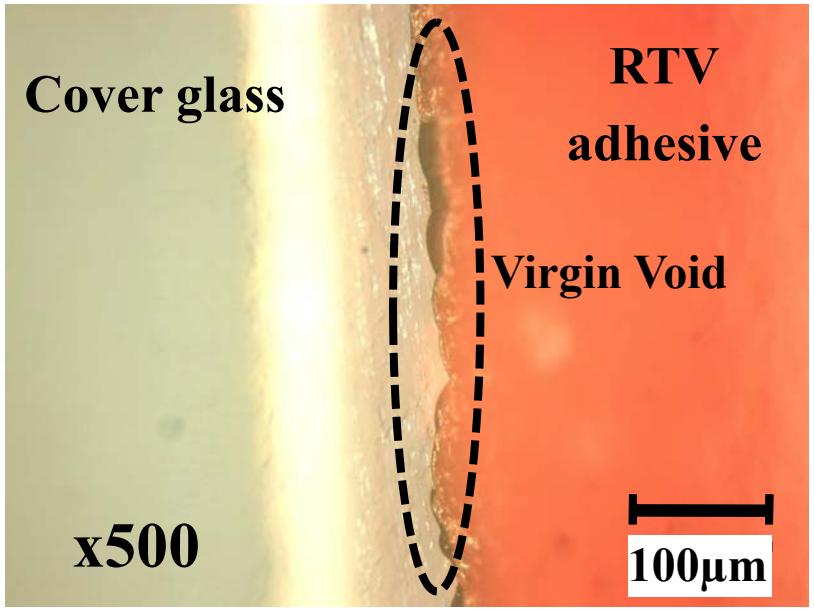
Cracks were founded at the 9 points in total.

Width of crack

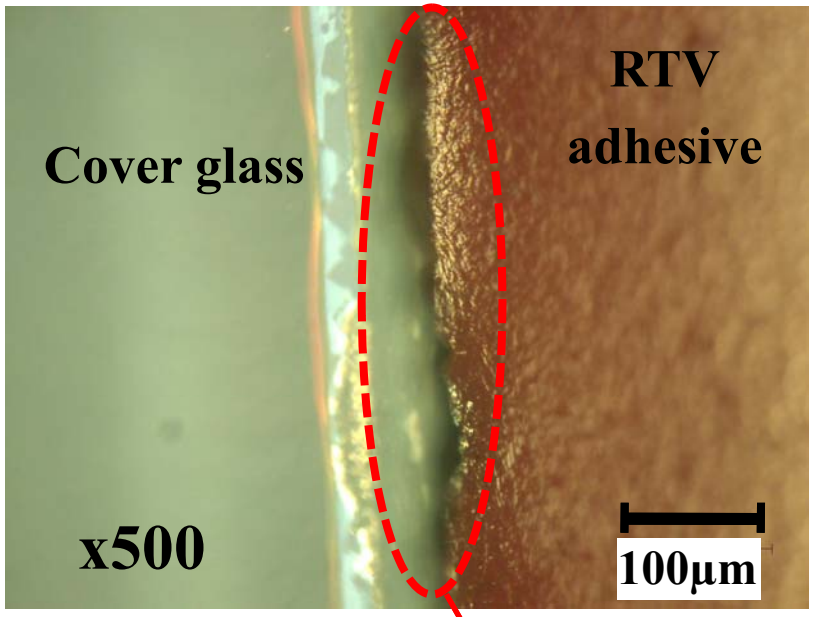


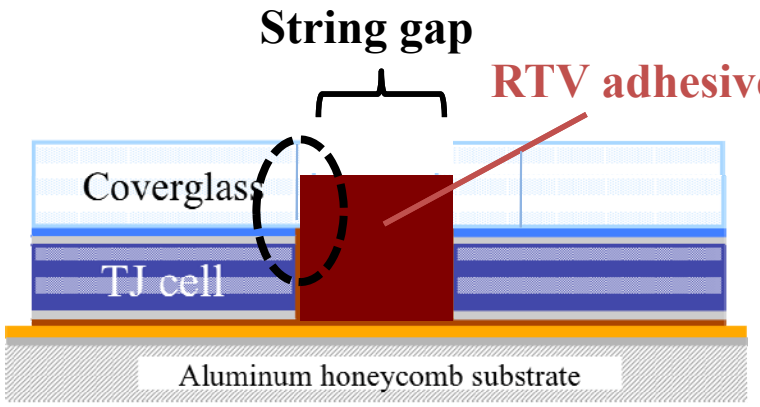
Visual examination result (2/2)

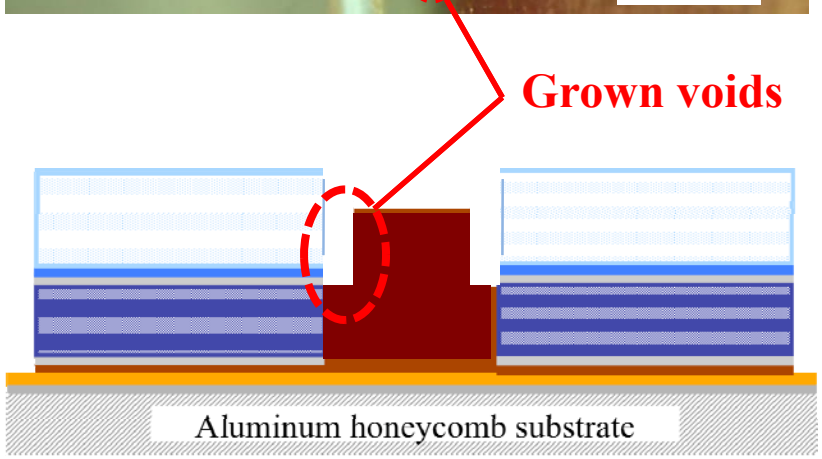
[Before]



[After]





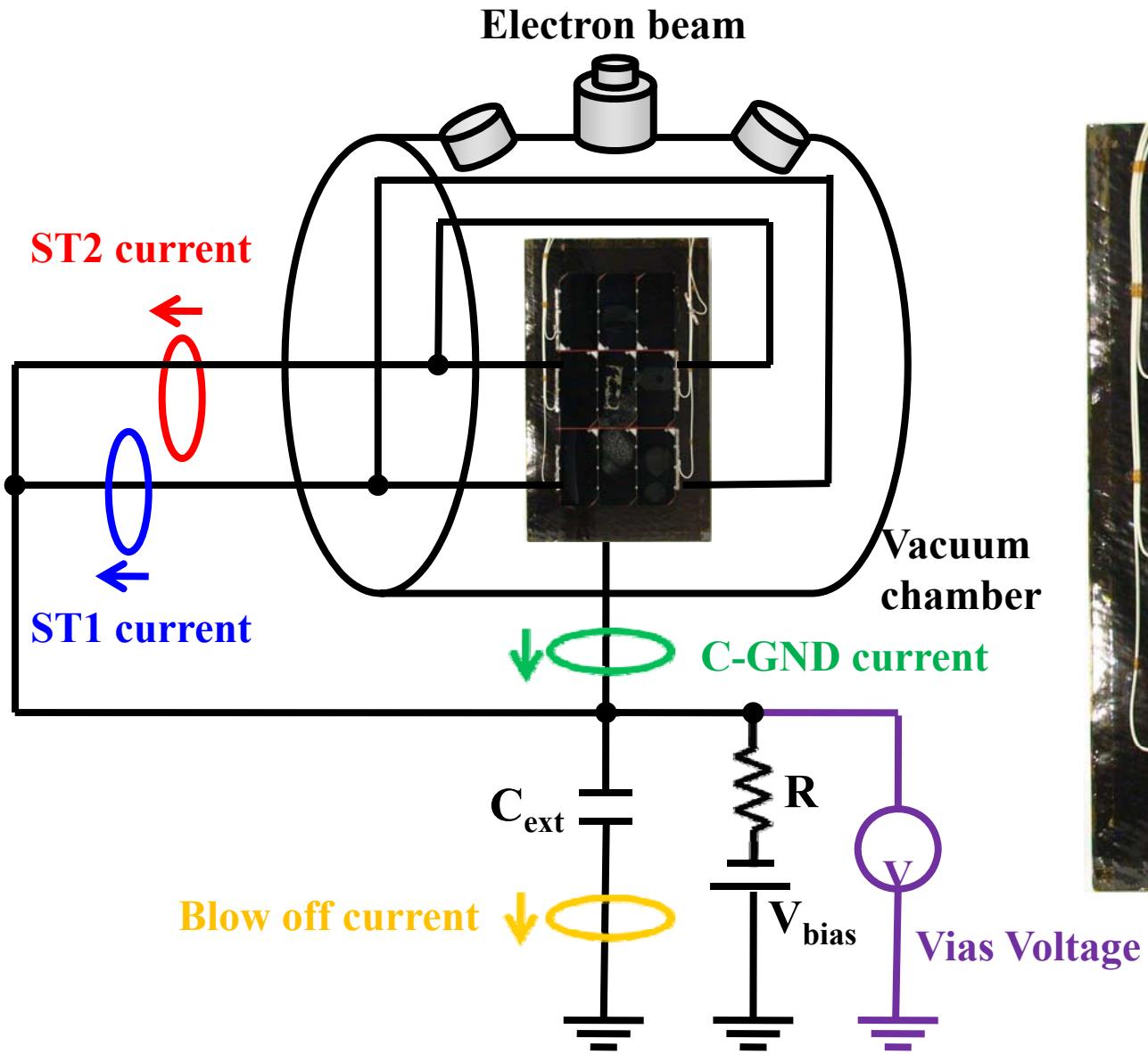


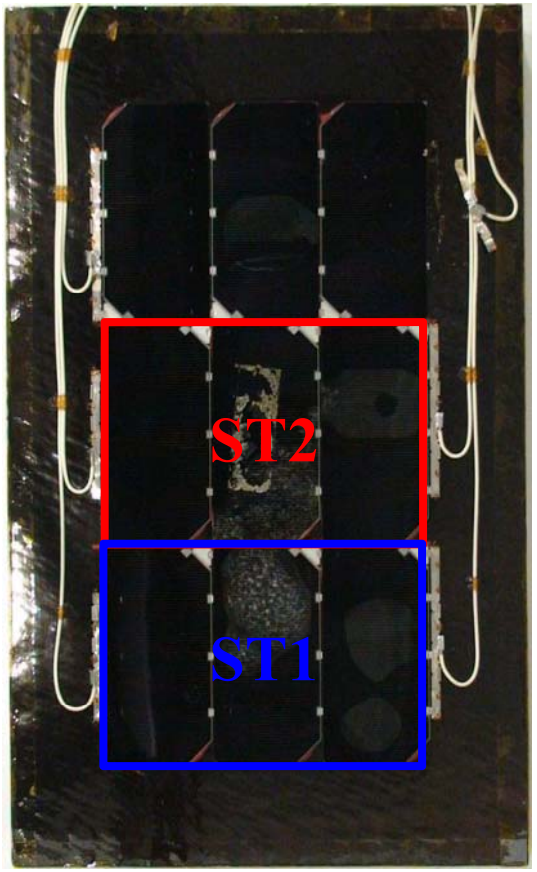
Growth of voids were found

at the interfaces between Cover glass and RTV-adhesive.

4. Primary arc test

Test schematic

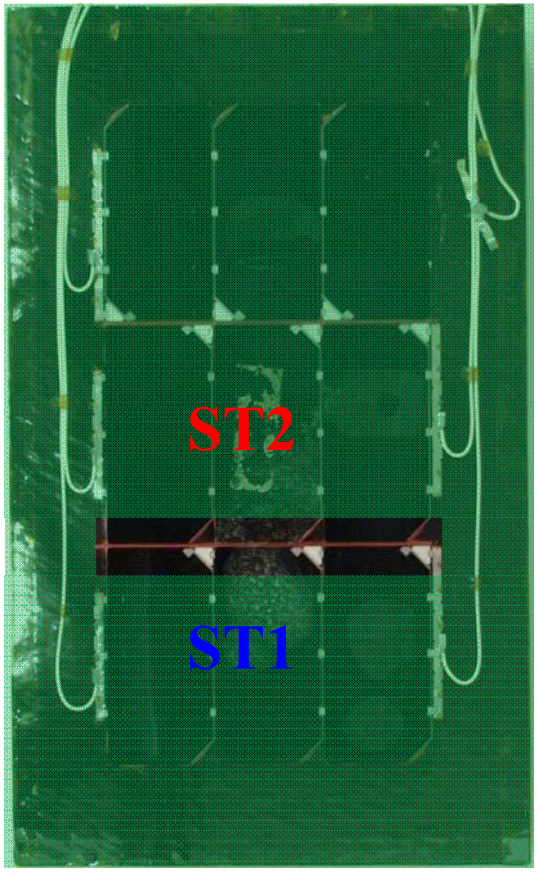




Test condition

:Polyester sheet

Circuit condition			Environment Condition		
Rb [MΩ]	Cext [nF]	Vbias [kV]	Back pressure [Pa]	Electron beam condition	
				Energy [keV]	Current [μA]
10	5	-5	3.0×10^{-3}	6.0	5~20



Test result

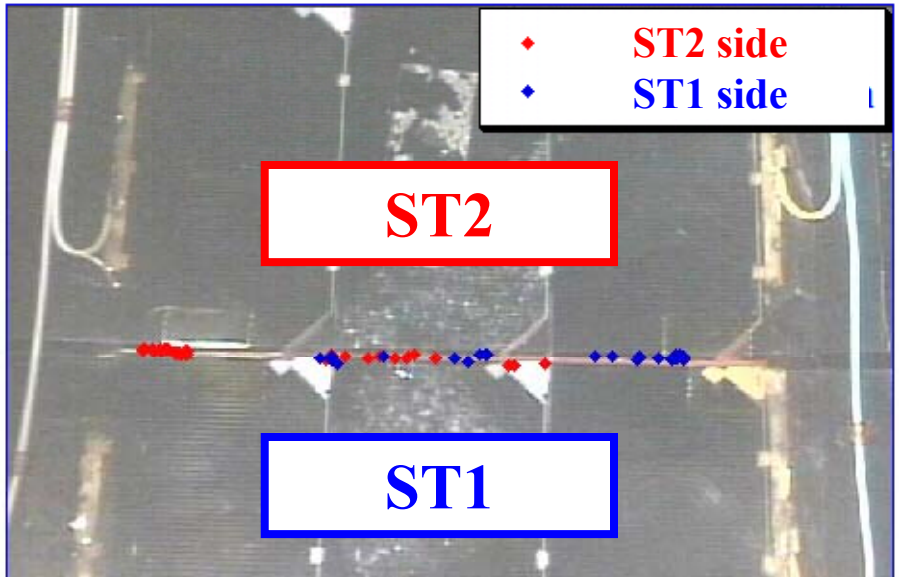
Virgin

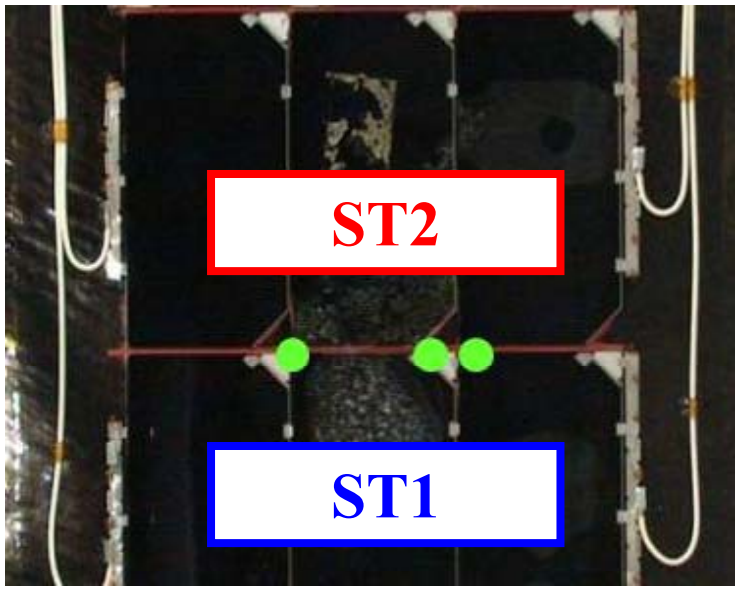
Number of Arcs	Position	
Total	ST2	ST1
0	0	0

Irradiated

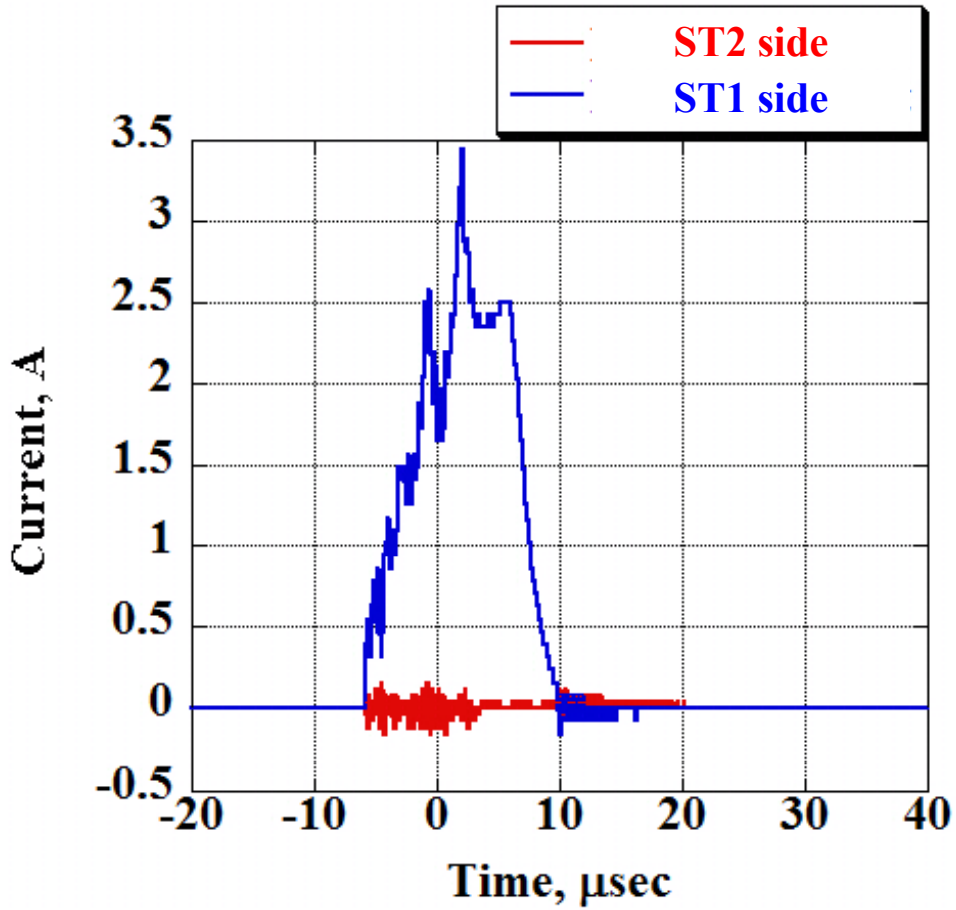
Number of Arcs	Position	
Total	ST2	ST1
97	64	33

● :Crack

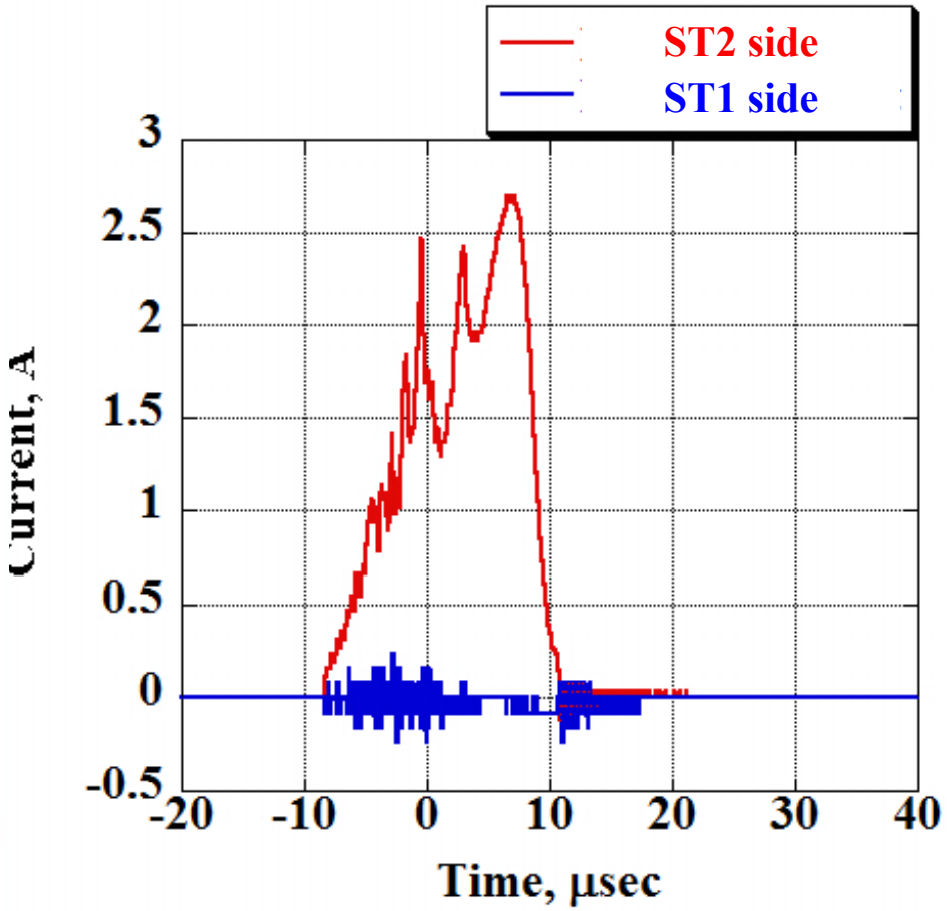




PA waveforms



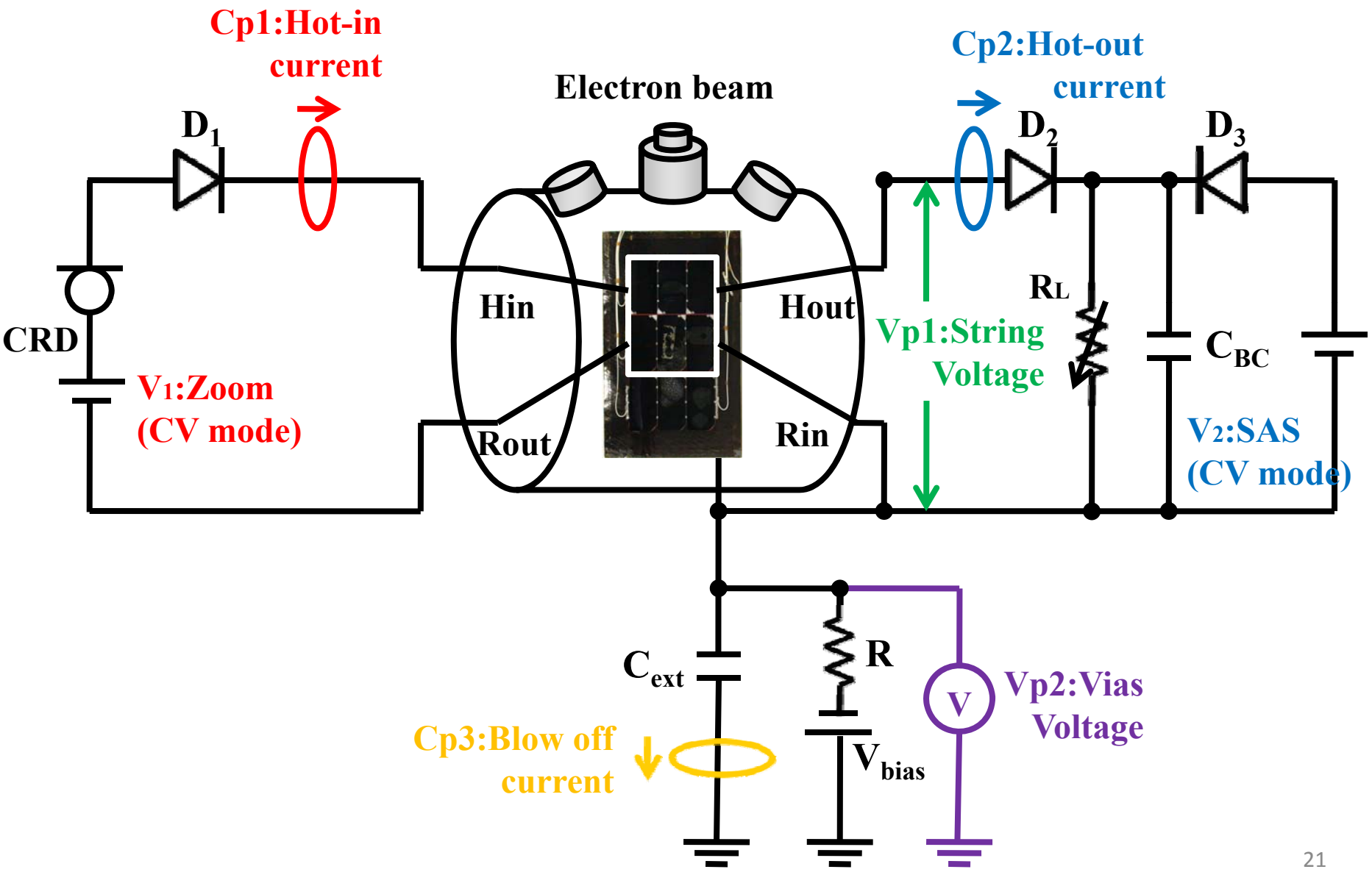
Waveform occurred on ST1 side



Waveform occurred on ST2 side

5. Secondary arc test

Test schematic

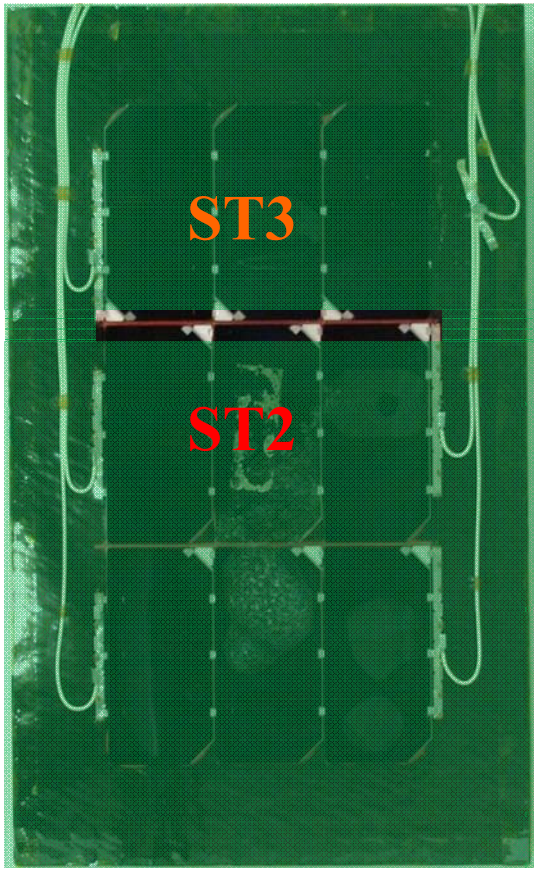


Test condition

Circuit condition					
String capacitance Cst[nF]	Rb [MΩ]	Cext [nF]	Vbias [kV]	String Voltage [V]	String current [A]
0	10	5	-5	100	2.4

Environment Condition		
Back pressure [Pa]	Electron beam condition	
	Energy [keV]	Current [μA]
2.0~5.0 ×10^{-4}	4.0~6.0	10~50

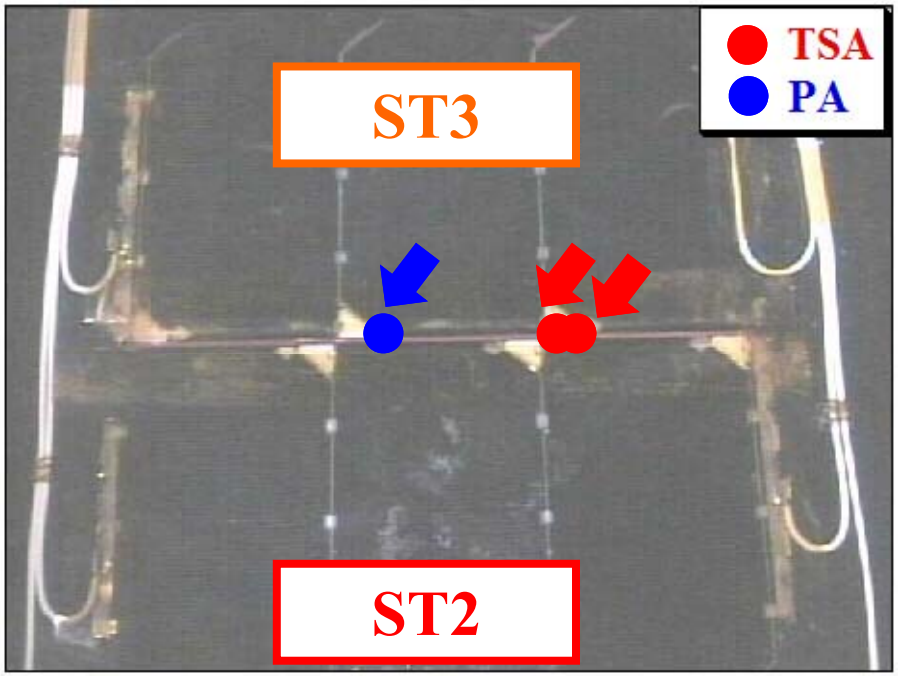
:Polyester sheet

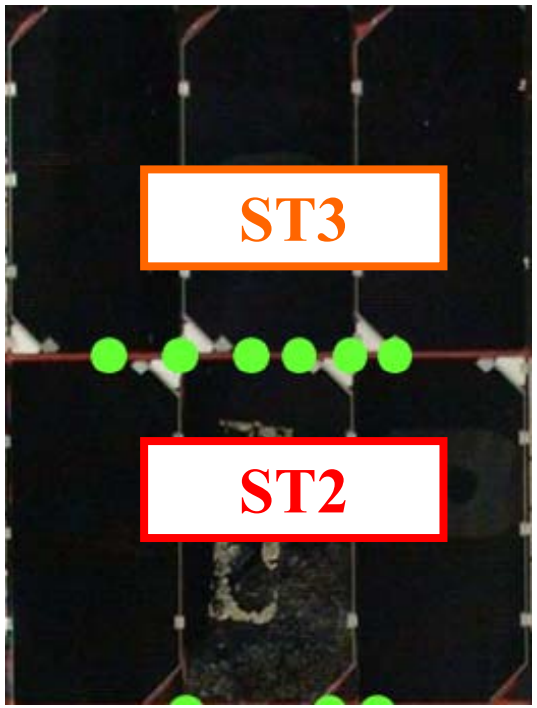


Test result

Number of Arcs					Probability[%]			TSA Duration[msec]	
Total	PA	NSA	TSA	PSA	NSA	TSA	SA	Avr	Std
3	1	0	2	0	0	66	66	54.1	17.5

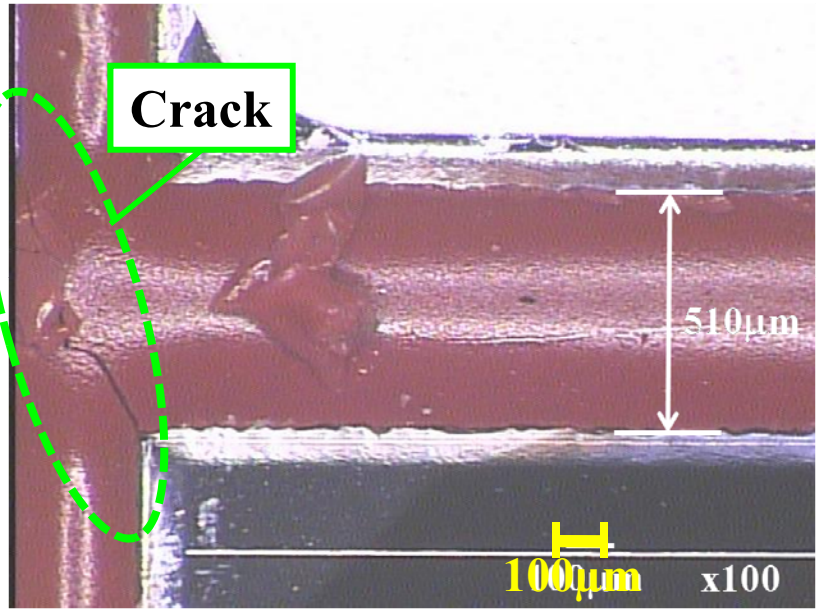
● :Crack



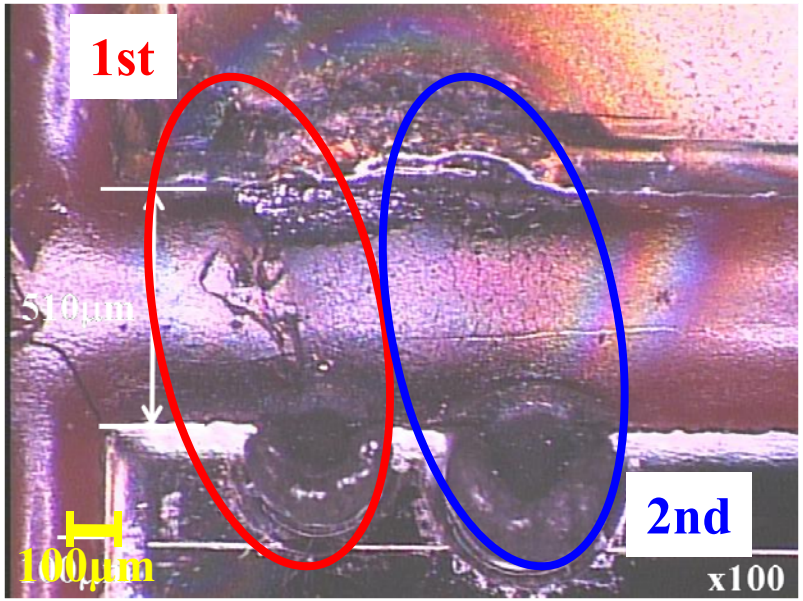


Trace of TSAs

Before

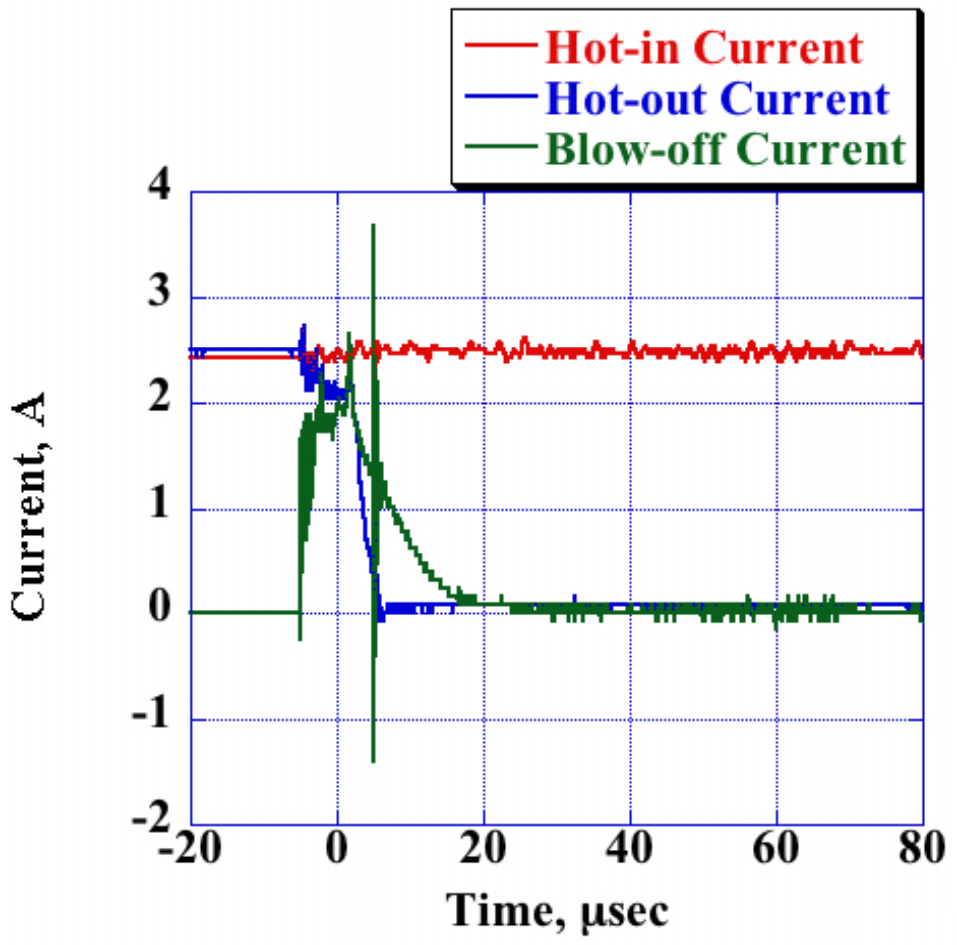


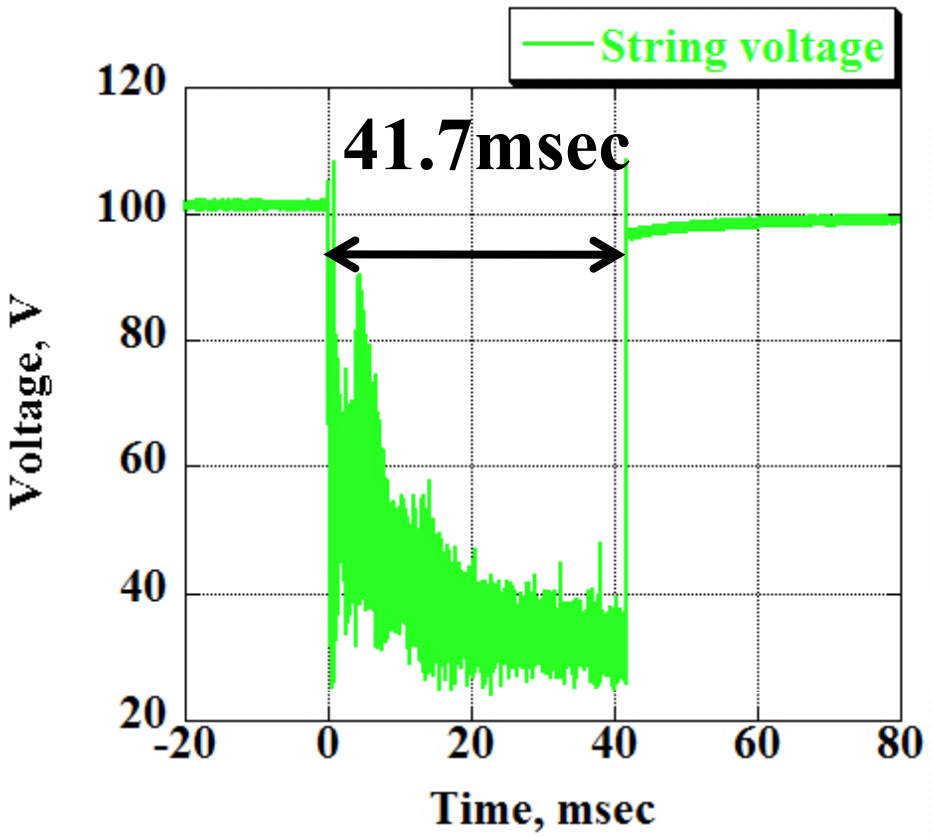
After



2 TSA occurred outside the crack.

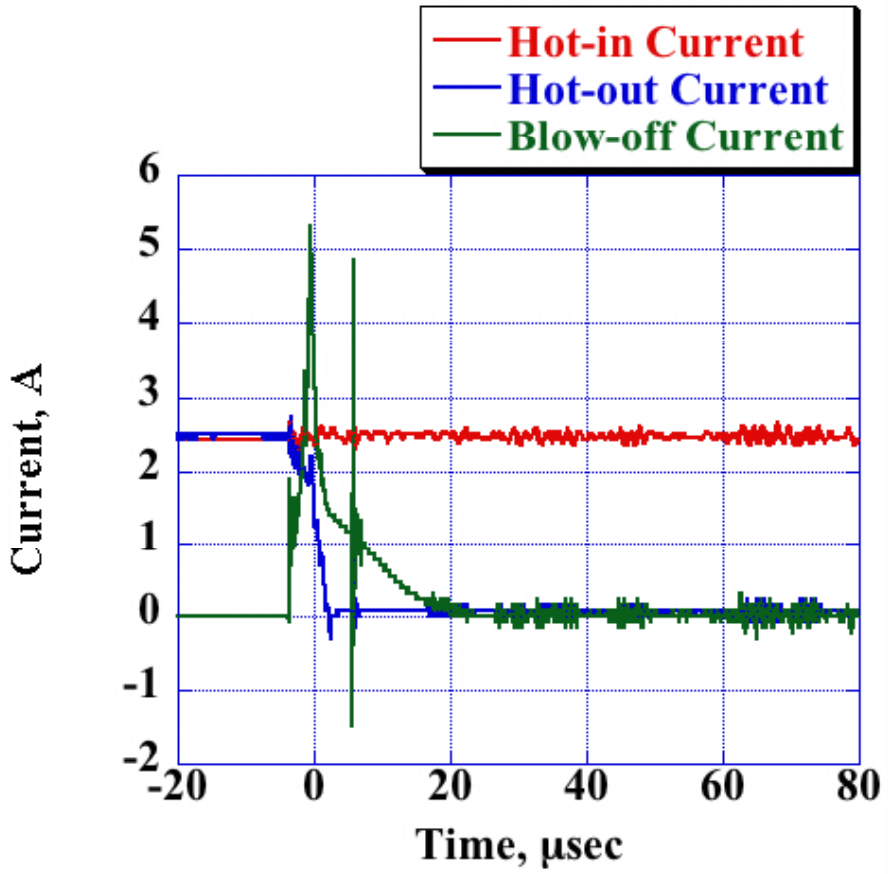
Waveforms of 1st TSA

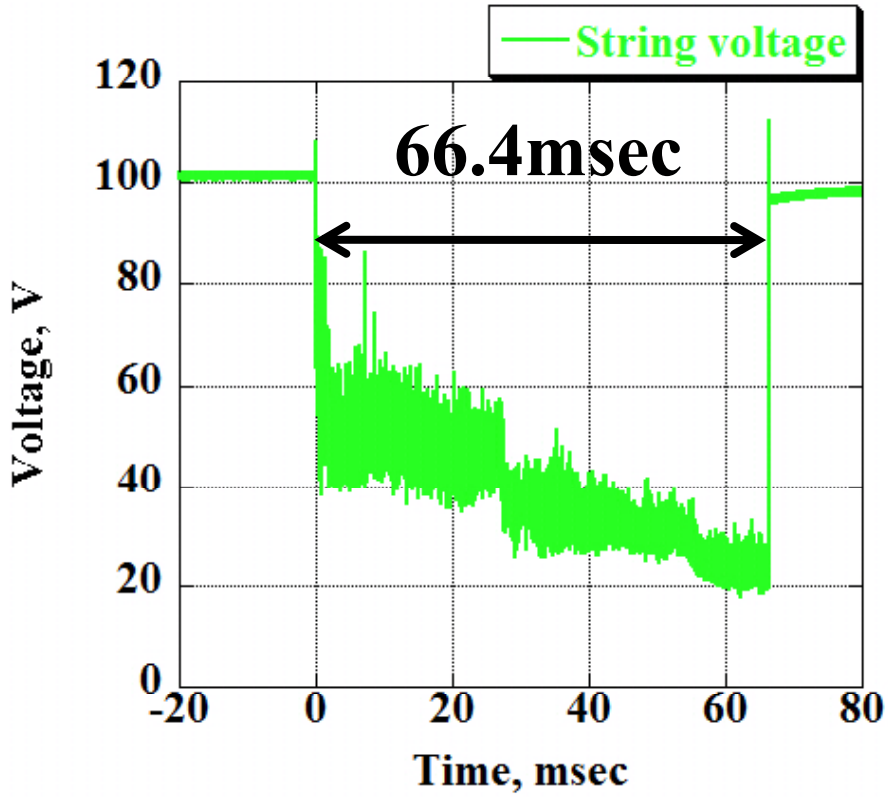




Long duration was observed.

Waveforms of 2nd TSA

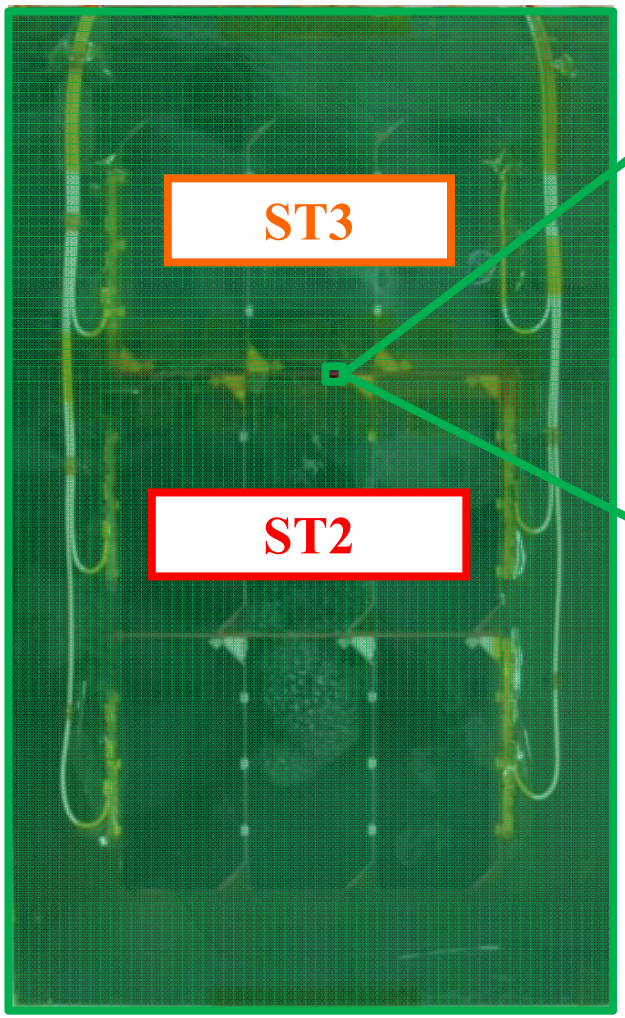


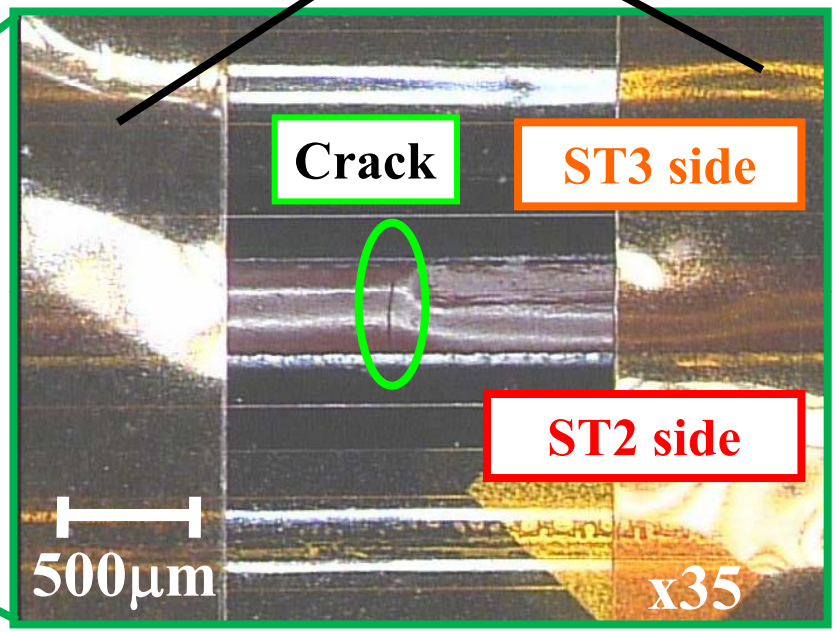


No effect of discharge on insulator resistance even though the duration were long.

Additional test condition

:Polyester sheet

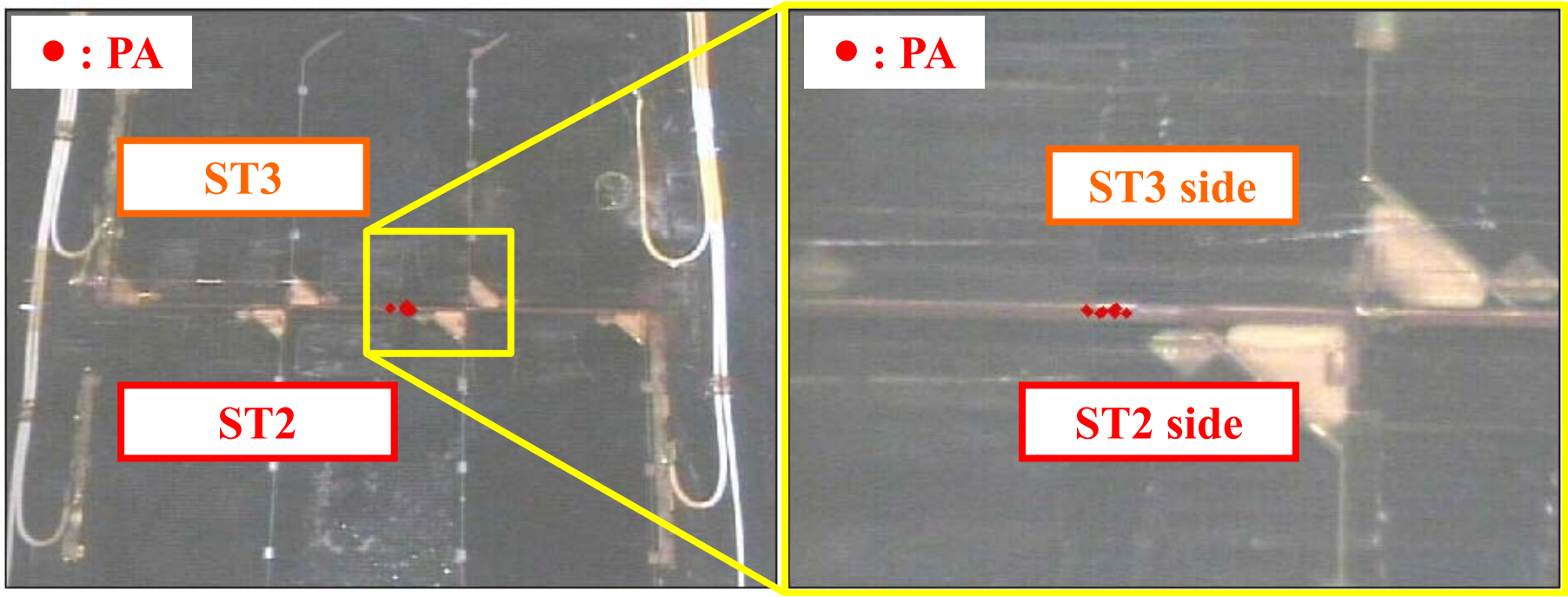




Electron beam exposed area was limited to the small area which contains crack to confirm secondary arcs occur or not.

Additional test result

Number of Arcs					Probability[%]			TSA Duration[msec]	
Total	PA	NSA	TSA	PSA	NSA	TSA	SA	Avr	Std
22	22	0	0	0	0	0	0	0	0



No secondary arc occurred.

6. Summary

- Aging caused following damages of RTV adhesive.
  - Cracks
  - Voids
- Primary arcs occurred on the aged solar array coupon with RTV adhesive.
  - A crack or void caused an exposure of triple junction where primary arcs occur easily .
  - More primary arcs occurred on the voids.
- Secondary arcs occurs on the irradiated solar array coupon.
  - 2 TSA occurred in the gap
- Future woke

  Secondary arc test with rising string current to evaluate whether TSA occurs at the crack

Acknowledgement

This research was supported by New Energy Industrial Comprehensive Development Organization (NEDO) of Japan.