

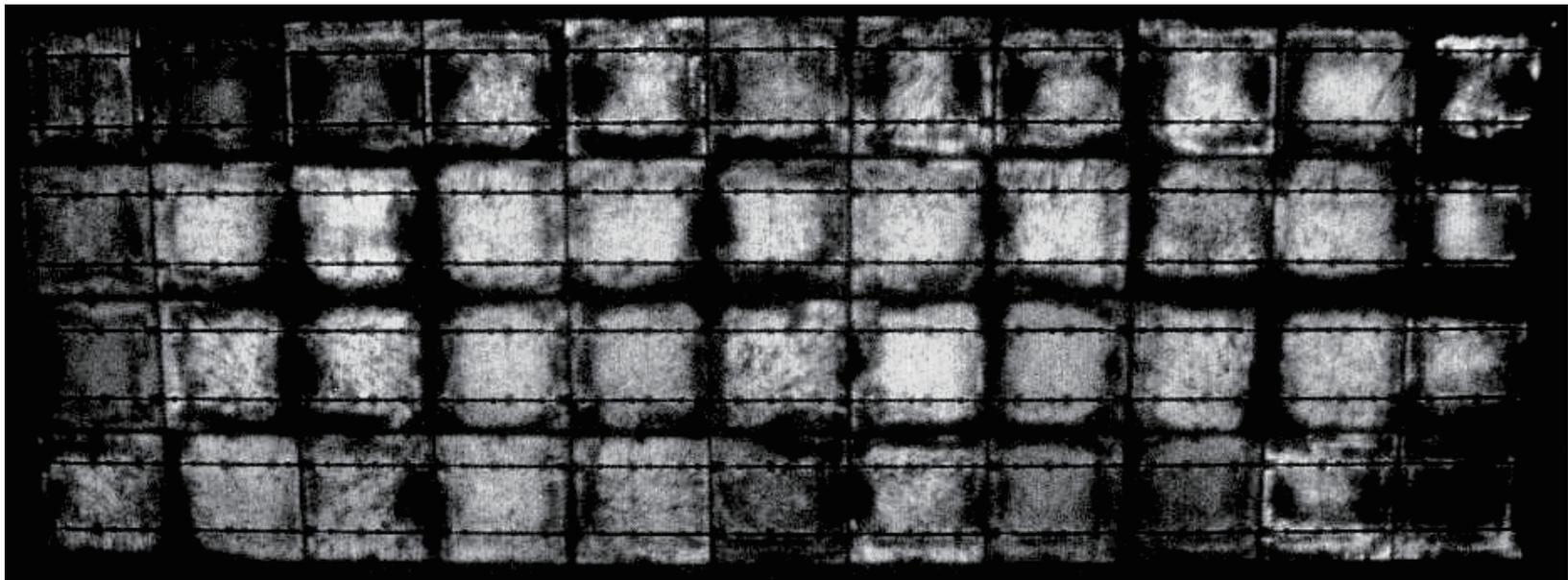
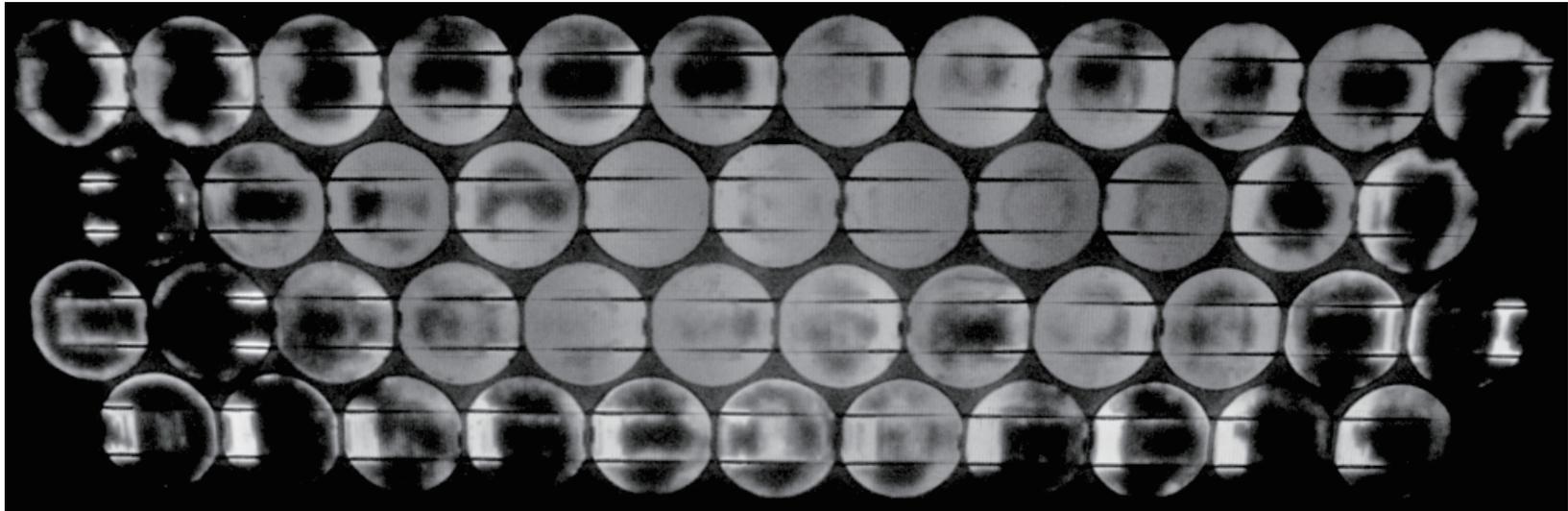
結晶シリコン太陽電池モジュール における寿命評価指標の探索

太陽光発電研究センター 計量標準総合センター ¹モジュール信頼性チーム・³化合物薄膜チーム
²応用電気標準研究グループ

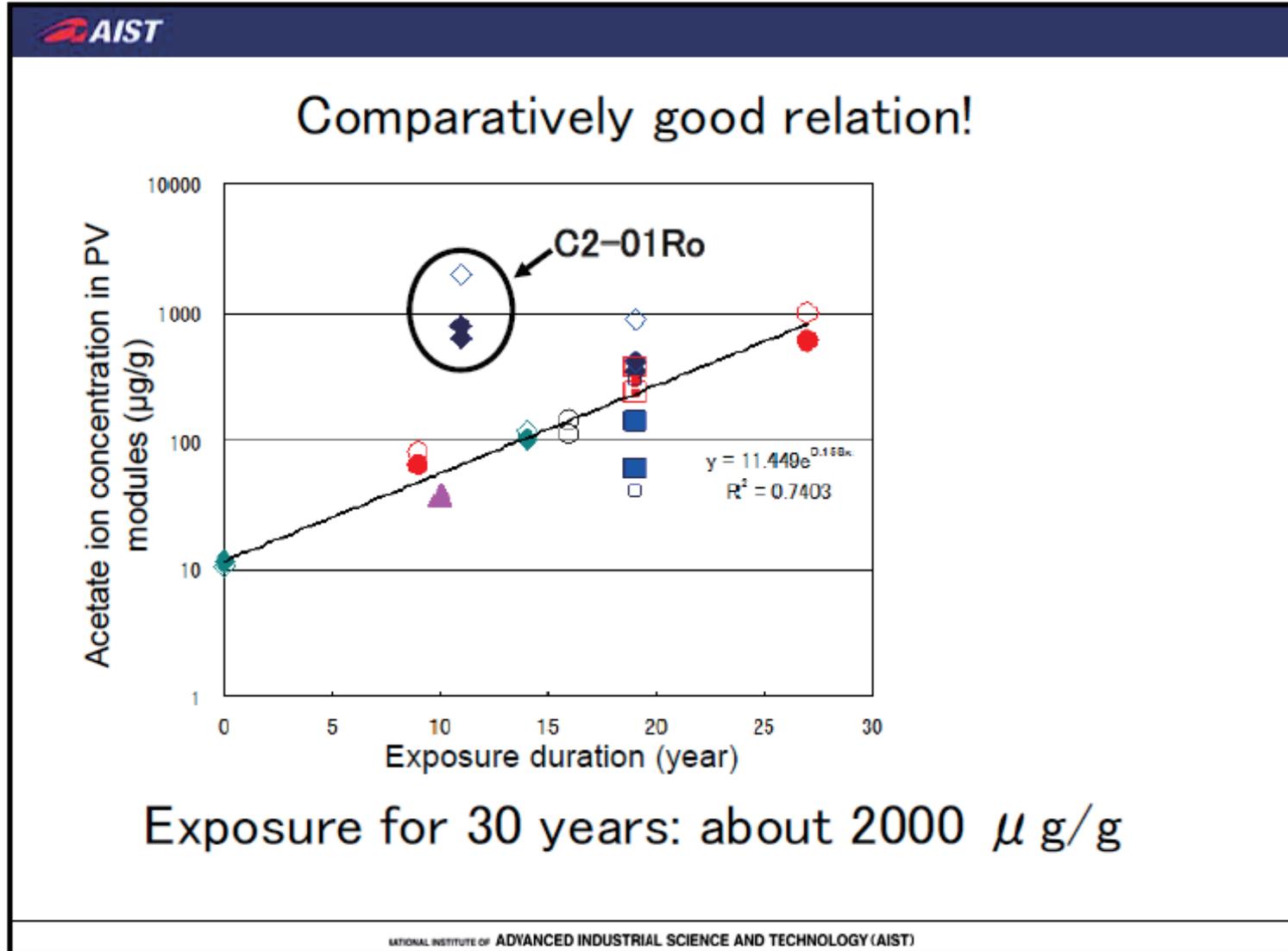
棚橋 紀悟¹・坂本憲彦²・柴田肇³・増田淳¹

本検討は、NEDO委託事業「太陽光発電の寿命予測ならびに試験法の開発」により実施された。NEDOよりのご支援に深謝申し上げます。

長期屋外曝露したc-Si PVモジュールのEL像



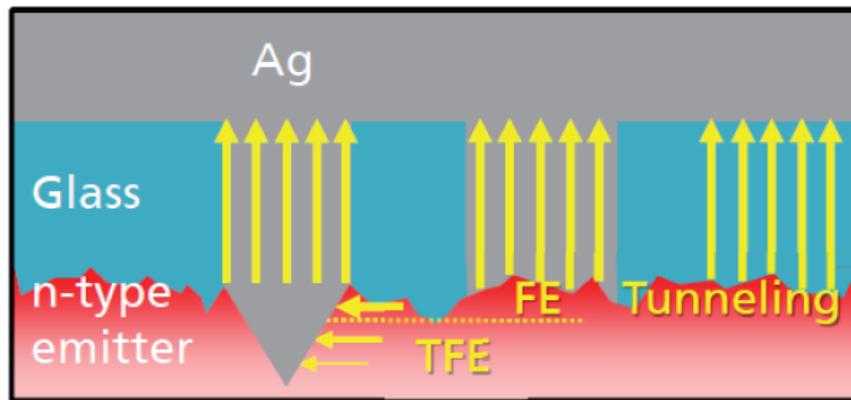
先行研究： 長期屋外曝露したPVモジュール内の酢酸濃度変化



Masuda et al., 2014, EU-PVSEC

Background

Proposed Current Transport Mechanisms in Silver Contact¹⁾



Field Emission (FE)

$$N_D \geq 10^{20} \text{ cm}^{-3}$$

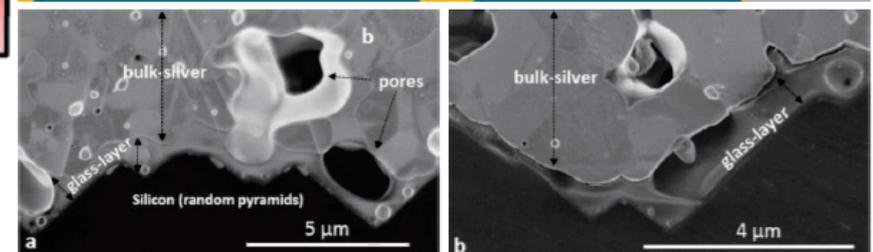
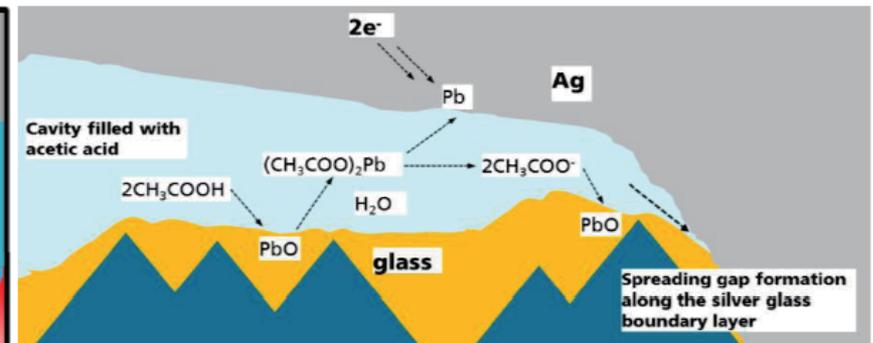
Thermionic Field Emission (TFE)

$$10^{17} \text{ cm}^{-3} < N_D < 10^{20} \text{ cm}^{-3}$$

Electron Tunneling

through glass layer
(directly or *via* nano-Ag colloids)

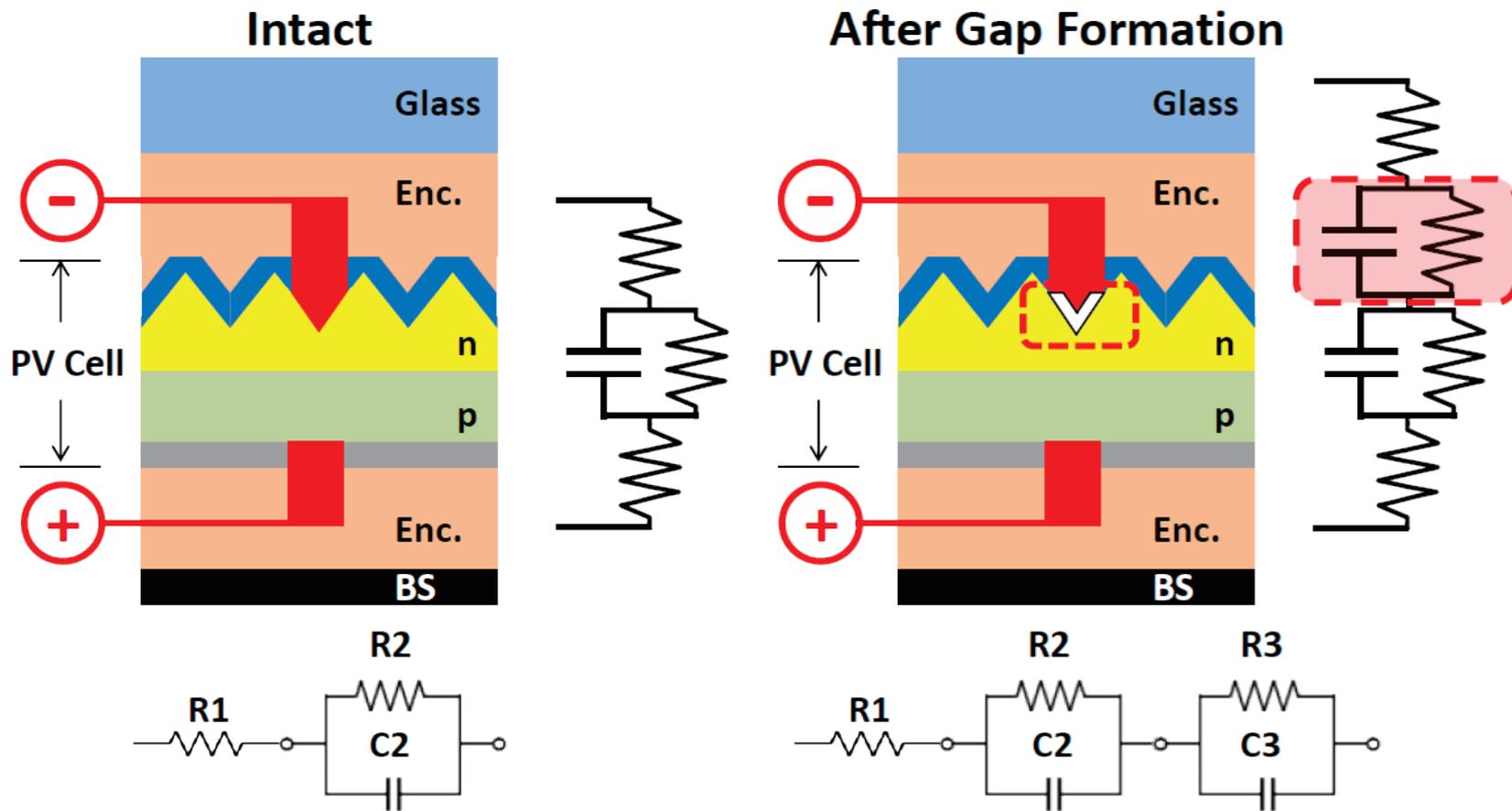
Dissolution of Glass-Silver Boundary Layer by Acetic Acid²⁾



- 1) R. Hoenig et al., "Macroscopic and Microscopic Electrical Behavior of Screen Printed Silver Contacts to Phosphorus-Doped Emitters", presented at 5th Metallization Workshop, 2014.
- 2) A. Kraft et al., "Investigation of Acetic Acid Corrosion Impact on Printed Solar Cell Contacts", IEEE J. Photovolt. 5 (3): 736-743, 2015.

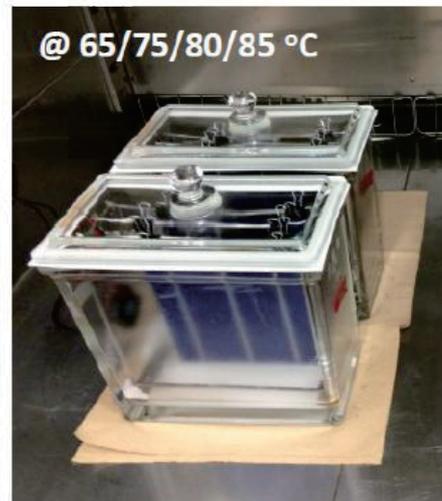
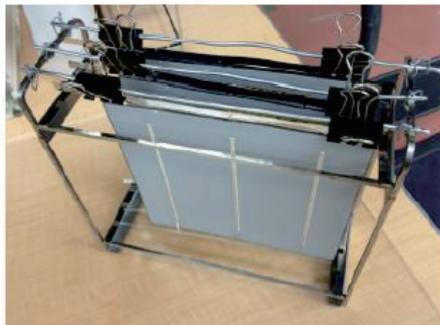
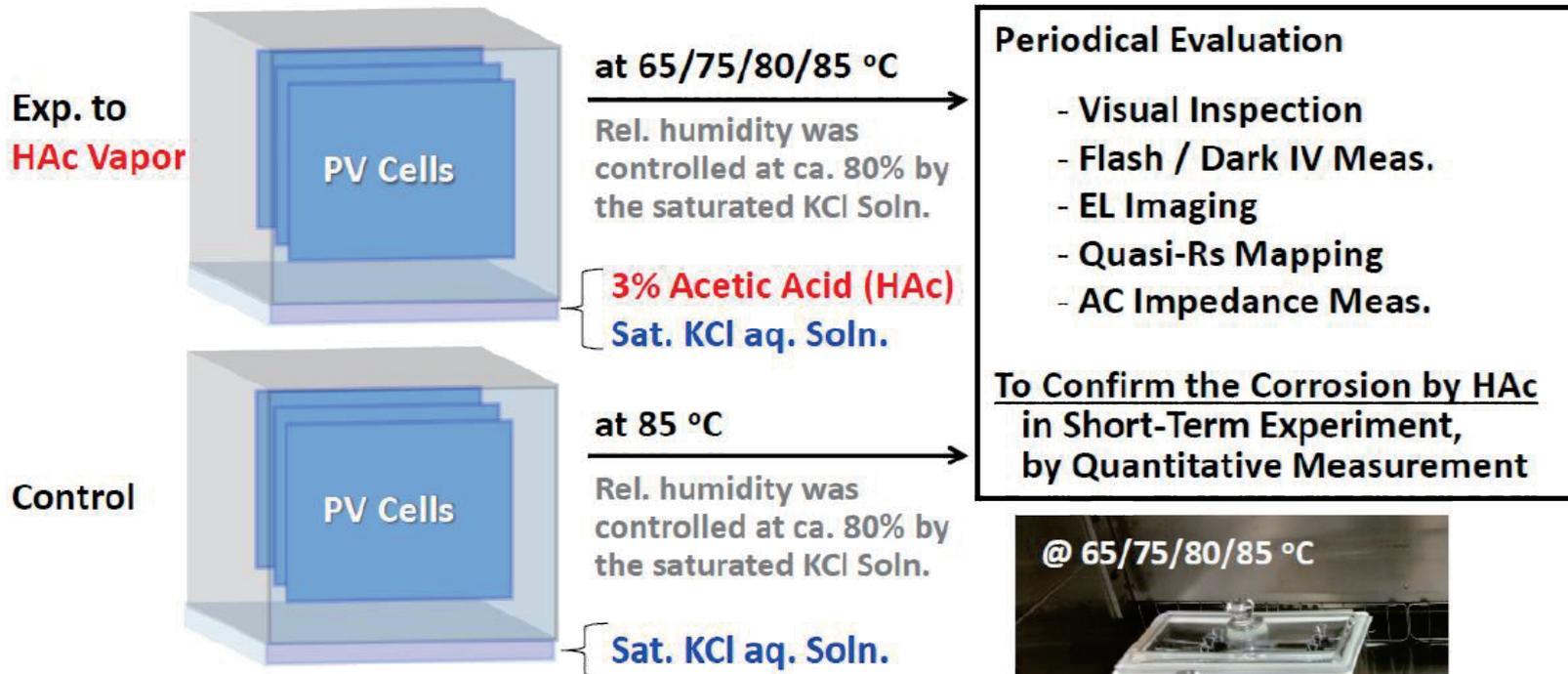
Objective

To Confirm the Formation of Gap underneath Finger Electrodes, by the Evolution of AC Equivalent Circuit



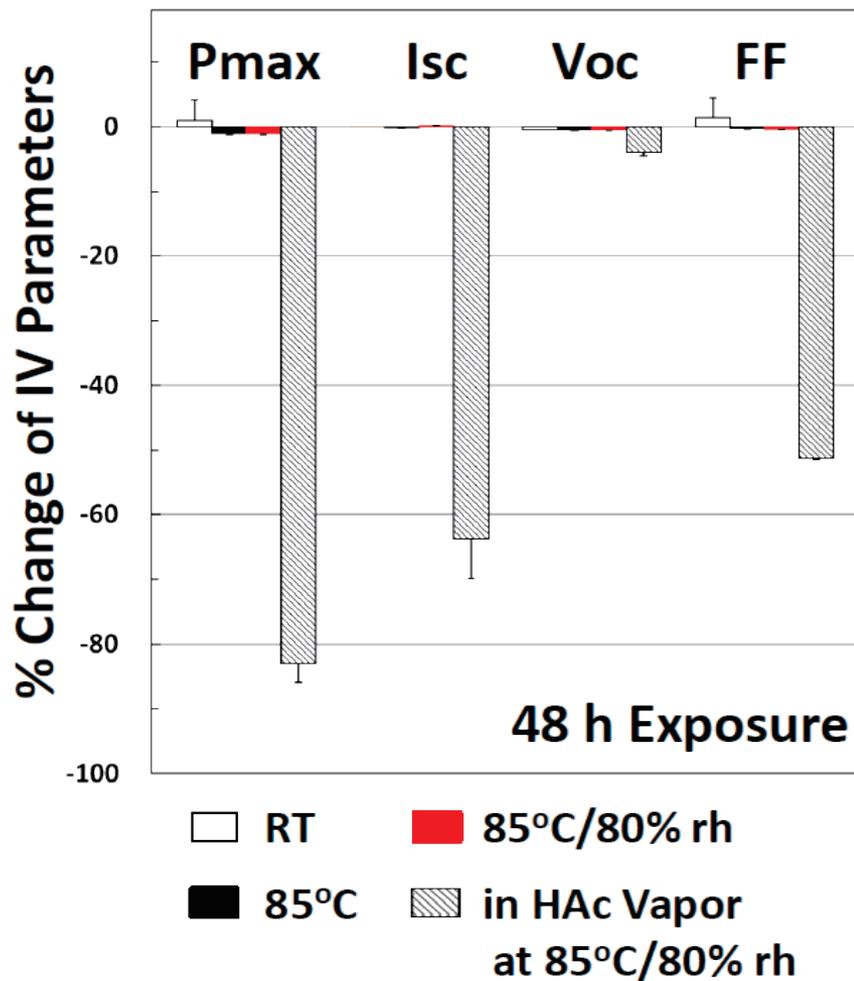
Experimental Procedures

Exposure of Bare PV Cells to HAc (Acetic Acid) Vapor

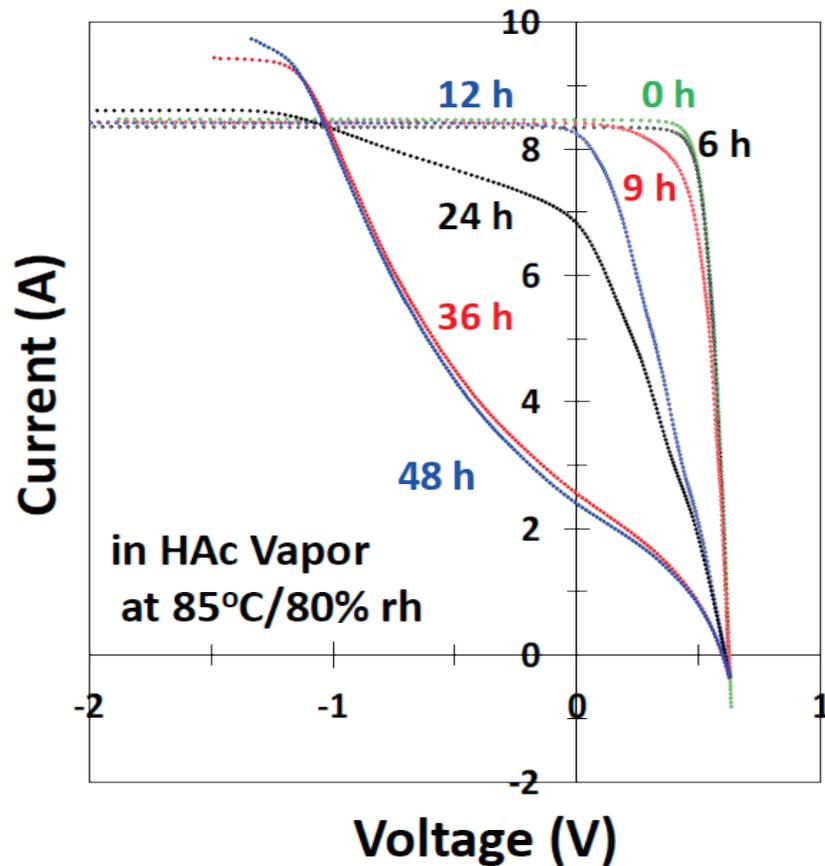


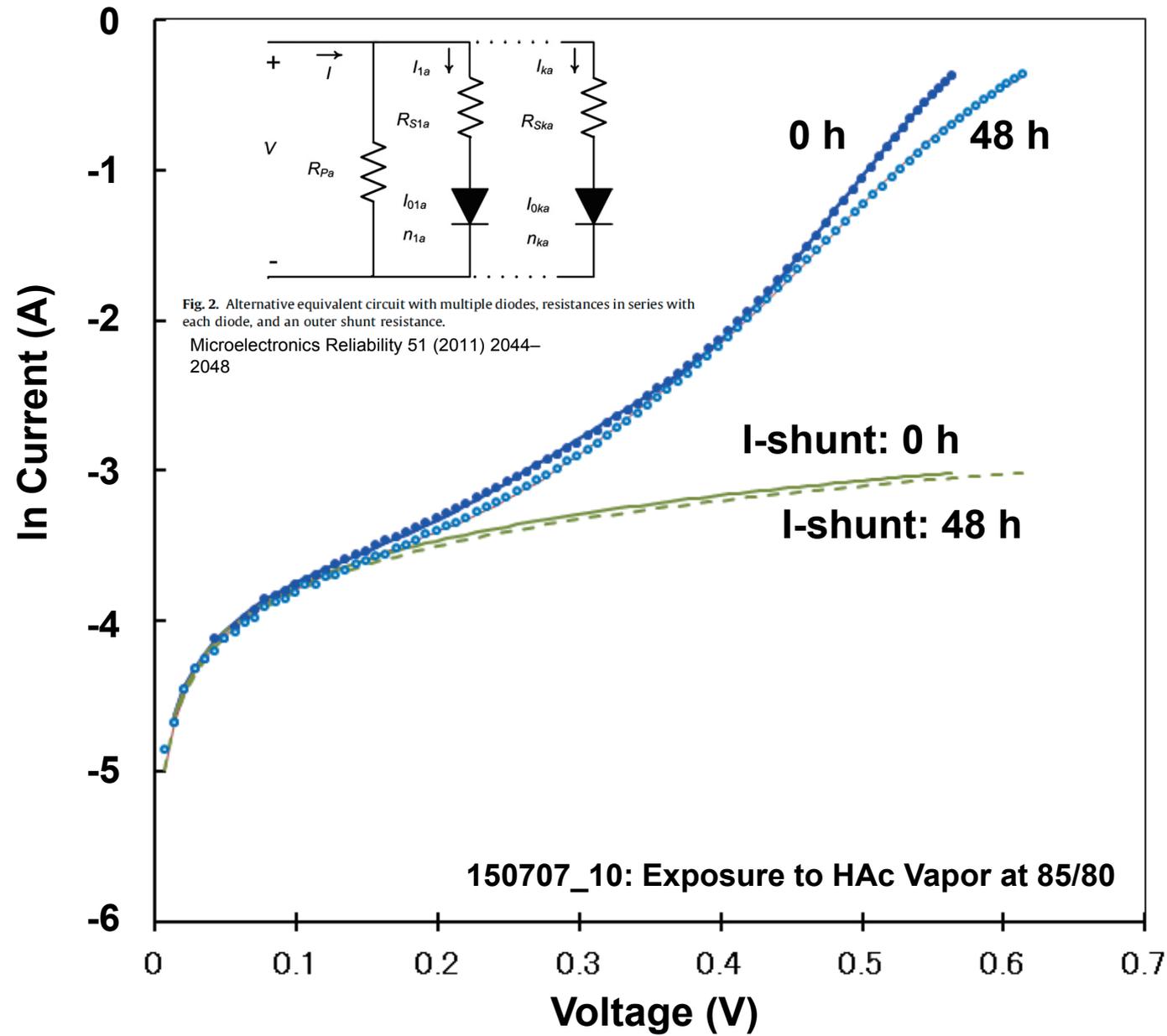
Flash IV Characteristics

IV Parameters



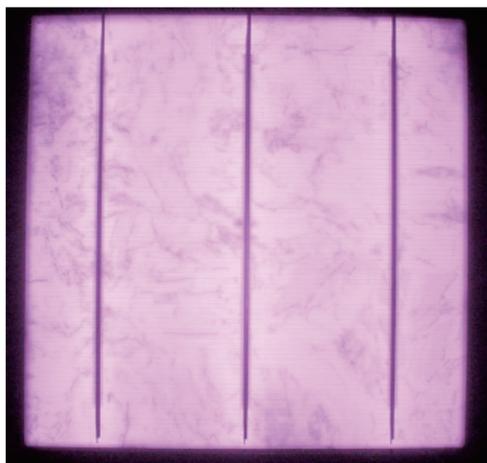
IV Curves



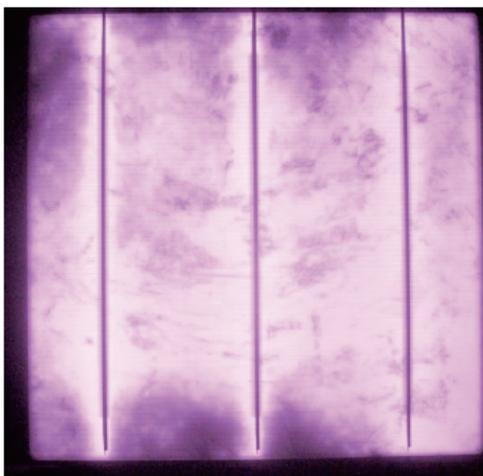


EL & Quasi-Rs Images

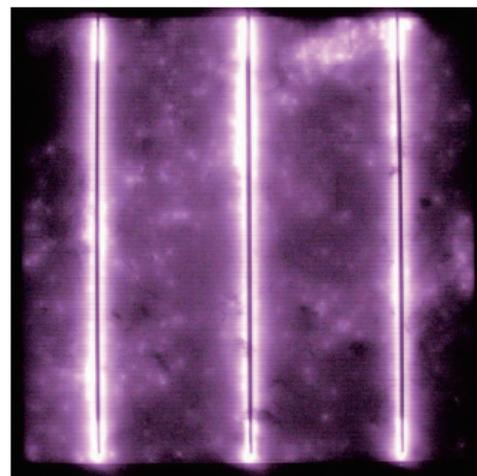
Exposure to HAc Vapor at 85°C/80% rh



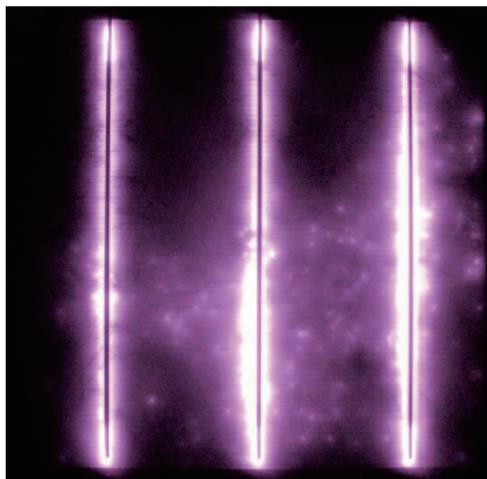
6 h



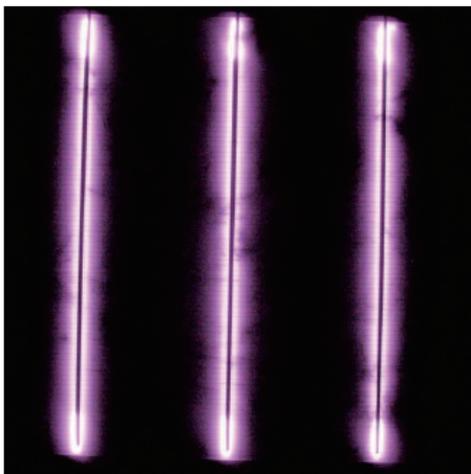
9 h



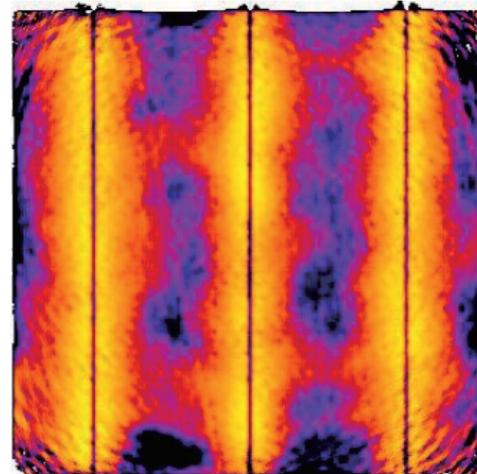
12 h



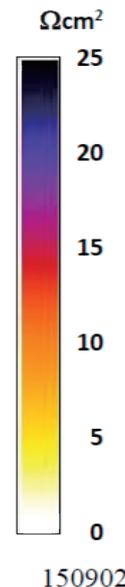
24 h



36 h

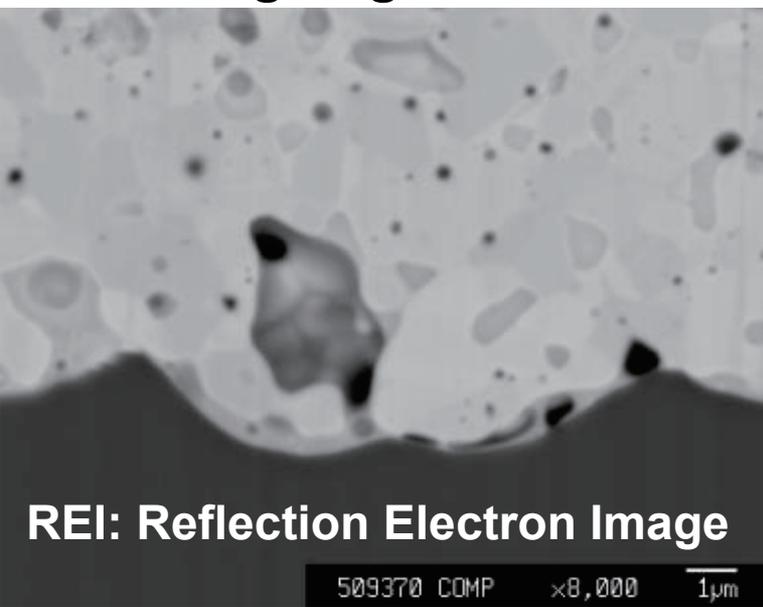


Quasi-Rs Map (36 h)

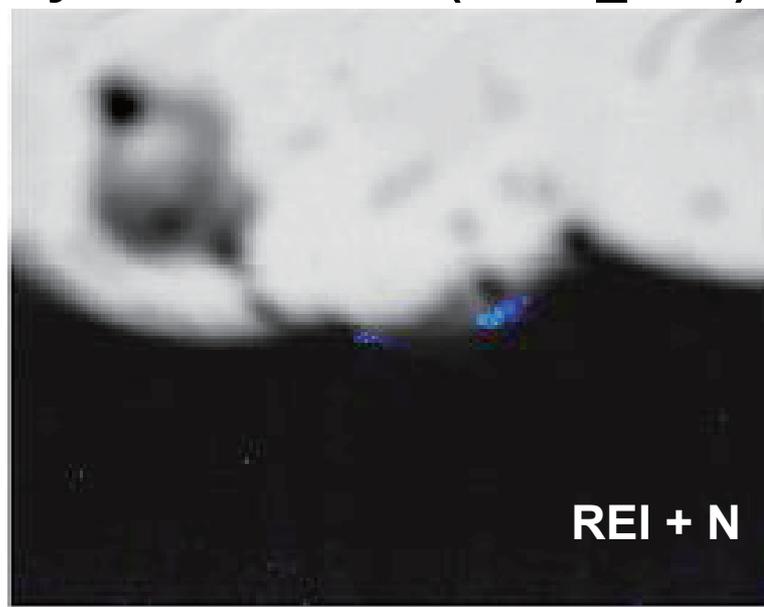


EPMA for the Ag-finger / Silicon Boundary

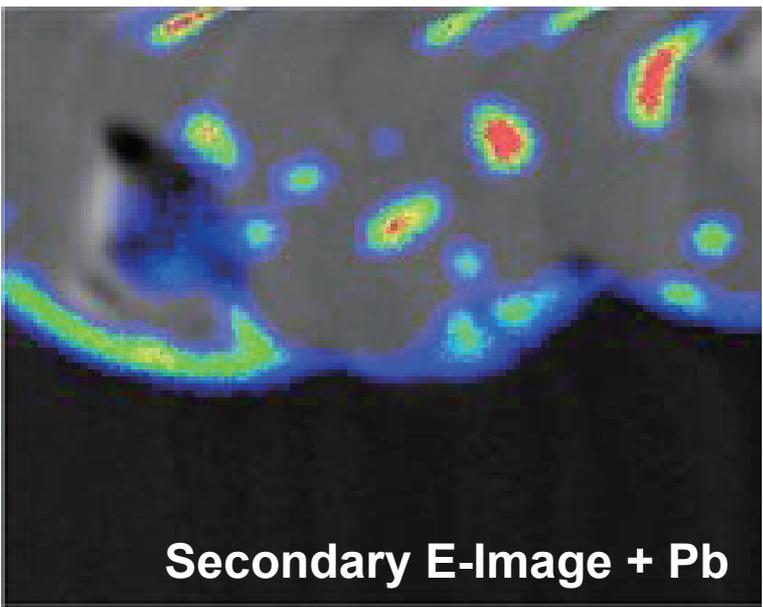
CONTROL (85/80_48 h)



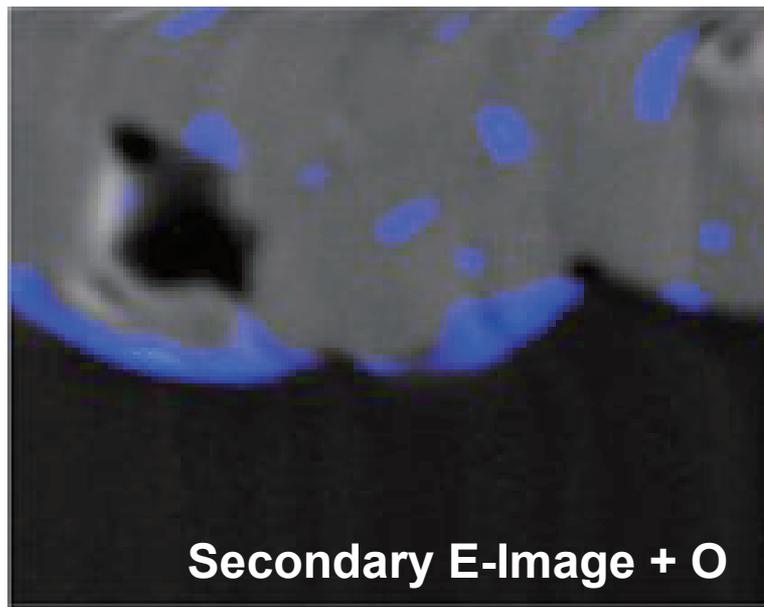
REI: Reflection Electron Image



REI + N



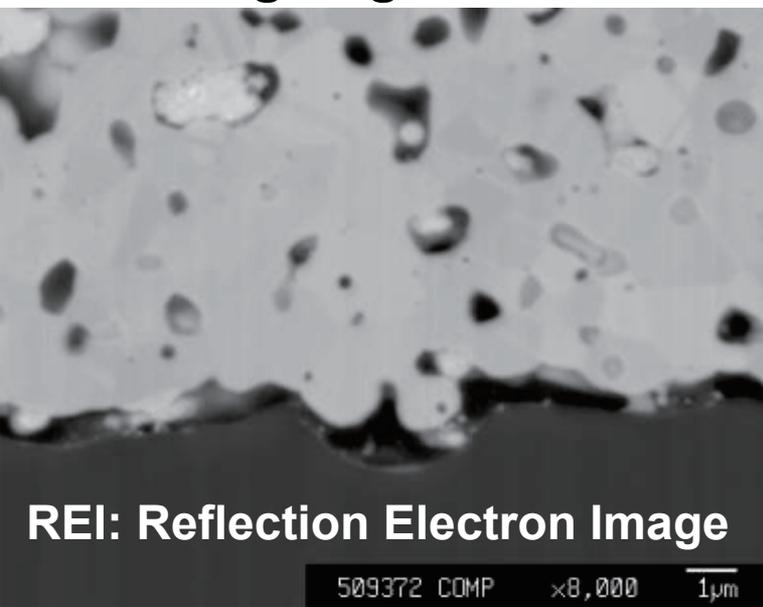
Secondary E-Image + Pb



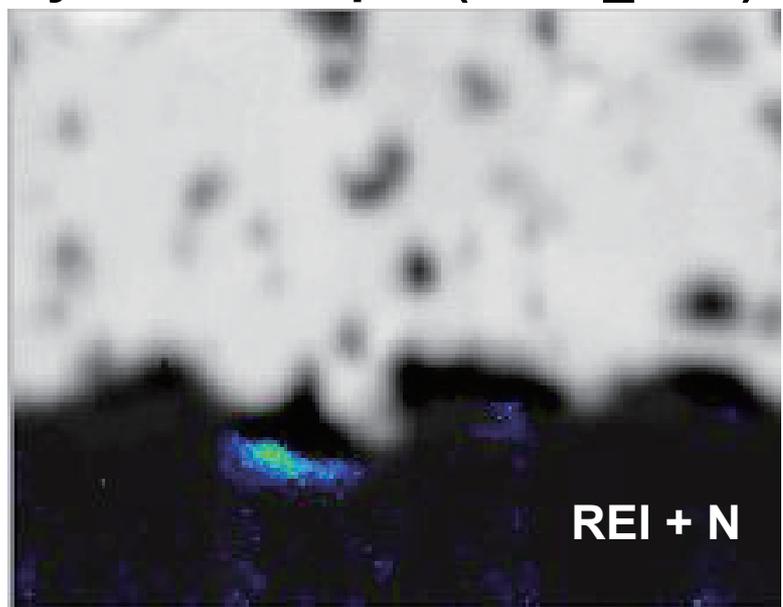
Secondary E-Image + O

EPMA for the Ag-finger / Silicon Boundary

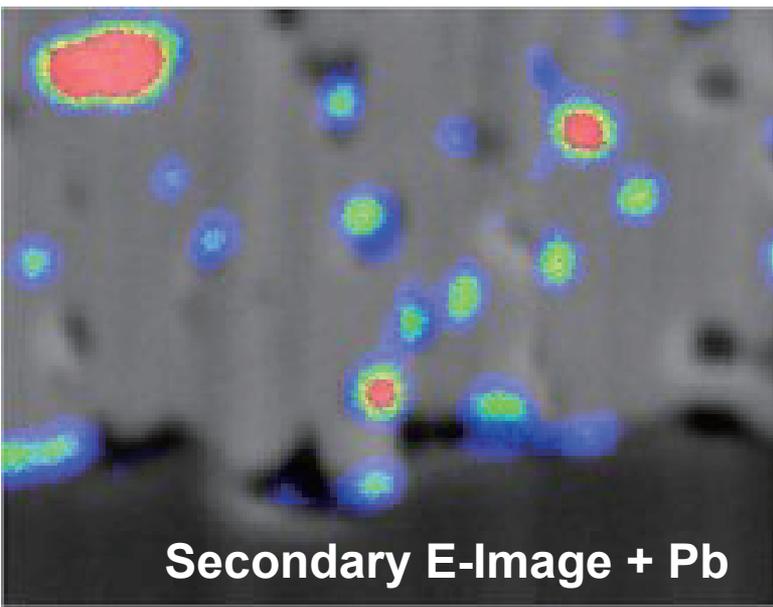
HAc Vapor (85/80_48 h)



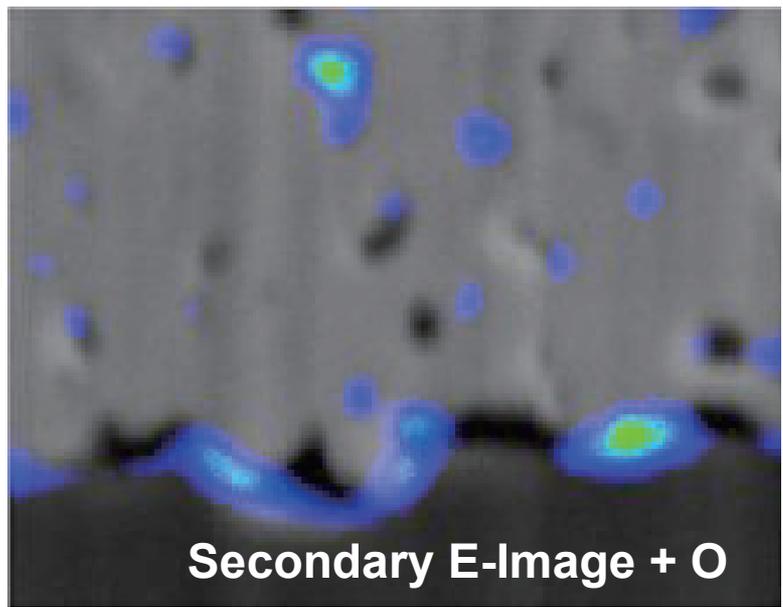
REI: Reflection Electron Image



REI + N

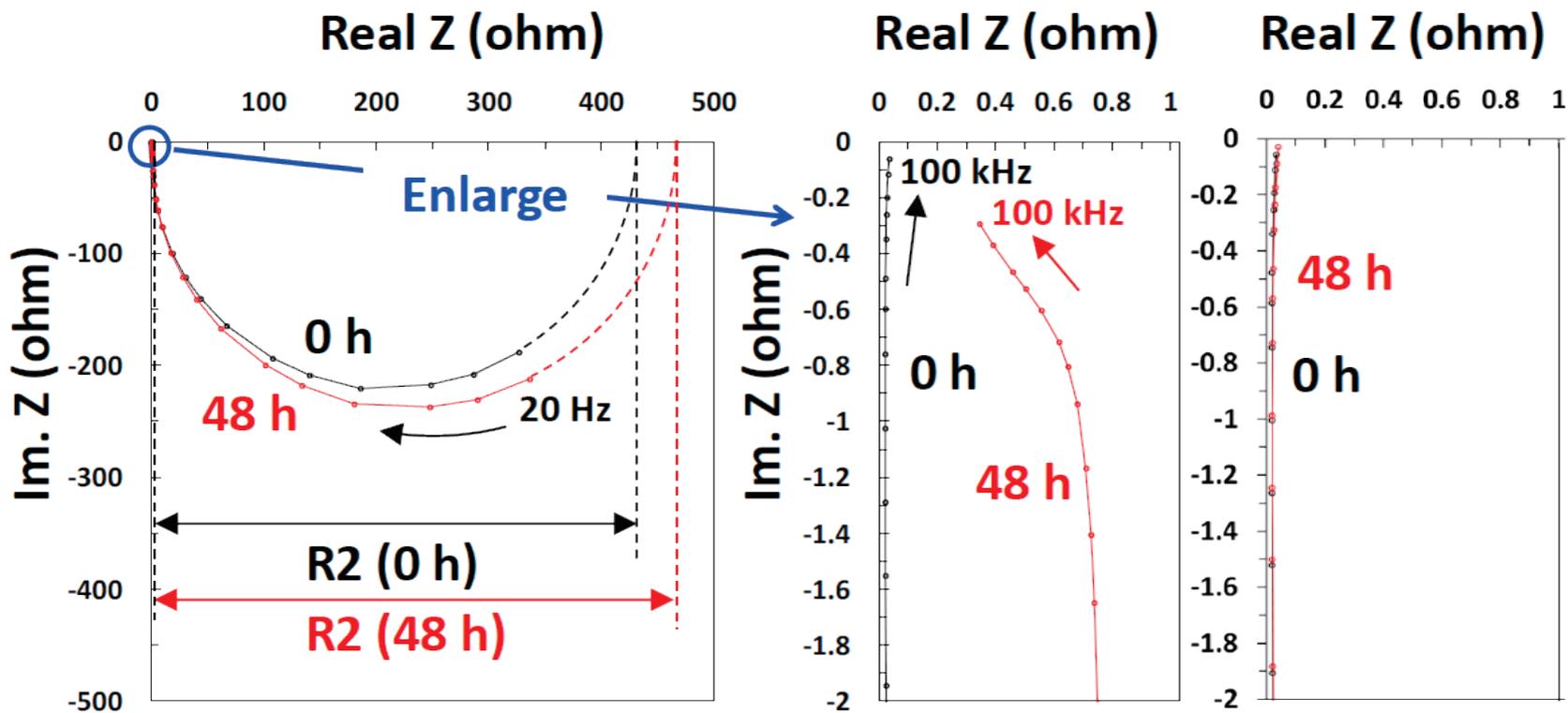


Secondary E-Image + Pb



Secondary E-Image + O

AC Impedance Characteristics



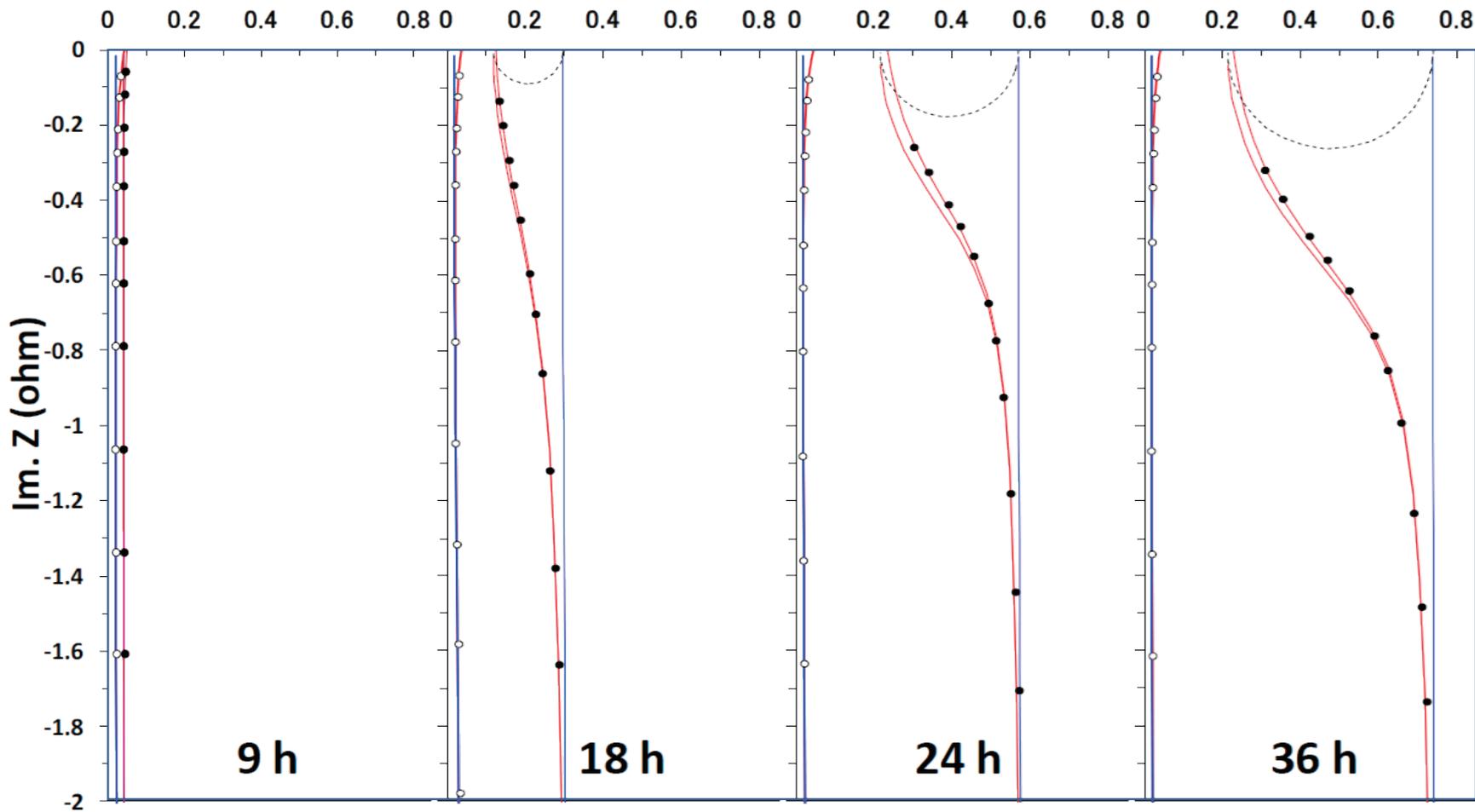
Exposure to HAc Vapor at 85°C/80% rh

Control (85°C/80% rh)

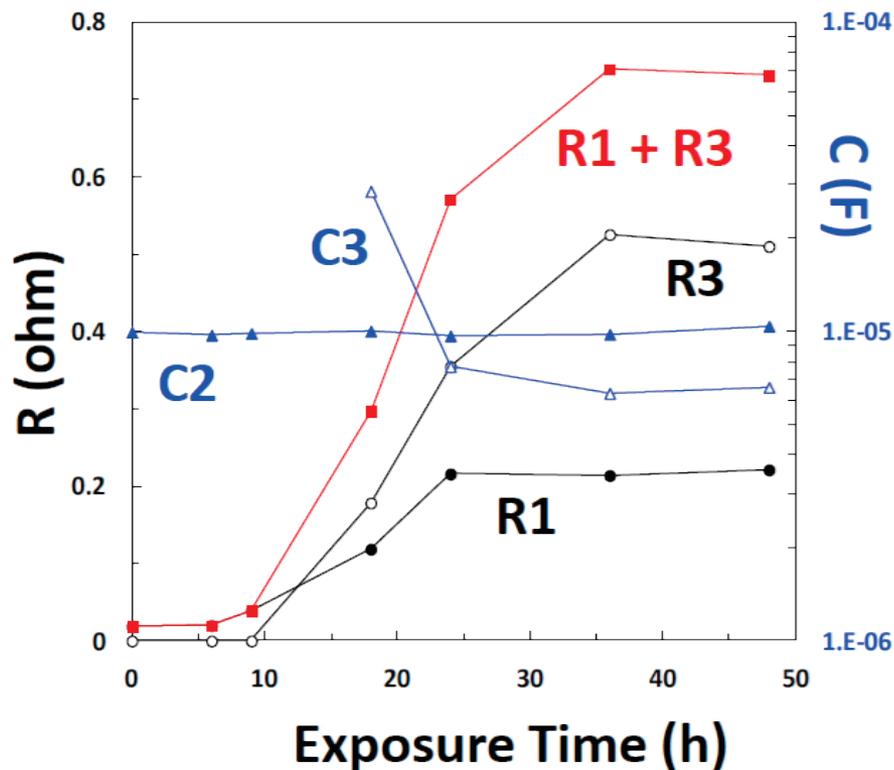
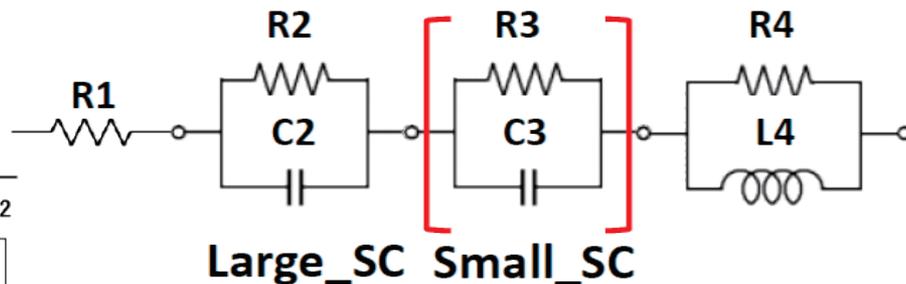
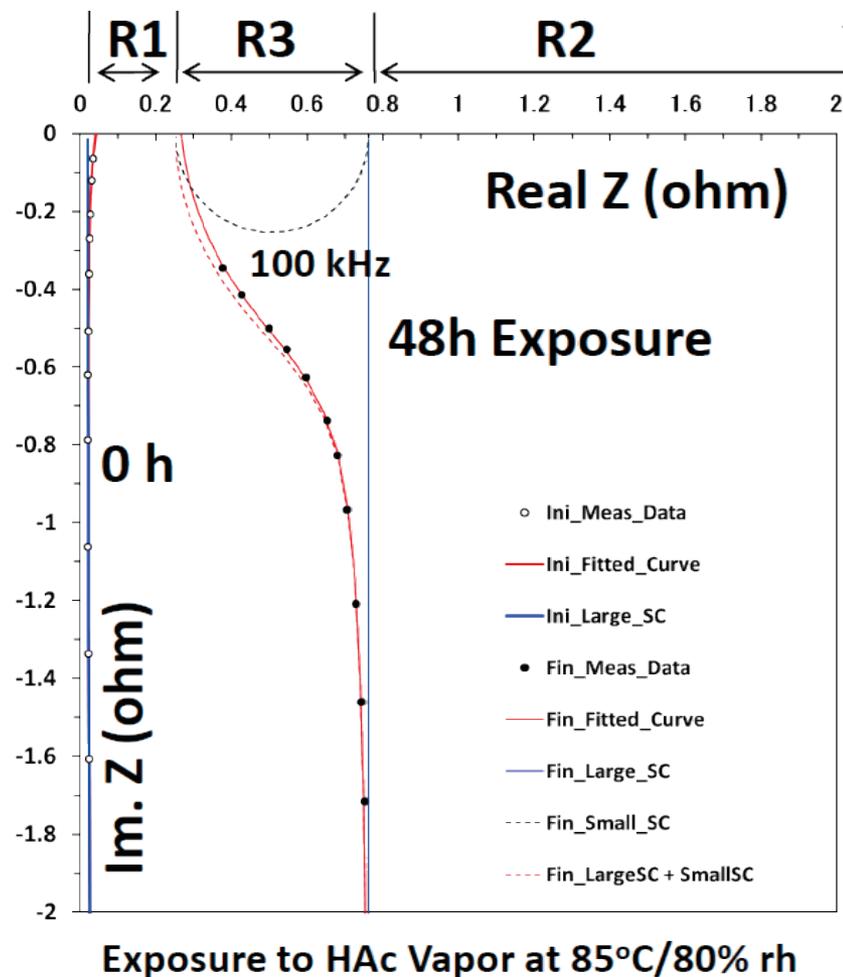
AC Impedance Characteristics

Exposure to HAc Vapor at 85°C/80% rh

Real Z (ohm)

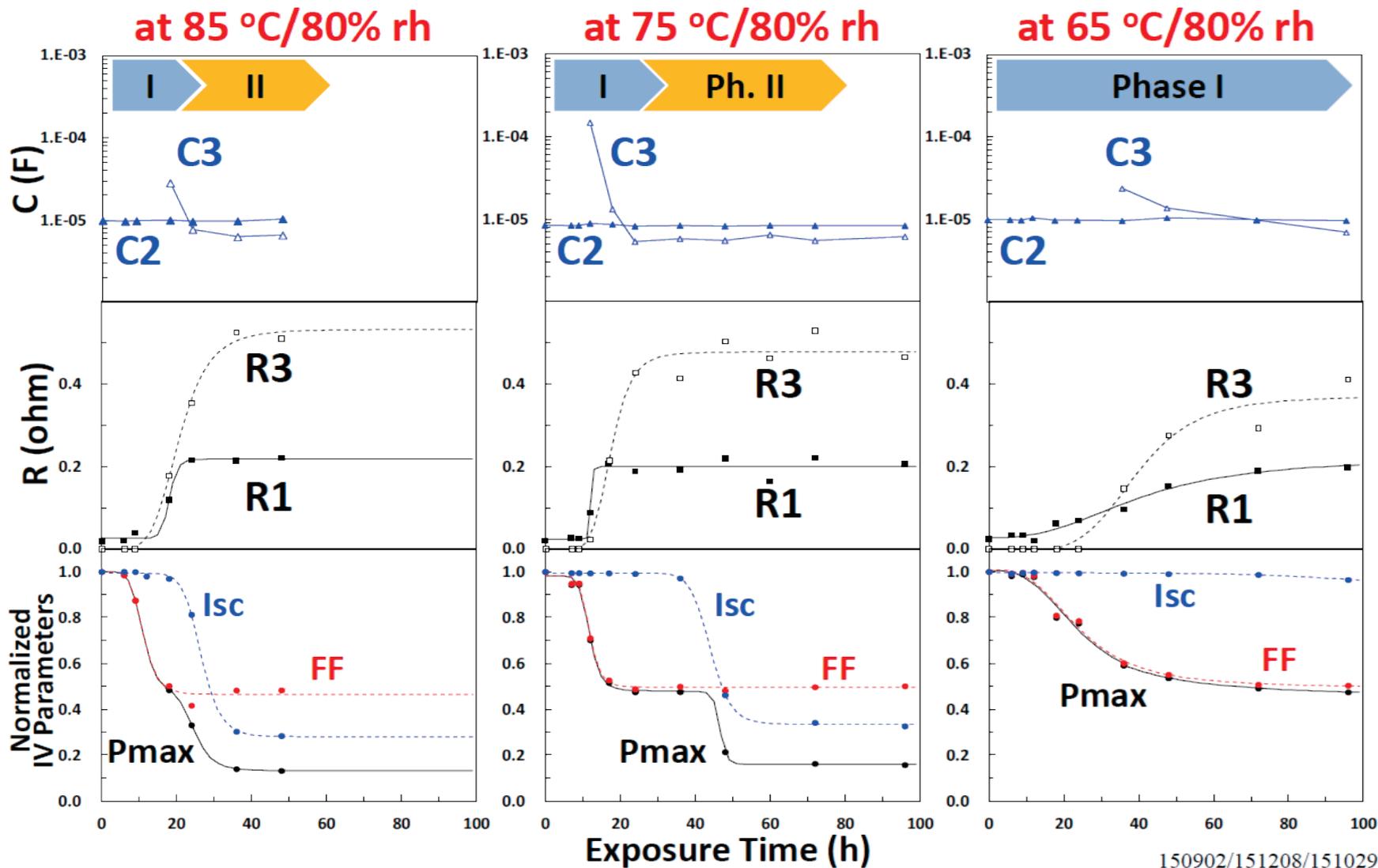


AC Impedance Characteristics



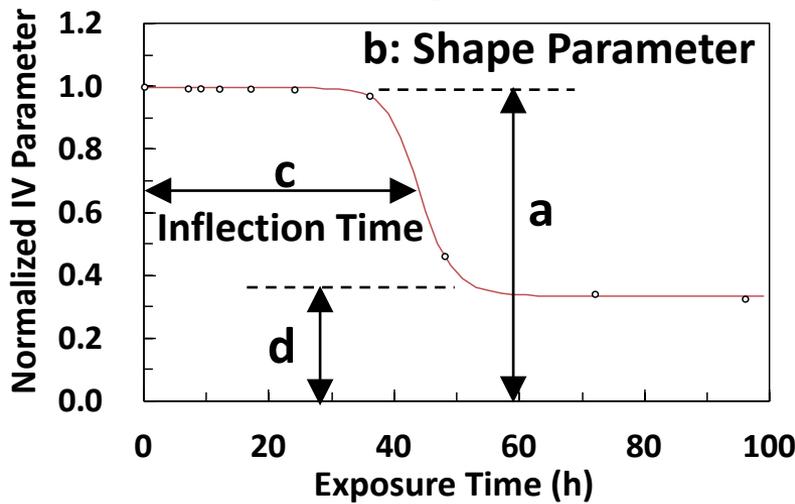
150707_05/150902

AC Impedance & IV Parameters

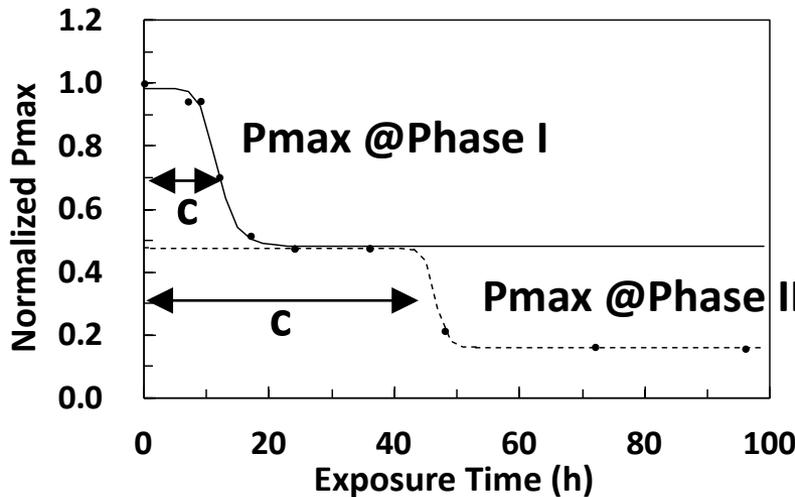


150902/151208/151029

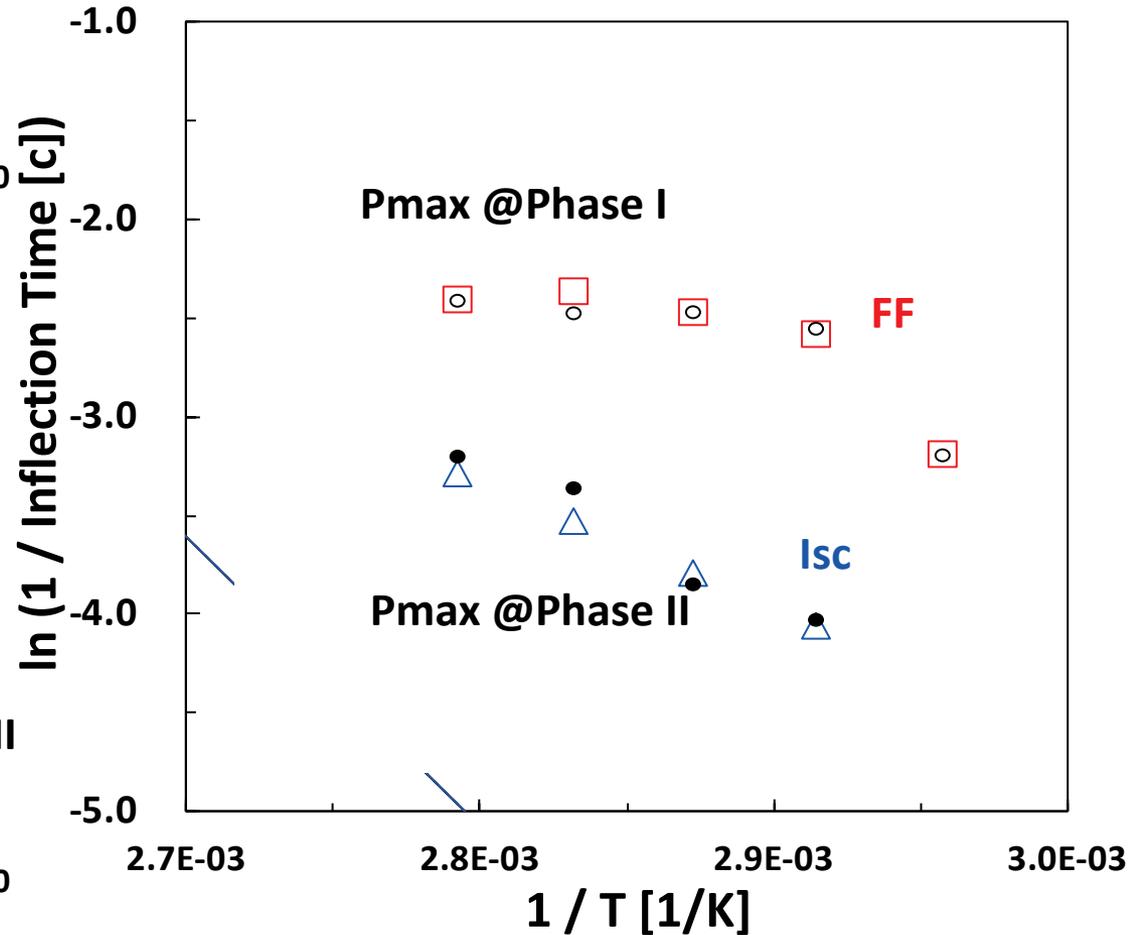
4 Parameter Logistic Model



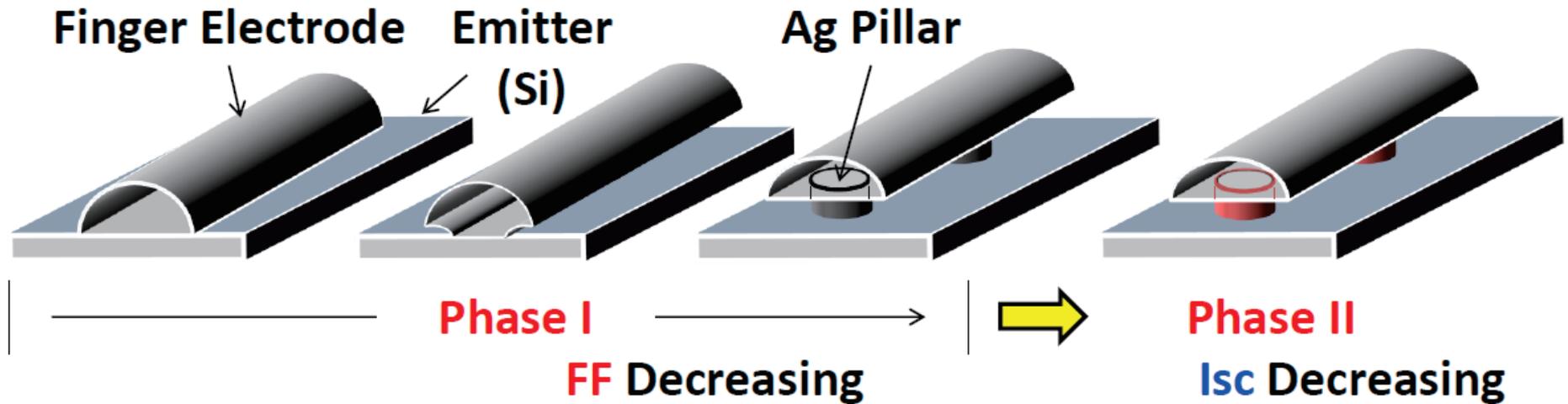
$$y = \frac{a - d}{1 + (x/c)^b} + d$$



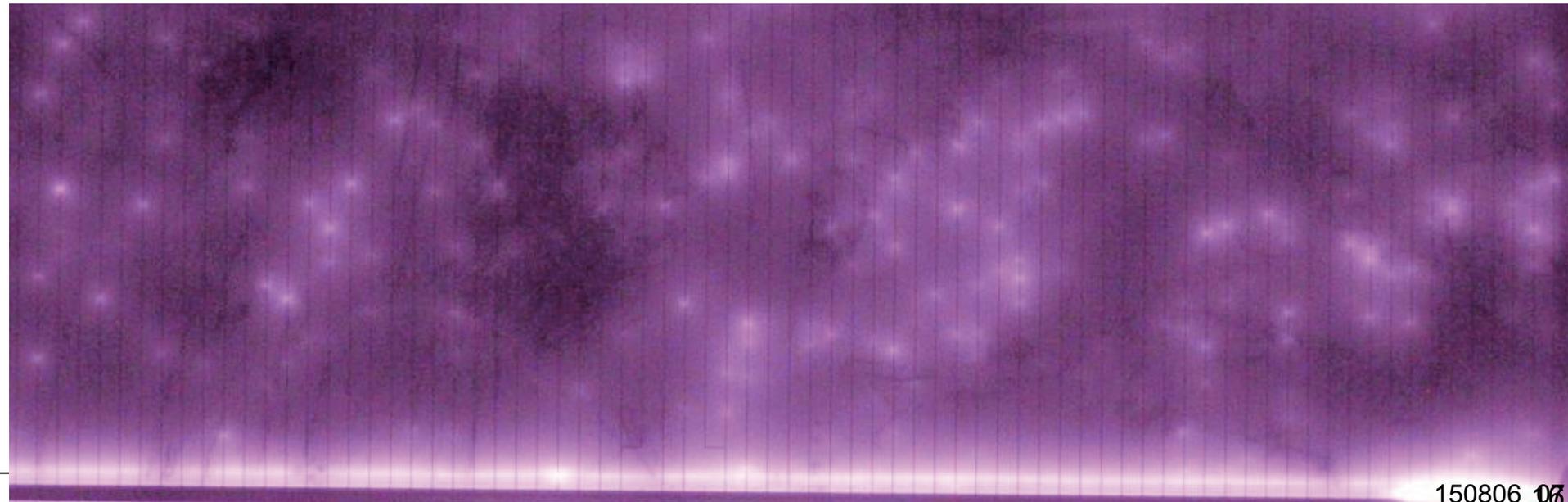
	Ea [eV]	mean
Pmax @Phase I	0.347	0.362
FF	0.376	
Pmax @Phase II	0.629	0.588
Isc	0.547	



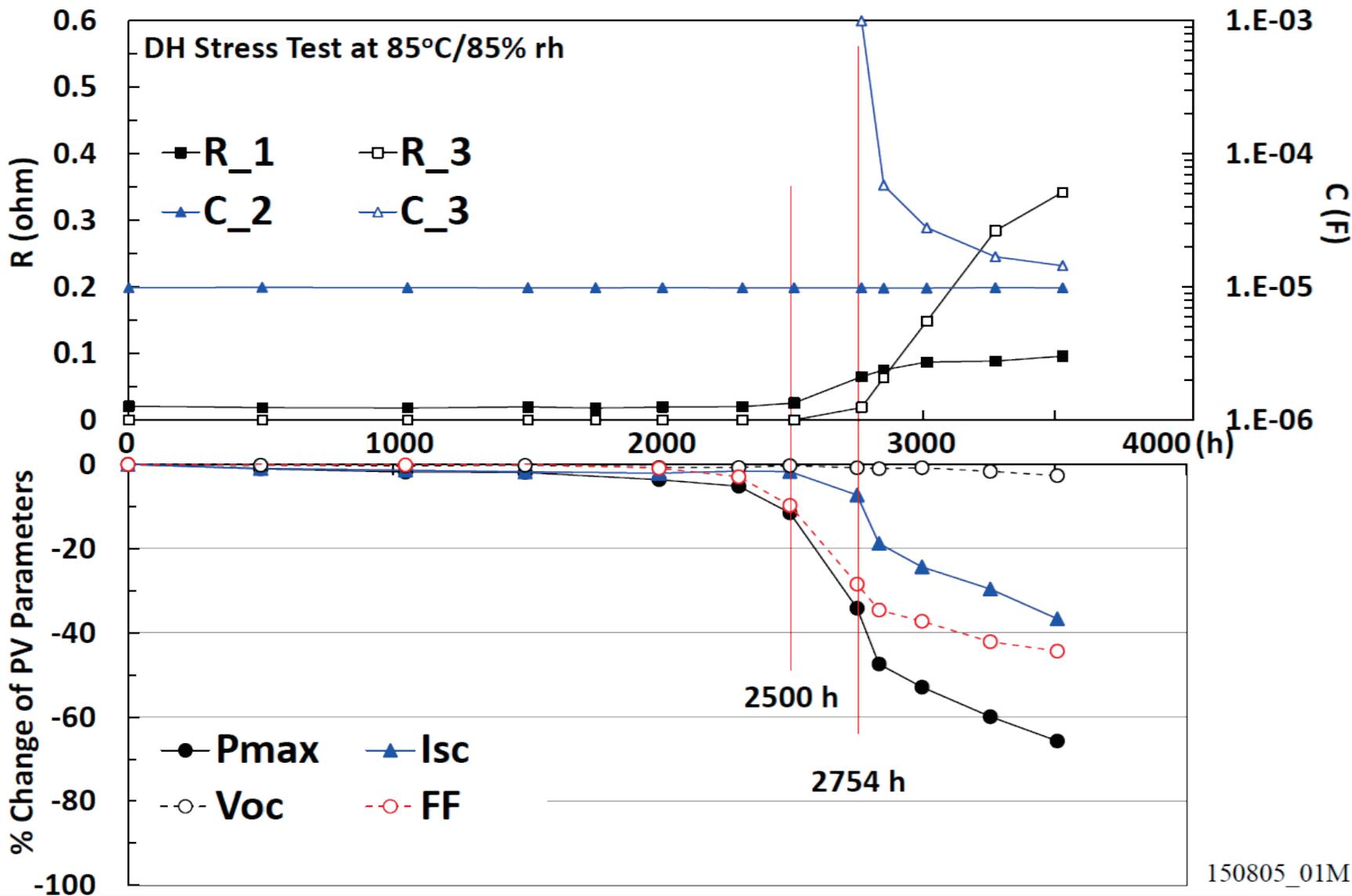
Putative Degradation Process on c-Si PV Cells Exposed to HAc



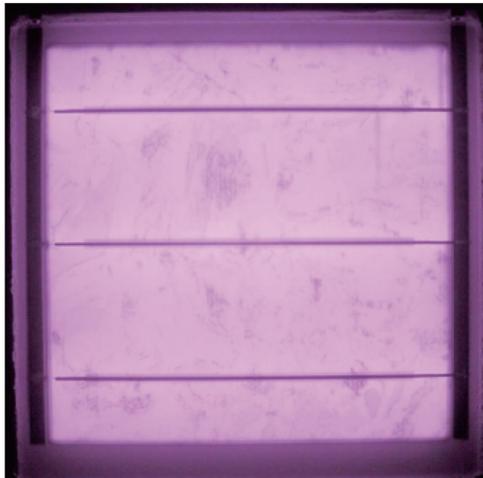
“Constellation” on PV Cell: Bright Spots are Only on Finger Electrodes



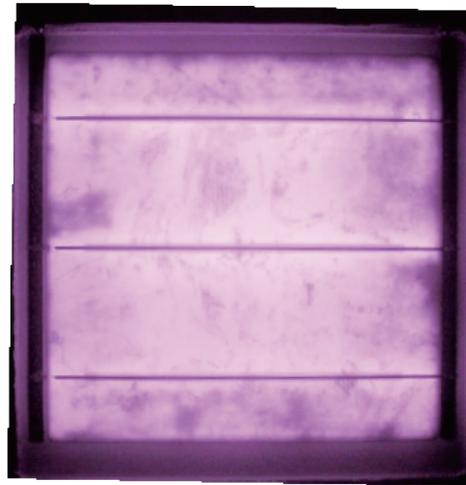
DH Stress Test of PV Module



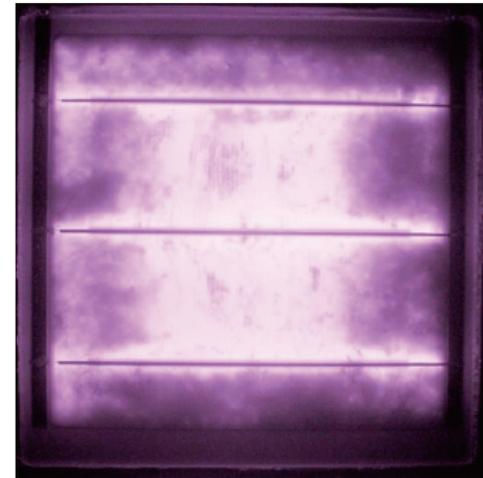
DH Stress Test of PV Module



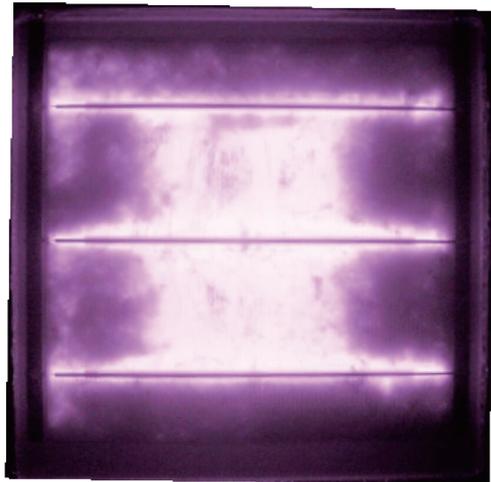
2006 h



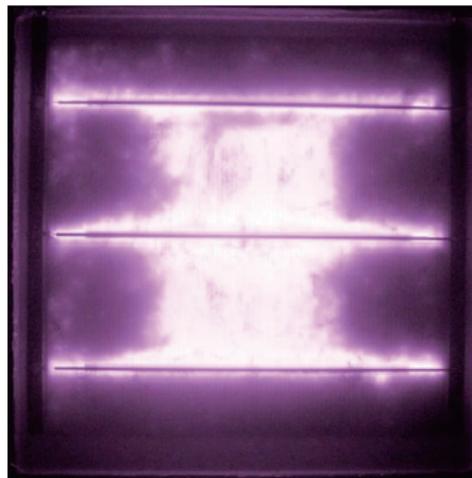
2500 h



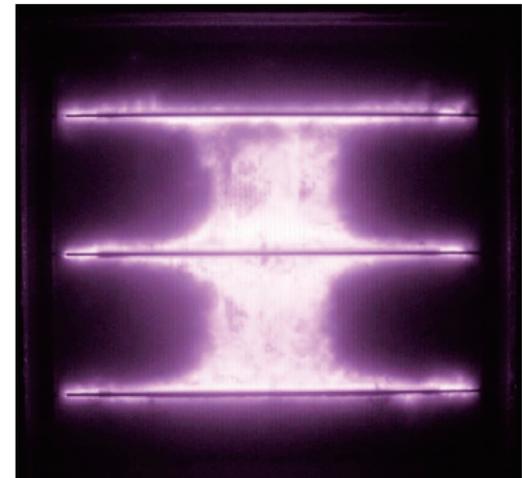
2754 h



2837 h



2999 h



3510 h

150805_01M

まとめ

- ・ c-Si PVセルを酢酸蒸気に曝露することにより、集電能力の低下の原因となるフィンガ電極下のギャップ形成を確認。
- ・ このギャップ形成にともなう(大幅な)FFの低下と、それに同期した新たな交流インピーダンス成分 (R3/C3)の発現・増大を確認。
- ・ 酢酸蒸気曝露によるc-Si PVセルの発電特性低下は、2段階で進行している点を確認。

Phase I: FF低下・R3/C3の発現と増減

Phase II: Isc低下

両者は、異なる反応機構で進行している模様 (E_a の差異)。

- ・ DH試験に供したPVモジュールにおいても、酢酸蒸気曝露したPVセルと同様の劣化状況を確認。

R3などは、PVモジュールの寿命推定に有用なインデックス(“Aging Signature”)になる可能性あり。