in situ AC Impedance Measurement in c-Si PV Modules during Rapid Thermal Cycling Test

Tadanori Tanahashi[1], Soh Suzuki[1], Norihiko Sakamoto[2], Akihiro Mito[2],
Katsuhiko Shirasawa[3] and Hidetaka Takato[3] ([1]ESPEC CORP., [2]AIST-NMIJ, [3]AIST-FREA)

FREA FUKUSHIMA RENEWABLE ENERGY INSTITUTE, AIST

Technology development for the high-rate introduction of renewable energy

NMIJ ESPEC

Introduction & Procedures

Motivation & Background

FREA: Fukushima Renewable Energy, AIST

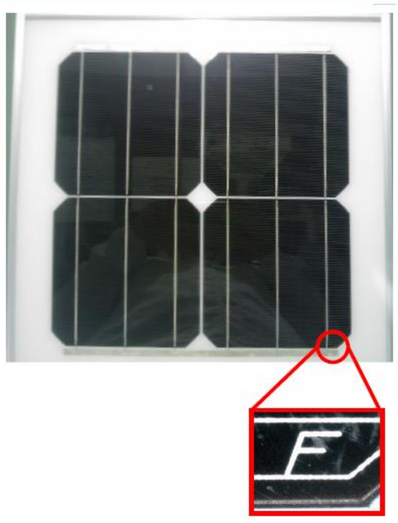
Aim: High Efficiency / Low Cost c-Si PV Cells & Modules
Thin Wafer PV Cells, Light Weight PV Modules…

Our Task: Thin Wafer PV Cells + Ribbon with Opt. Properties
-> Reliable / Durable Interconnected PV Modules

To Confirm the Reliability of Soldering Interconnection on these New Designed PV Modules,

- Higher Stress than Conventional Thermal Cycling
  - -40 °C/85 °C → -60 °C/100 °C
  - Thermal Cycling → Rapid Thermal Cycling
  - 200 cycles → 3,000 cycles +
- *in situ* Detection of Failures during Testing
  in situ AC Impedance Spectroscopy

Thin Wafer PV Cells / Light Weight Glass → "FREA PV Module"



Tested PV Mini-Module

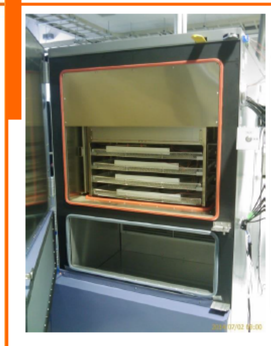
Thin Wafer PV Cells
Mfg. in FREA Lab.
100 μm Thickness
n-type c-Si / p-doped

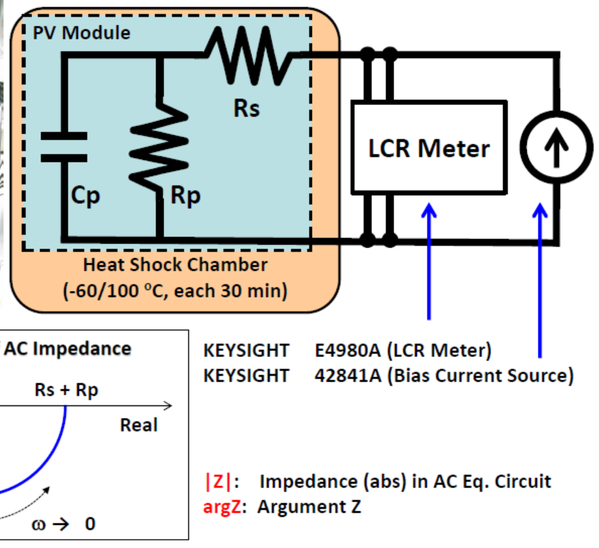
Chemical Strengthen Glass
0.8 mm Thickness

Interconnection
Cu-Ribbon (1.3 mm)
by Soldering

with J-Box & Cables

Experimental Setup & AC Equivalent Circuit of PV Module





KEYSIGHT E4980A (LCR Meter)
KEYSIGHT 42841A (Bias Current Source)

|Z|: Impedance (abs) in AC Eq. Circuit
argZ: Argument Z

Summary

We previously reported that the "spike-like" elevation of whole impedance was observed, which was calculated by the measurement of I_{AC} and V_{AC}, prior to the occurrence of interconnection failure during Rapid Thermal Cycling (RTC) test. In this study, the AC impedance parameters (|Z| and θ) were continuously measured during this testing.

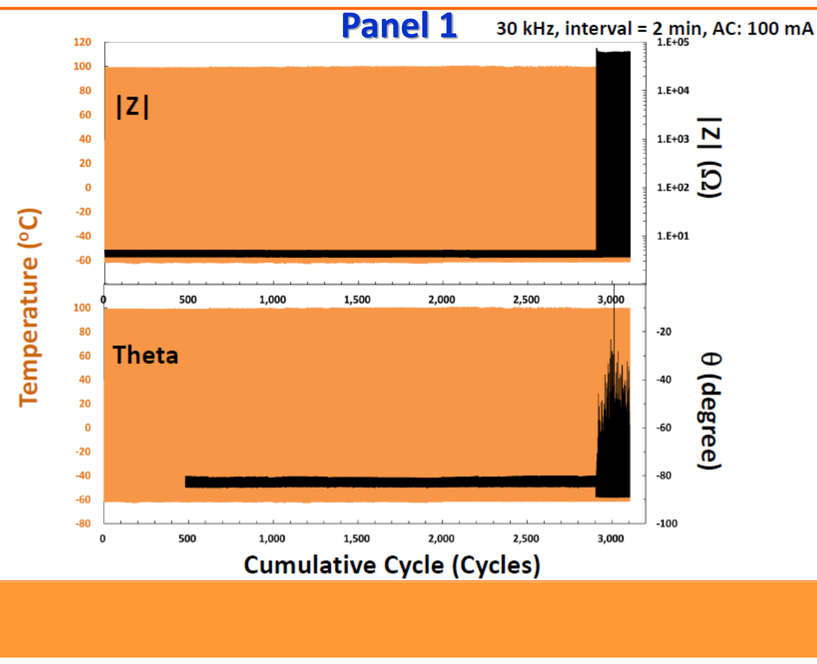
Then, we obtained the results as follows;

- The logarithmical impedance-elevation identified by |Z| elevation was observed at ca. 3,000 cycles of RTC (**Panel 1**). Interestingly, the increasing of |Z| consistently accompanied with θ decreasing.
- These level-changes of |Z| and θ were observed in the temperature elevation phase, and also in the low temperature phase after the PV modules were sufficiently adapted at low temperature (**Panel 5-8**).
- When the PV module was completely adapted to any temperature just after these phenomena were happened, the level-changes of AC parameters were not detected at all (**Panel 9-10**). Simultaneously, any alterations of EL and IR images were not confirmed at room temperature (**Panel 11**).
- From the AC impedance spectroscopy (20 Hz ~ 50 kHz) during the |Z| elevating period (at -60 ºC), it is revealed that the levels of |Z| and θ were >10^4 Ω and almost -90º, respectively (**Panel 12-13**).

These results suggest that the soldering failure in PV modules (including the disconnection in junction box) can be observed when the RTC testing was conducted for prolonged cycles (ca. 3,000 cycles), and that this failure can be detected only during the RTC testing, as a complete detachment between electrical junctions, by the continuous *in situ* AC impedance measurement.

AC Impedance: Time Course during Rapid Thermal Cycling

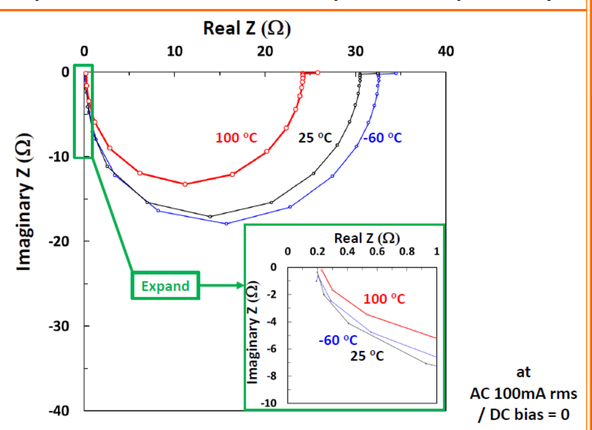
Panel 1 30 kHz, interval = 2 min, AC: 100 mA



Experimental Results

Panel 2

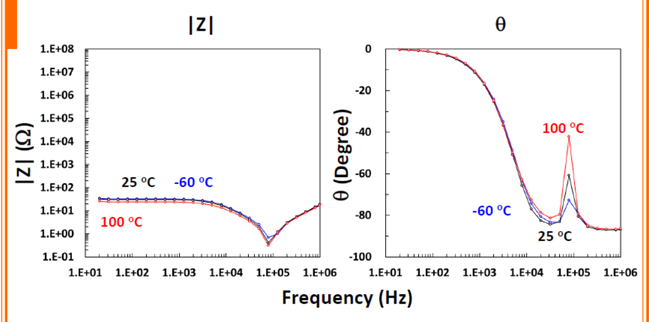
AC Impedance Characteristics: Temperature Dependency



at AC 100mA rms / DC bias = 0

Panel 3

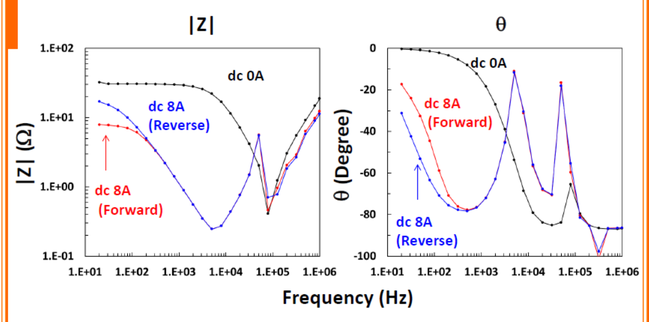
AC Impedance Characteristics: Temperature Dependency



at AC 100mA rms / DC bias = 0

Panel 4

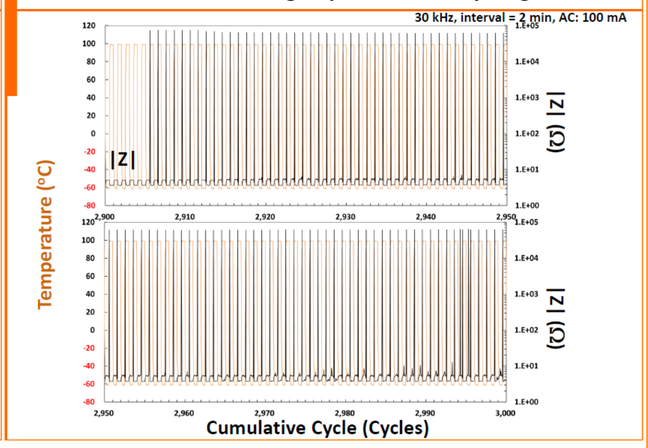
AC Impedance Characteristics: DC Bias Effects



at AC 100mA rms / 25 °C

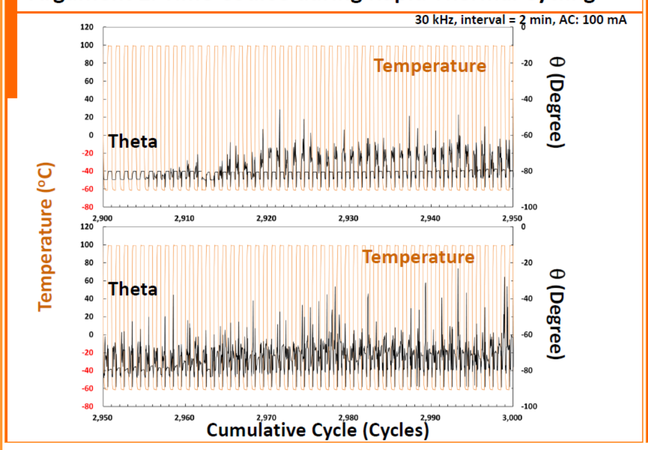
Panel 5

Abs Z: Time Course during Rapid Thermal Cycling



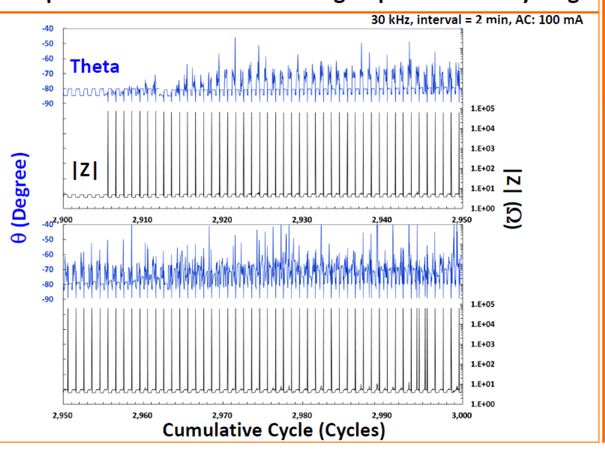
Panel 6

Argument Z: Time Course during Rapid Thermal Cycling



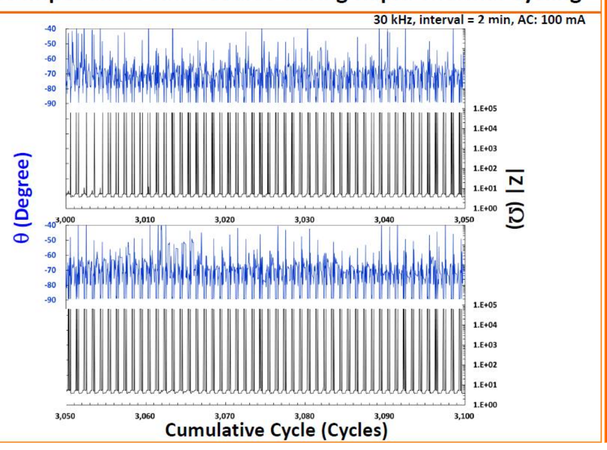
Panel 7

AC Impedance: Time Course during Rapid Thermal Cycling



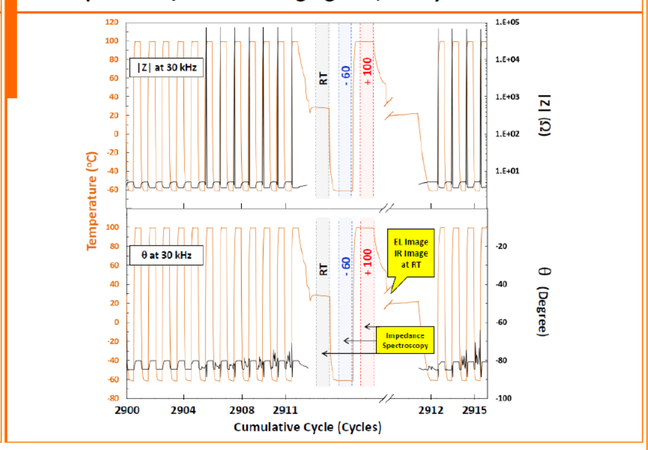
Panel 8

AC Impedance: Time Course during Rapid Thermal Cycling



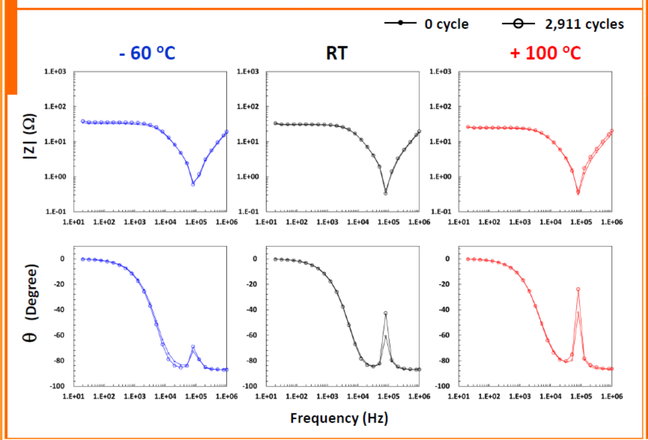
Panel 9

AC Impedance / EL & IR Imaging at 2,911 cycles



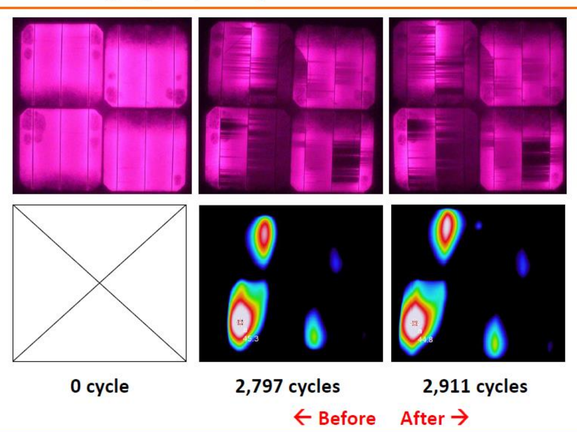
Panel 10

AC Impedance Spectroscopy at 2,911 cycles



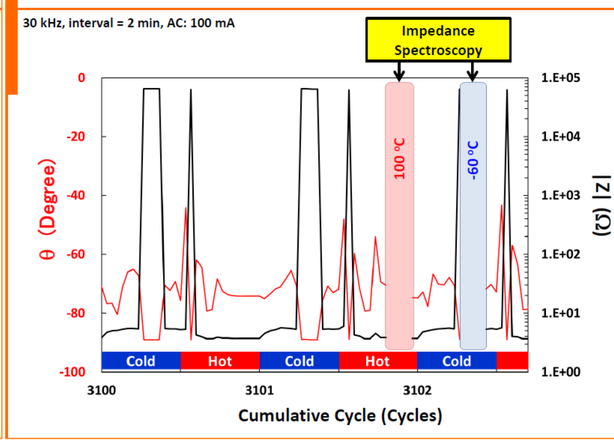
Panel 11

EL & IR Imaging at 2,911 cycles



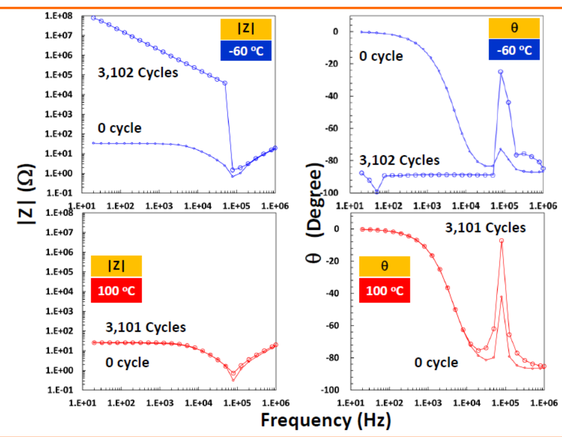
Panel 12

AC Impedance at Late Phase



Panel 13

AC Impedance Spectroscopy at Late Phase



Contact Person: Tadanori Tanahashi (t-tanahashi@espec.co.jp)

This work was supported by the "Next-generation Crystalline Si PV Consortium" (National Institute of Advanced Industrial Science and Technology, Japan).

This poster does not contain any proprietary or confidential information.