National Institute of Advanced Industrial Science and Technology
AIST

PVモジュール信頼性評価：加速試験中評価手法の開発

棚橋 紀悟
産業技術総合研究所　太陽光発電研究センター　モジュール信頼性チーム

Introduction & Procedures

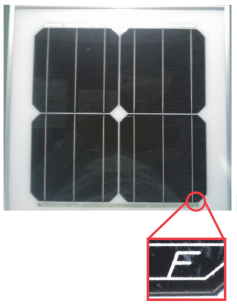
Motivation & Background

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

To Confirm the Reliability of 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

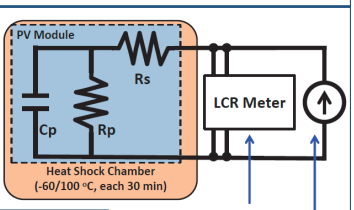
Thin Wafer PV Cells
Mfg. in FREA Lab.
100 μm Thickness
n-type c-Si / p-doped

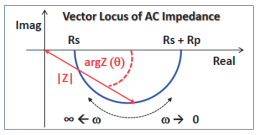
Chemical Strengthen Glass
0.8 mm Thickness

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 (JJAP 51: 10NF13, 2012). In this study, the AC impedance parameters (|Z| and θ) were continuously measured during this testing.

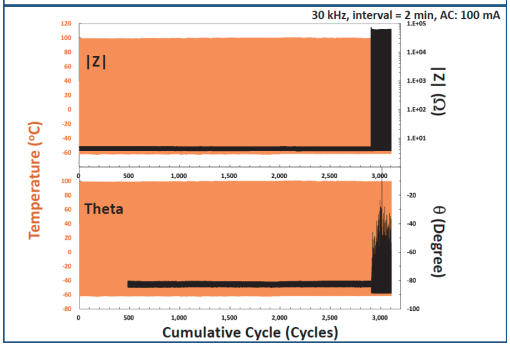
Then, we obtained the results as follows;

- 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.

Panel 1

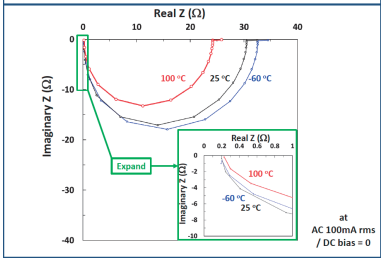
AC Impedance: Time Course during Rapid Thermal Cycling



Results

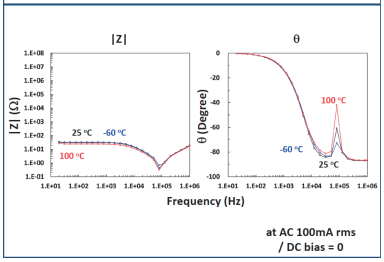
Panel 2

AC Impedance Characteristics: Temperature Dependency



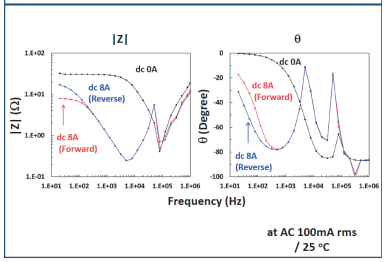
Panel 3

AC Impedance Characteristics: Temperature Dependency



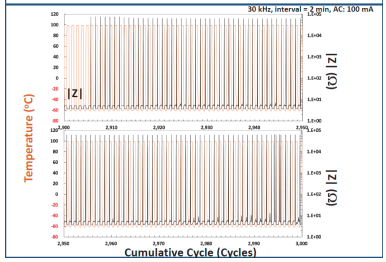
Panel 4

AC Impedance Characteristics: DC Bias Effects



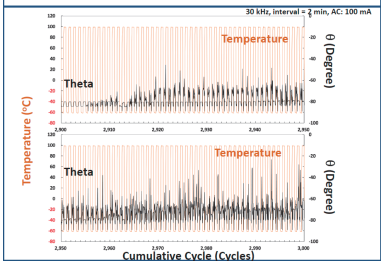
Panel 5

Abs Z: Time Course during Rapid Thermal Cycling



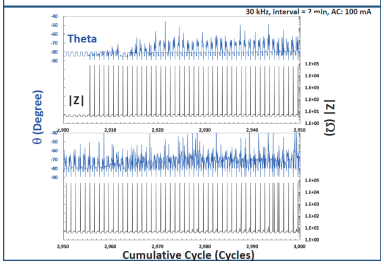
Panel 6

Argument Z: Time Course during Rapid Thermal Cycling



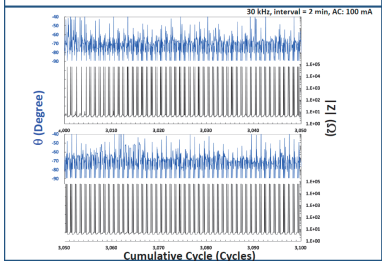
Panel 7

AC Impedance: Time Course during Rapid Thermal Cycling



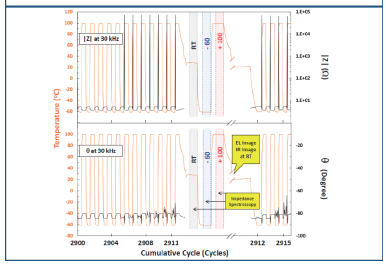
Panel 8

AC Impedance: Time Course during Rapid Thermal Cycling



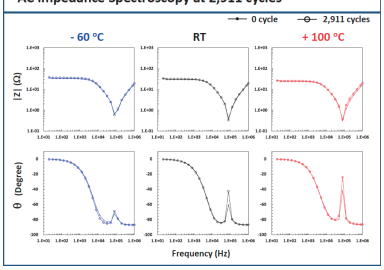
Panel 9

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



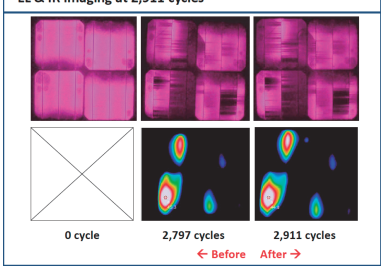
Panel 10

AC Impedance Spectroscopy at 2,911 cycles



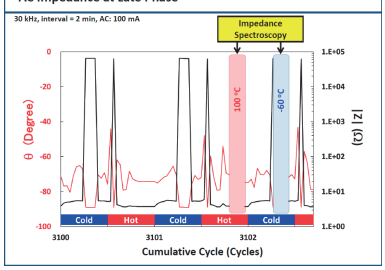
Panel 11

EL & IR Imaging at 2,911 cycles



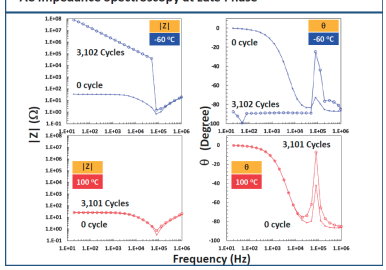
Panel 12

AC Impedance at Late Phase



Panel 13

AC Impedance Spectroscopy at Late Phase



本検討は、「次世代結晶シリコン太陽電池コンソーシアム」において、エスペック株式会社・再生可能エネルギー研究センター 太陽光チームの共同研究として実施された。共同研究者の鈴木 聡氏（エスペック）、坂本憲彦氏・三戸章裕氏（計測標準総合センター）、白澤勝彦氏・高遠秀尚氏（再生可能エネルギー研究センター）のご協力に深謝申し上げます。