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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
NEST NETWORK FOR ENERGY SUSTAINABLE TRANSITION

Spectroscopic Insights into Reverse Bias Effects in Wide-Bandgap Perovskite Solar Cells

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Center for Hybrid and Organic Solar Energy

Università degli Studi di Padova
Università degli Studi di Palermo
TOR VERGATA UNIVERSITÀ DEGLI STUDI DI ROMA
CNR Istituto di Struttura della Materia

Introduction: Wide-bandgap Perovskites

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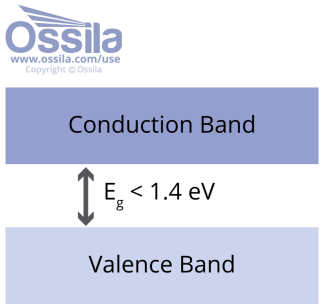
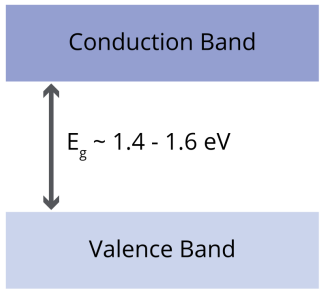
Perovskite: candidate for next-gen Solar cells

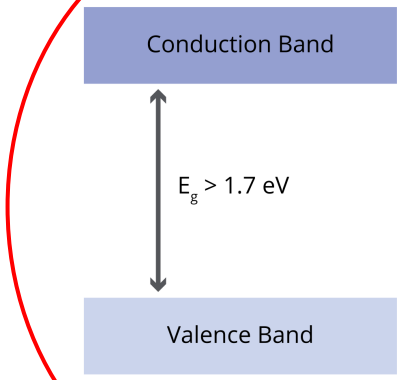
High degree of tunability: $A\ B\ X_3$



Narrow Bandgap Perovskites



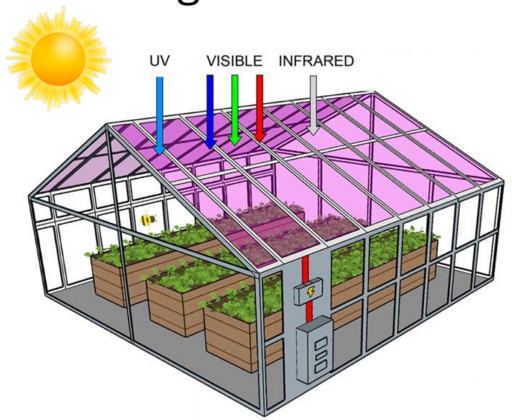
Intermediate Bandgap Perovskites



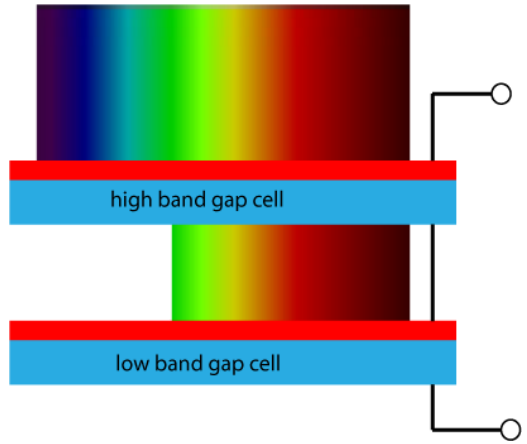
Wide Bandgap Perovskites

BIPV

AgriVoltaics



Tandem



Perovskite Downsides

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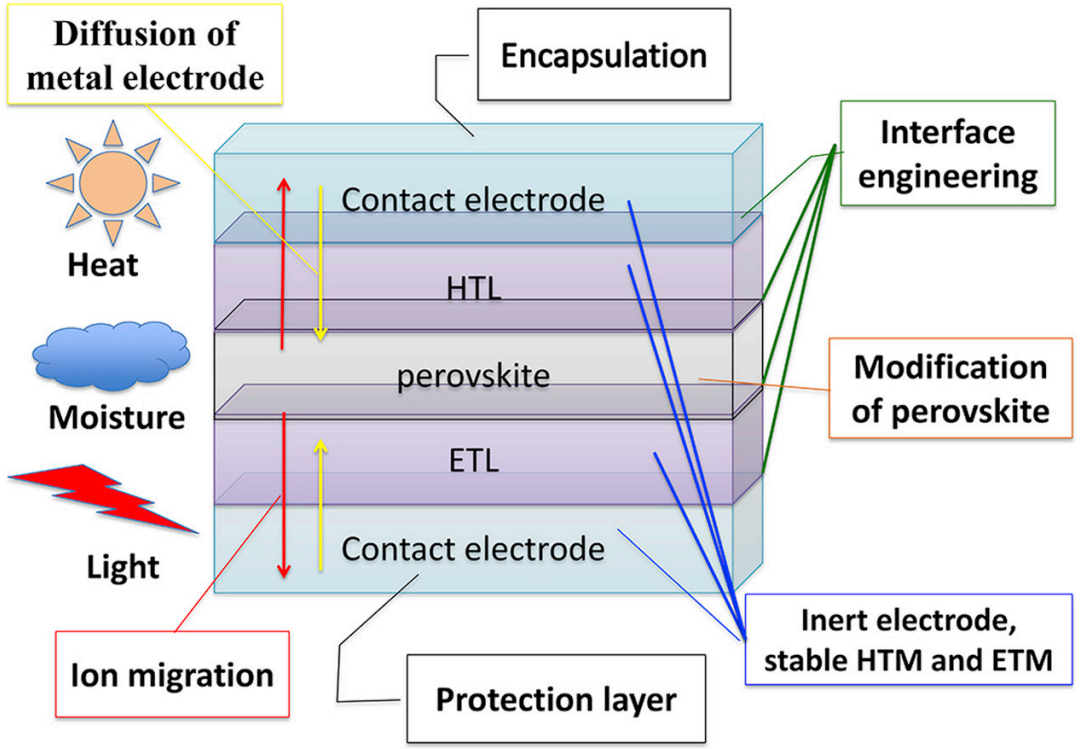
Operational factors

- Reverse bias stress
- Encapsulation
- Mechanical stress

Environmental factors

- Moisture/Oxygen
- Heat
- UV exposure
- Light soaking



Among many others

Chen et al. . Power Sou., 2017, 355:98

Reverse Bias

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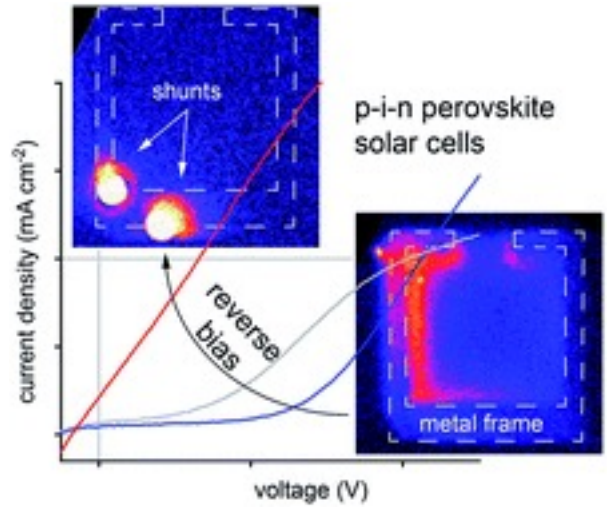
Condition caused by shading of panels during operation

Shaded cells are subjected to reverse current

↳ Cells act as load

↳ No generation, but absorption of energy



Razera, ***J. Mater. Chem. A***, 2020,**8**, 242-250

Consequences:

- Ion-migration
- Defects
- Irreversible electrochemical reactions
- Degradation of charge-transport layers

Previous Work

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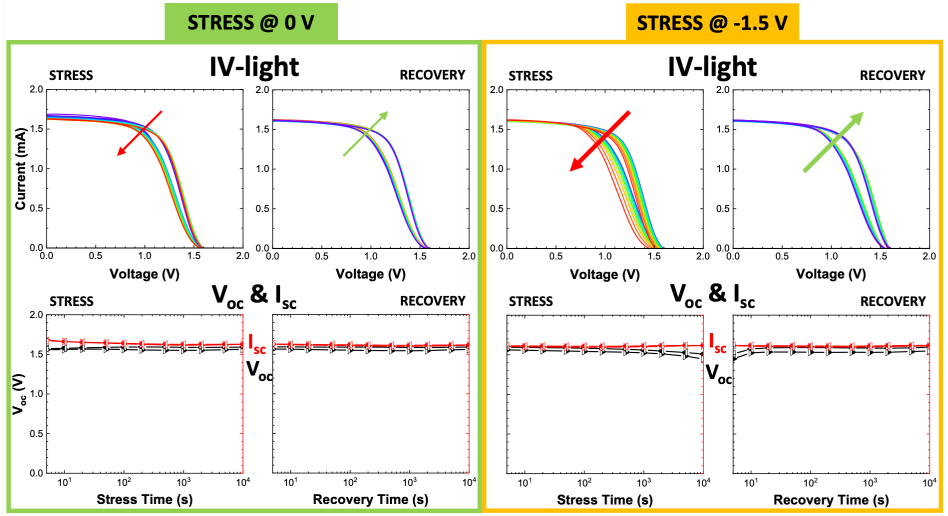
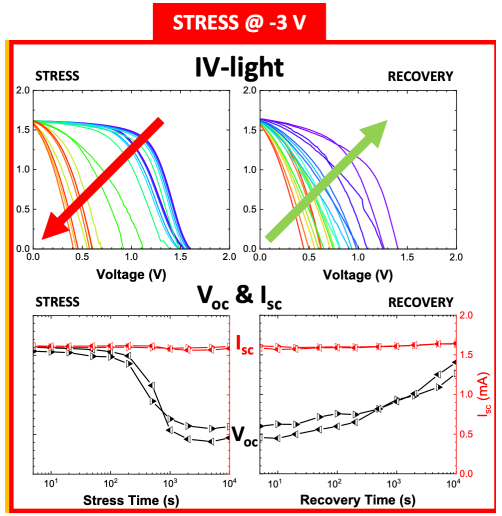
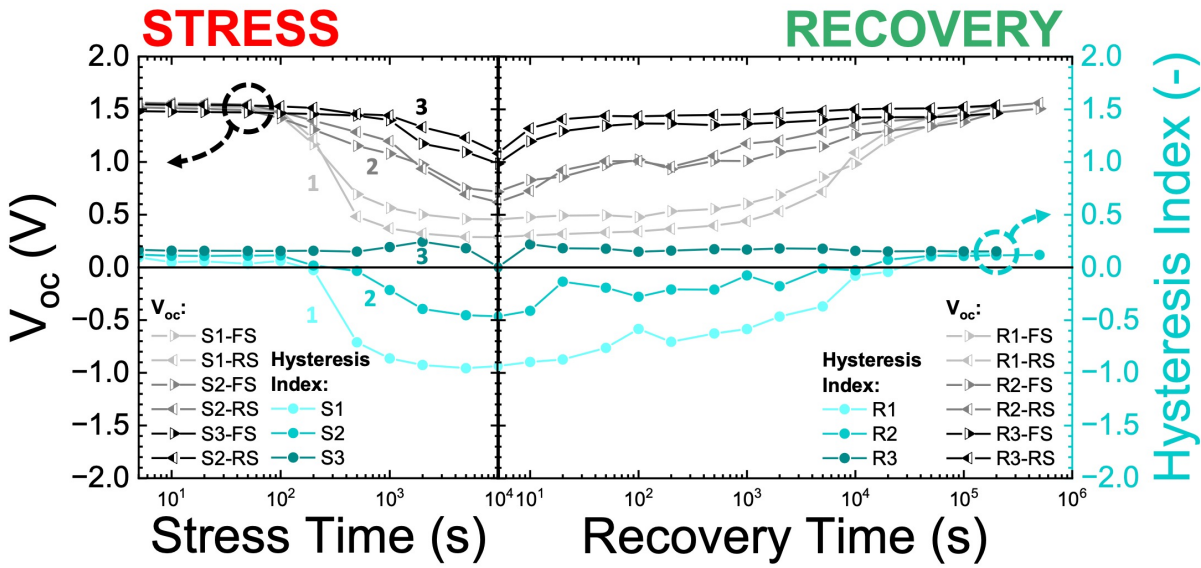
Study on the effects of reverse-bias on wide-band $FAPbBr_3$ perovskite solar cells





Recovery from degradation

$V < \frac{1}{2} V_{BreakDown}$



No hysteresis after recovery

Ascribed to ion-migration

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N. Tormena et al. Solar Energy Materials and Solar Cells 285 (2025) 113547

Goals of the Work

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Continue this path, by analyzing the reversibility of the phenomena by means of optical and spectroscopic techniques

- Microscopy imaging
- Confocal Raman Spectroscopy

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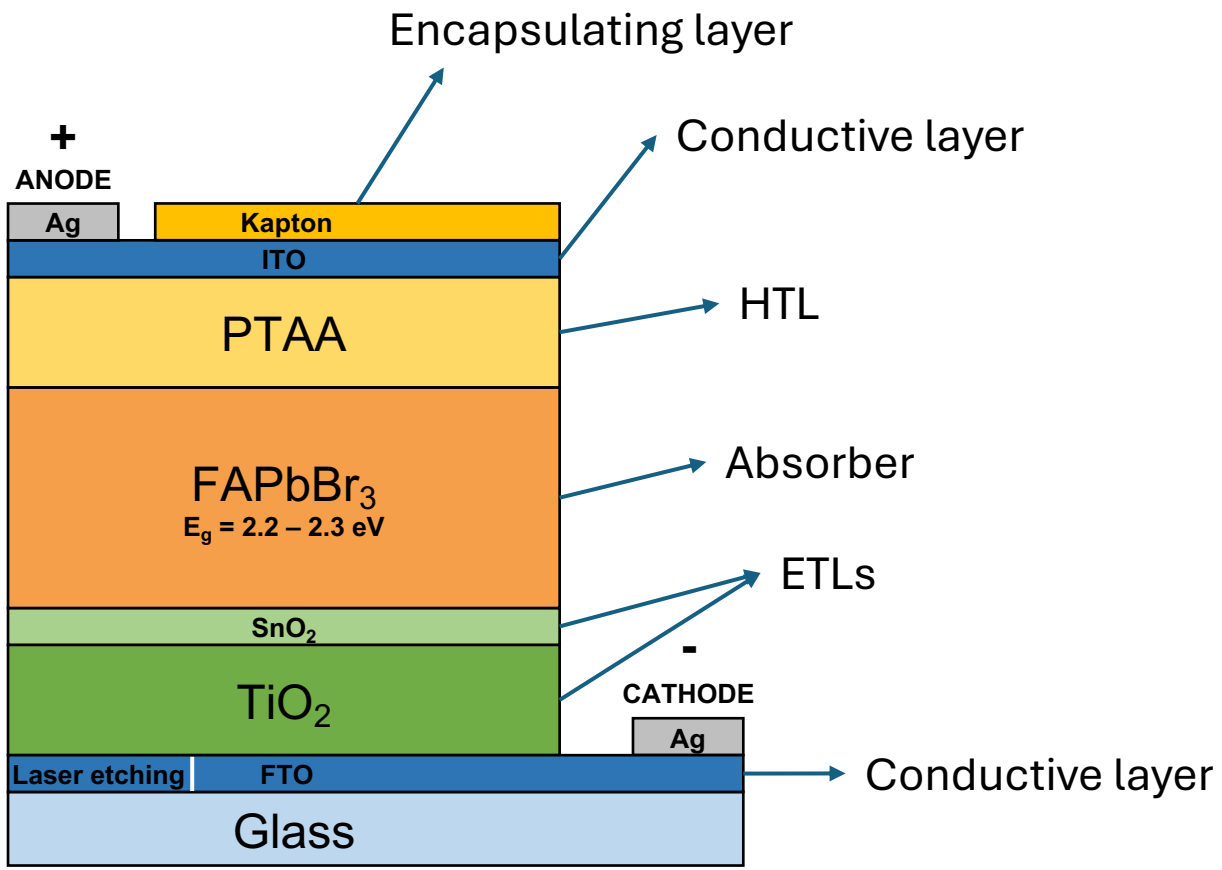
Solar cell structure



Brief recap on the Raman Effect

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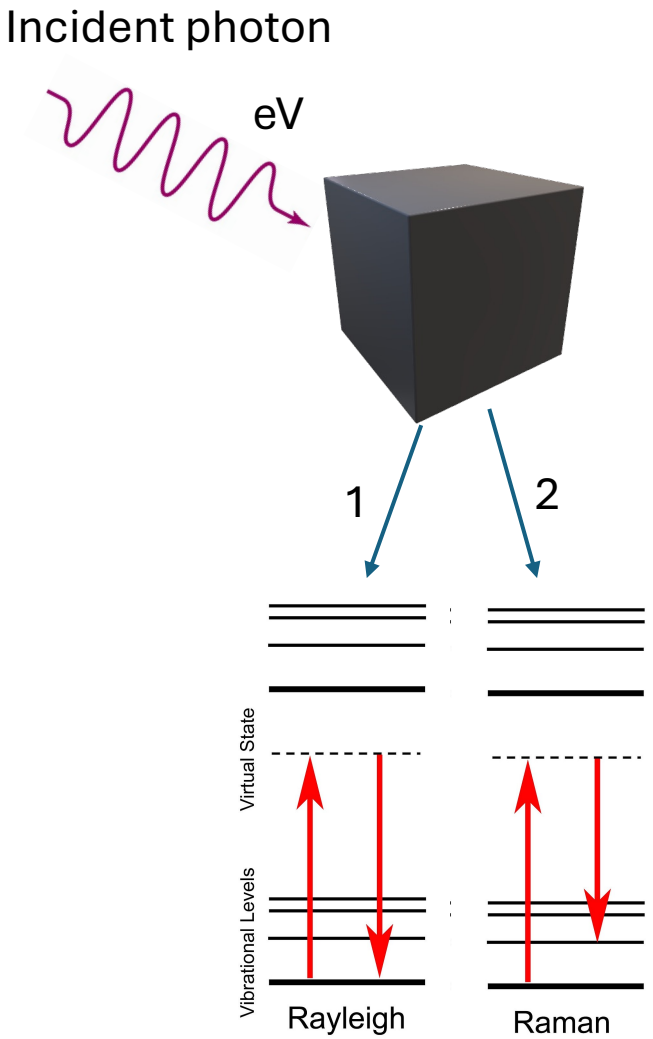
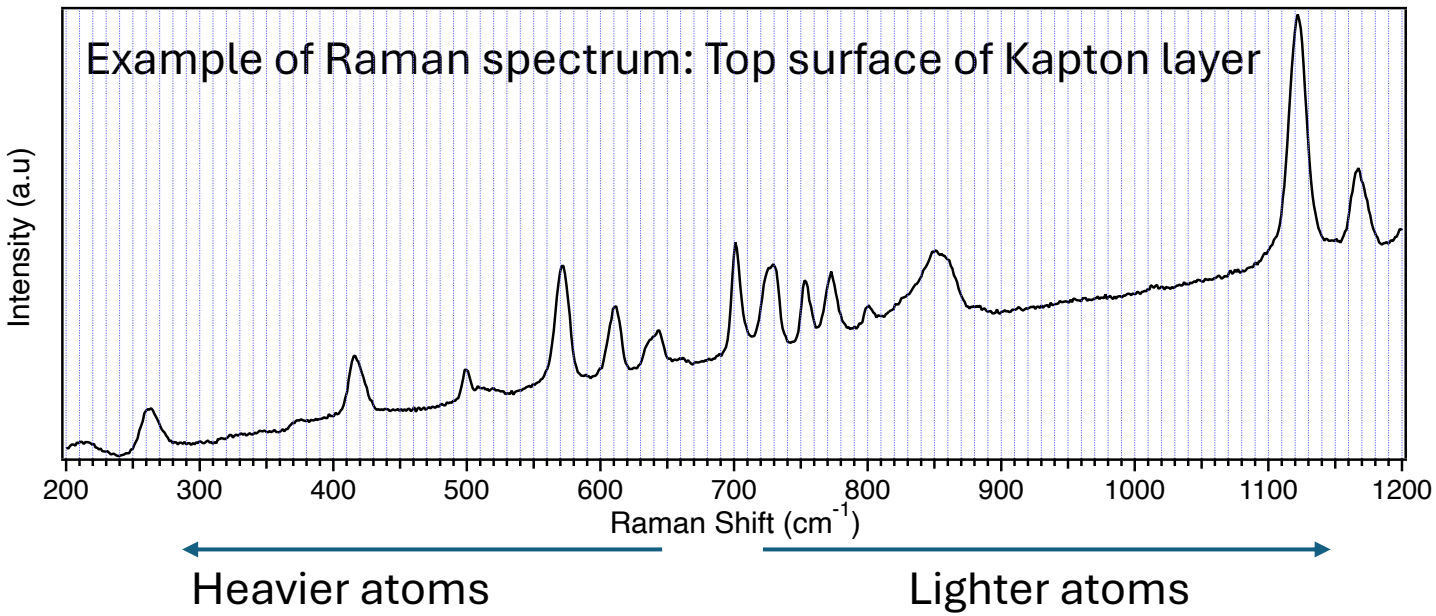


Emitted Raman photon → ΔE ~ vibrational energy absorbed

Higher vibrational energy -> higher ΔE of the photon

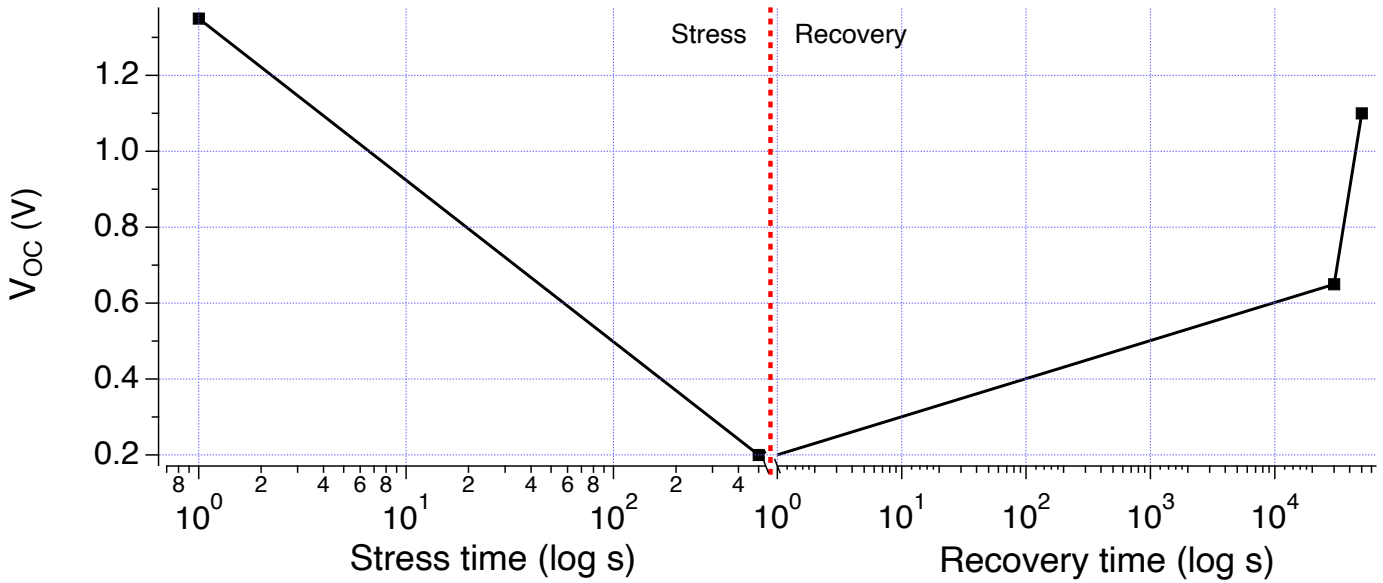
Such shifts are measured in wavenumbers (cm^{-1})

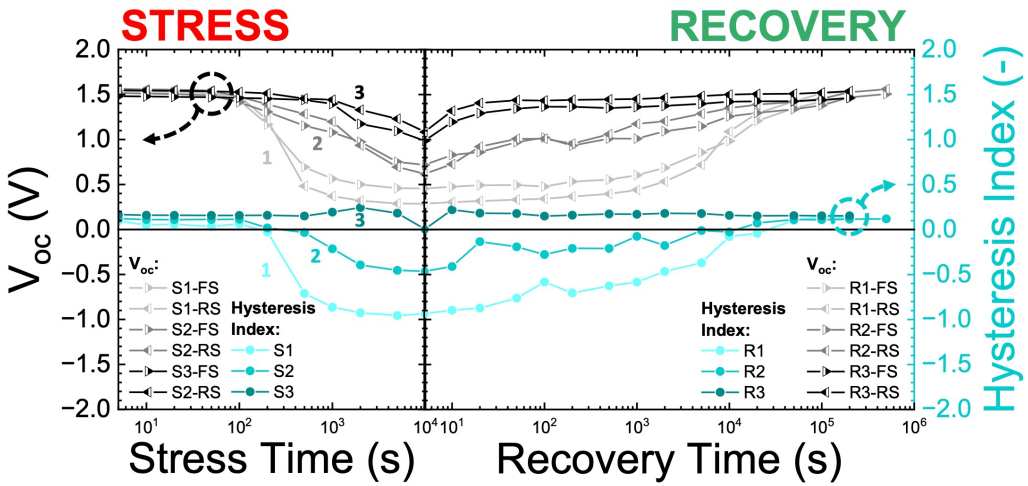


Stress test protocol and electrical behaviour

Stress conditions:

-3V reverse bias for different Δt





Similar behaviour!

$V_{oc} \sim 1.35\ V$

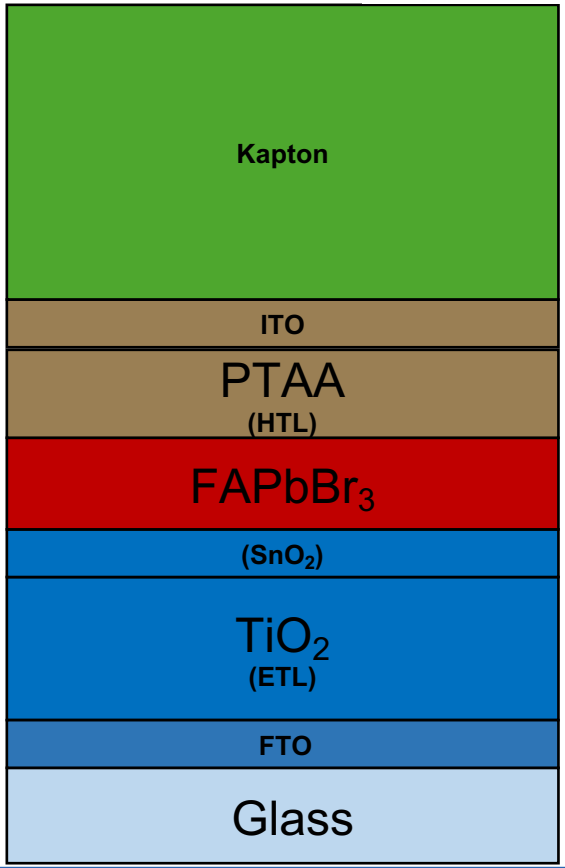
$V_{oc} \sim 1.1\ V$

$V_{oc} \sim 0.2\ V$

Baseline measurements: Optical and Raman

$\lambda_{exc} = 633\ nm$

Magn.100X



Baseline measurements: Optical and Raman

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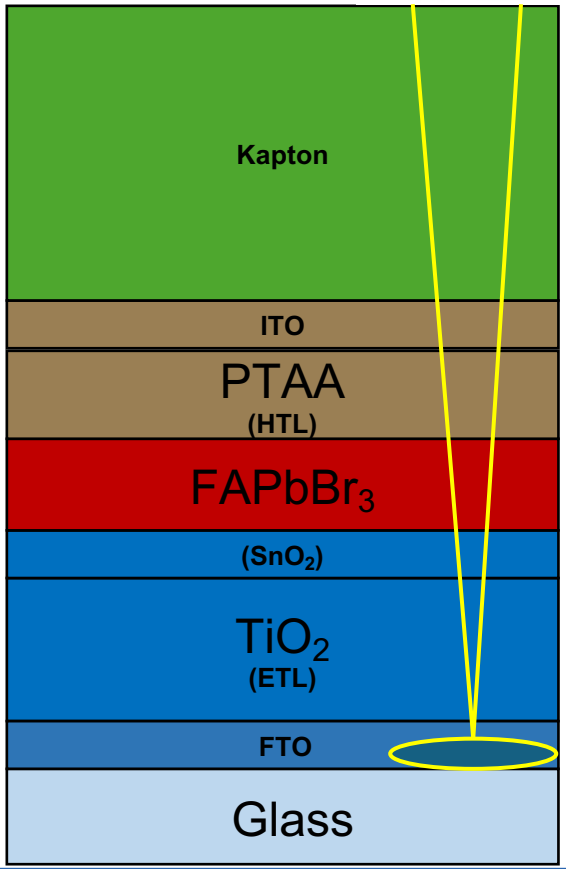
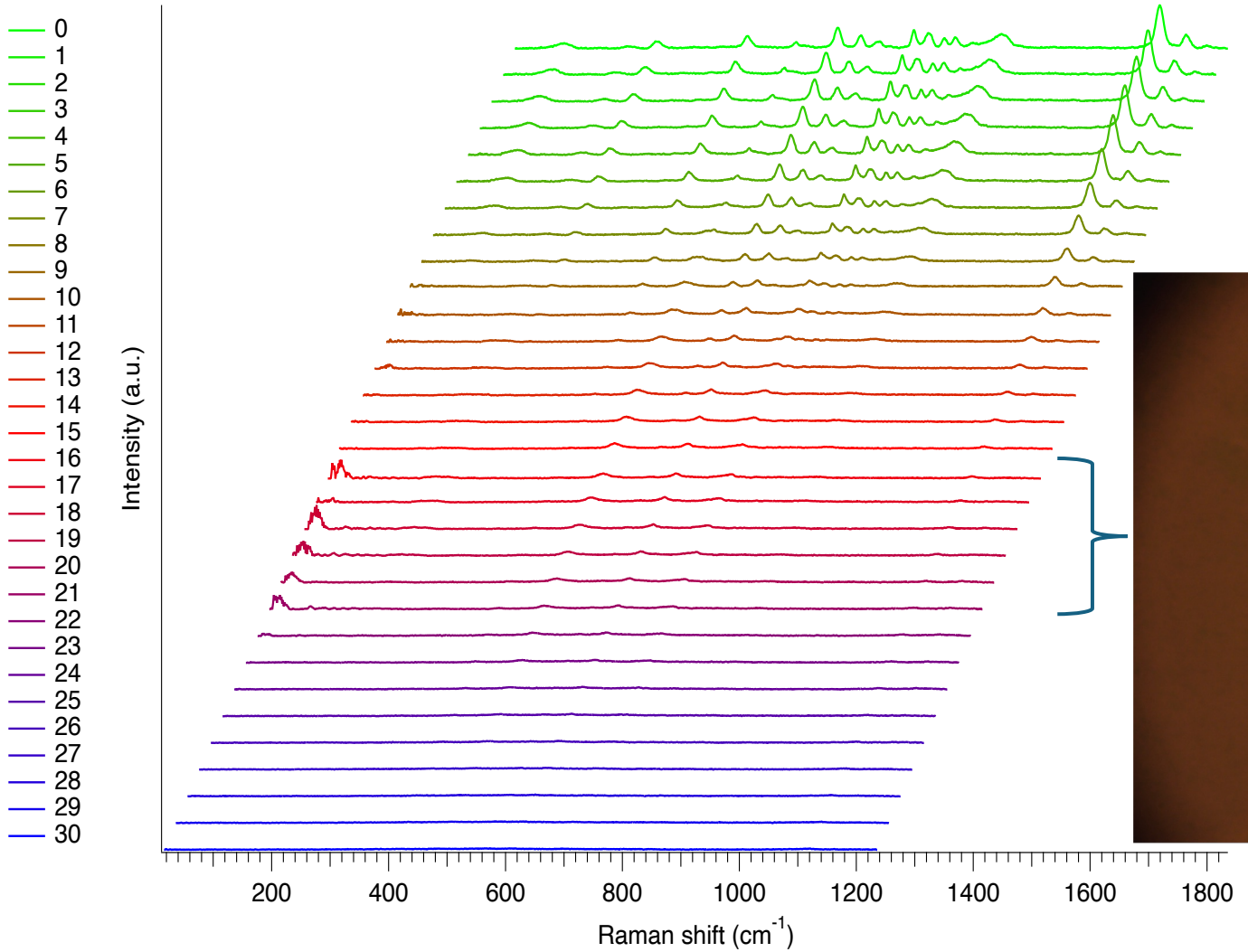
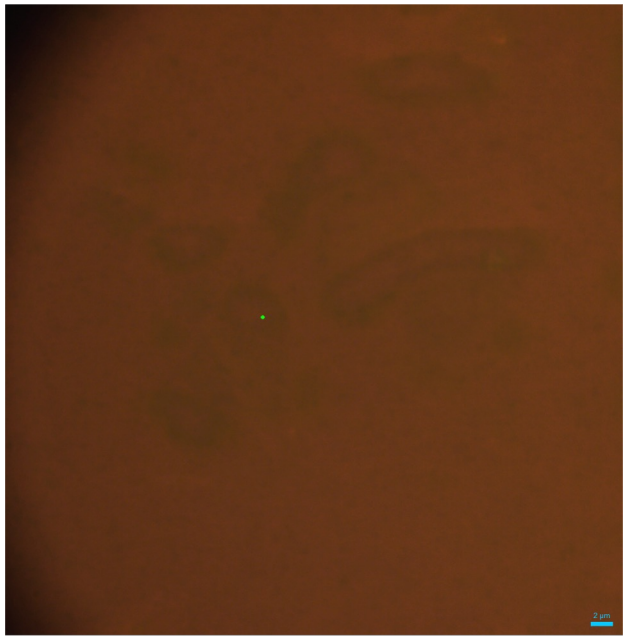




Optical image



Analysis of the layer following stress

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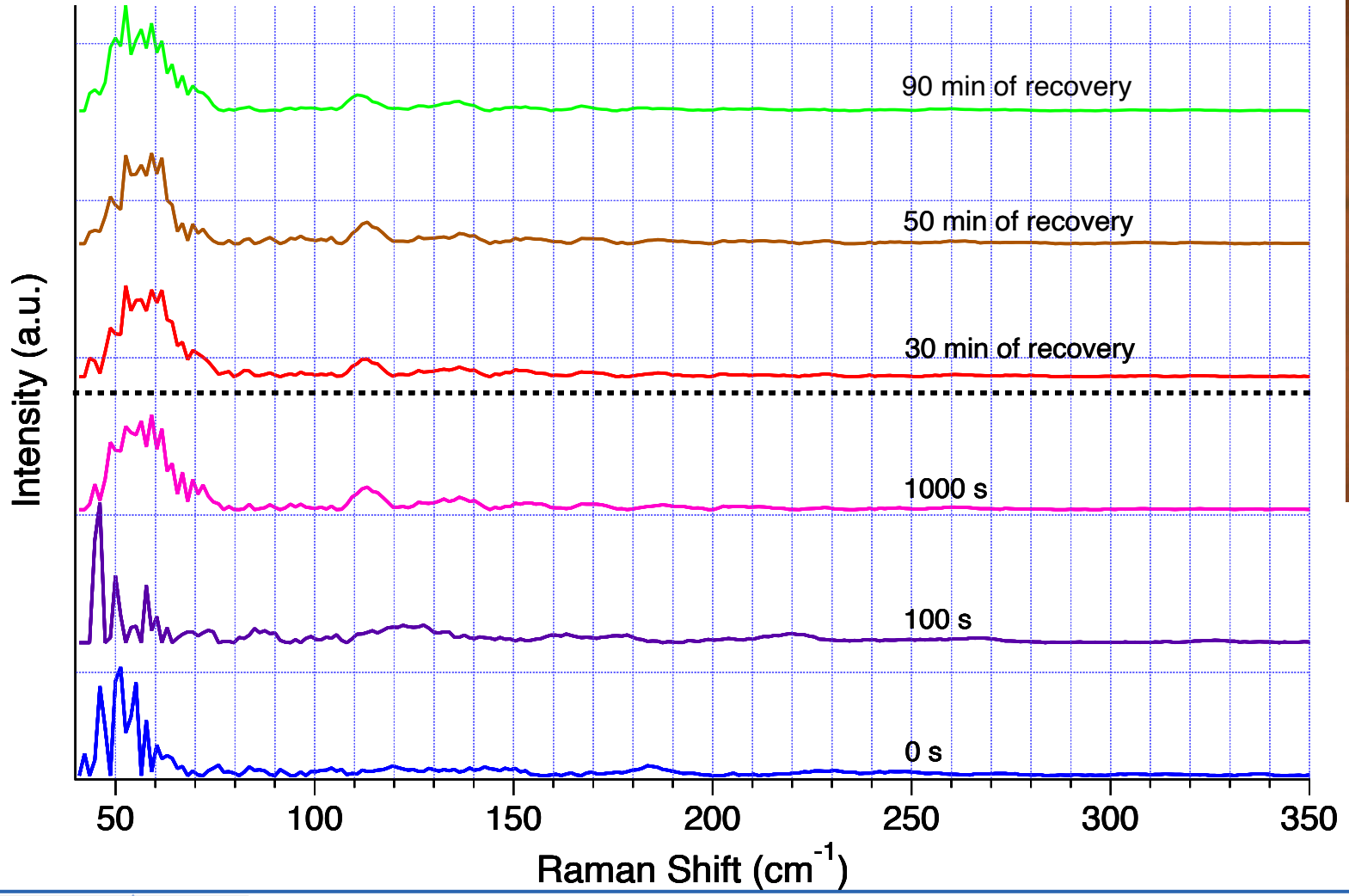
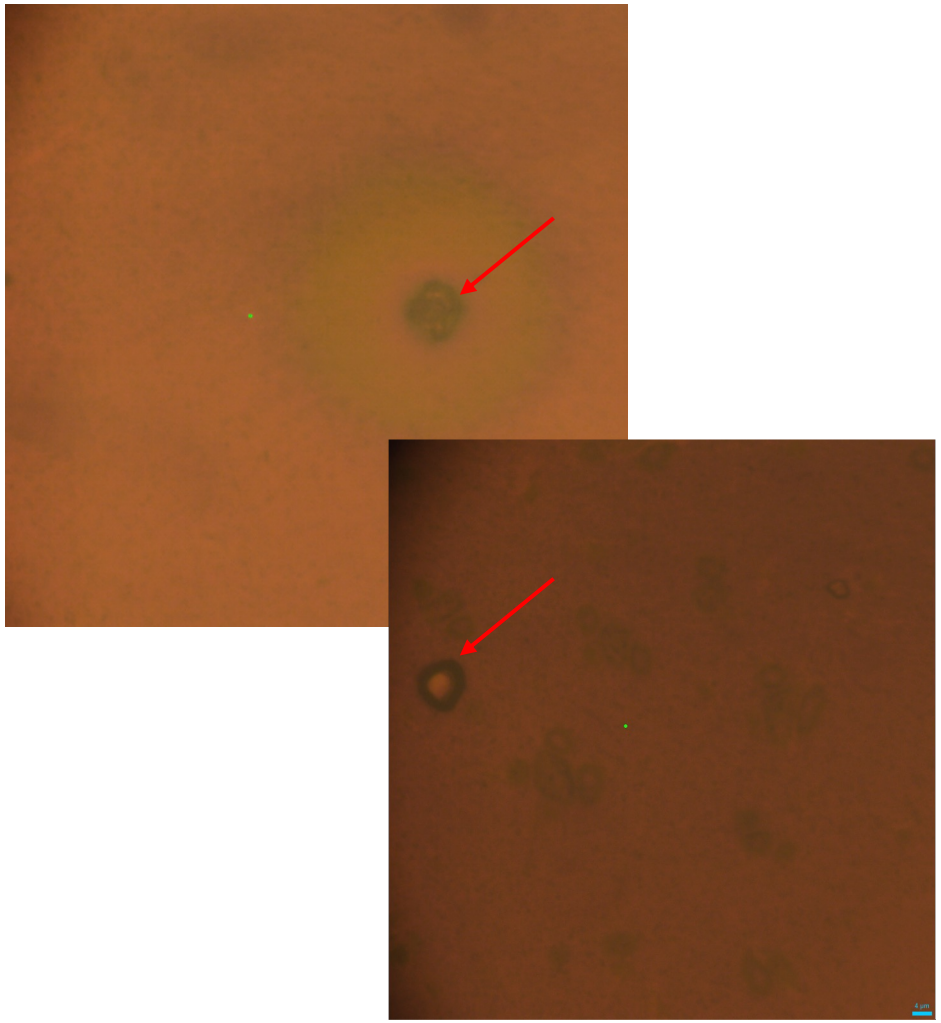
Eletrical Stress of -3V



Morphological changes



No recovery of the morphology

Defect composition

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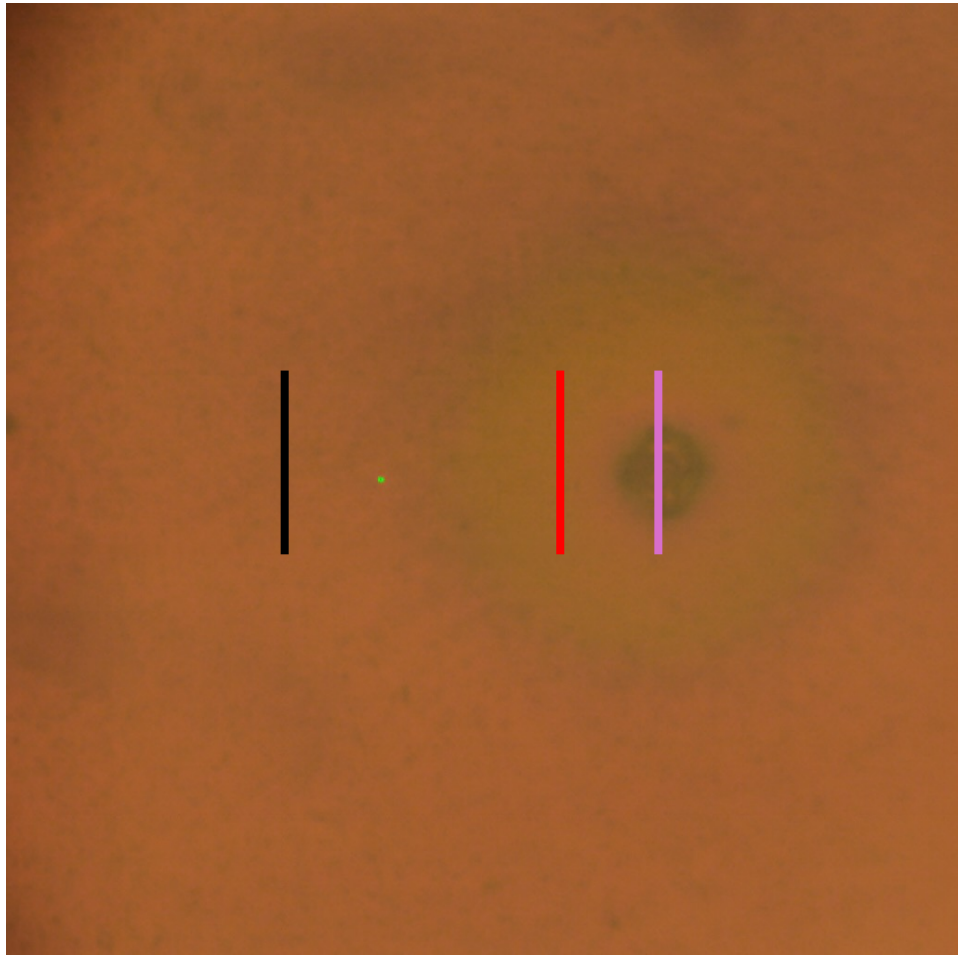
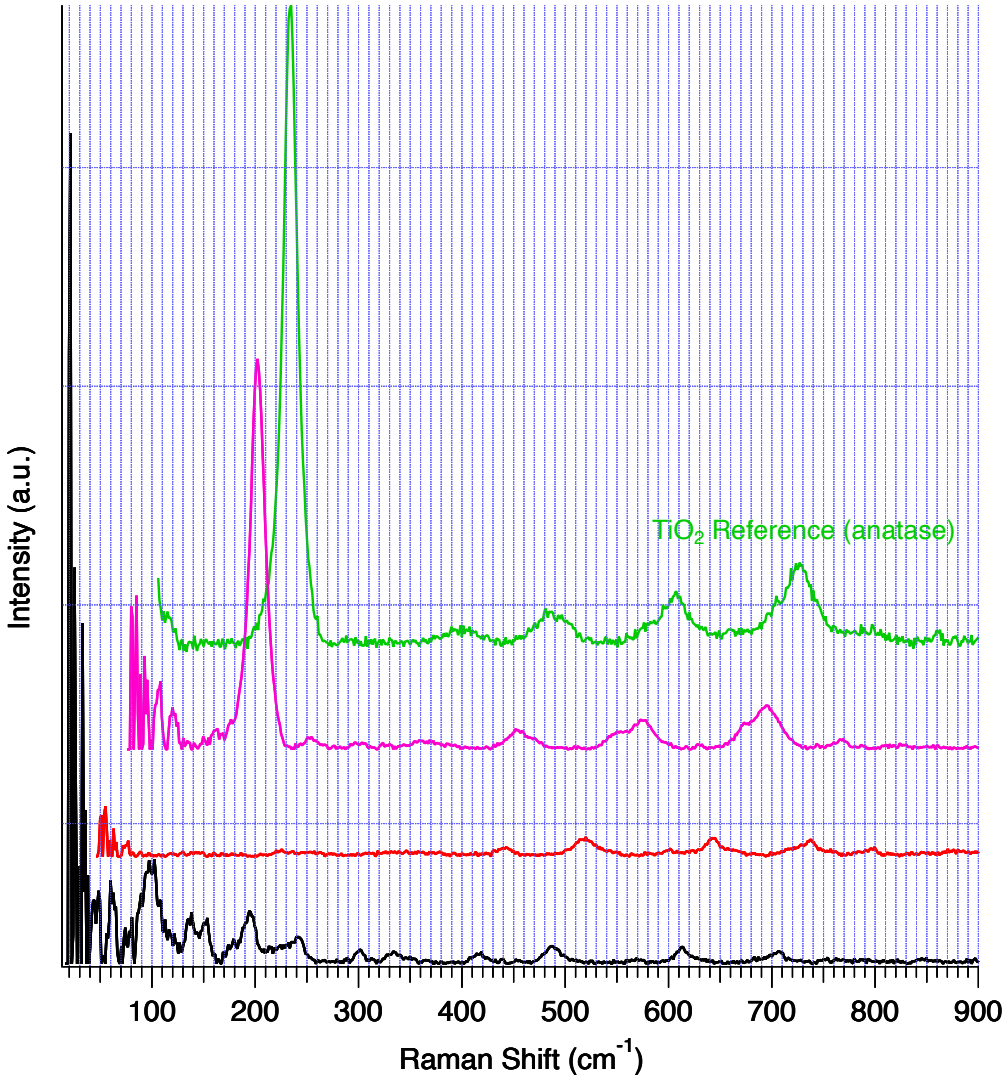
DOI:10.1038/s41598-017-08599-2





Comparison with Literature

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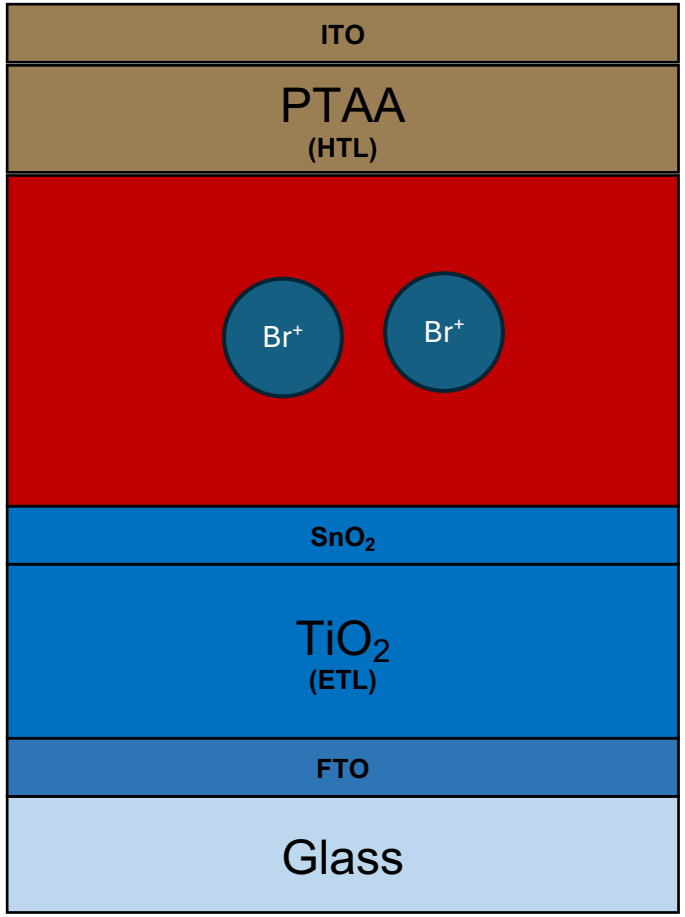
Suggested by Razera et al, J. Mater. Chem. A, 2020, 8, 242



Comparison with Literature

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Suggested by Razera et al, J. Mater. Chem. A, 2020, 8, 242

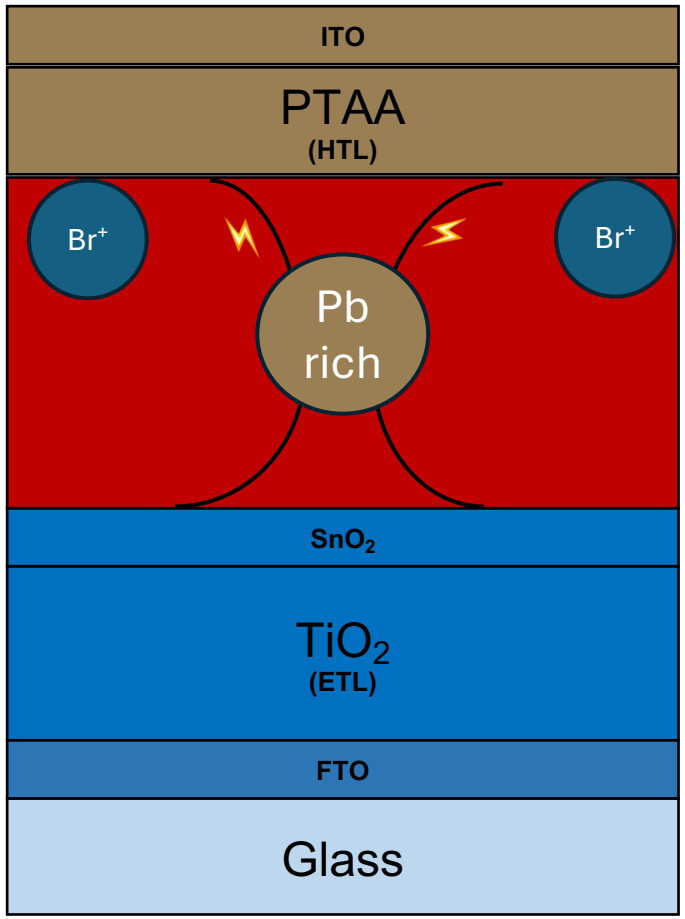
Ion migration

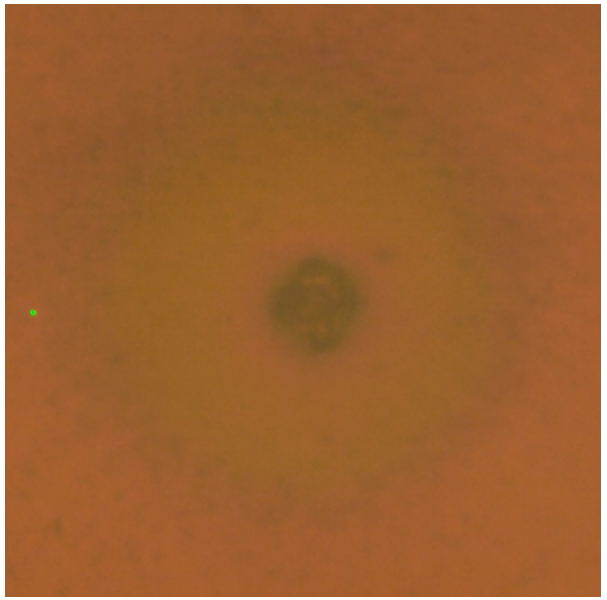
↓

Pb-rich areas

↓

Shunt formation





Resulting effect

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Conclusions

- Successfully observed perovskite layer within a Solar cell device via Raman spectroscopy
- Observation of variation of Raman bands following electrical stress
- Correlation of effects with current state of the art data

Future plans

- Tighter tracking of the evolution of the degradative process by Raman spectroscopy
- Synergy with the use of PL and TR-PL measurements
- Testing of updated architectures

Acknowledgements

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Thank you for the attention

…. And see you in Palermo