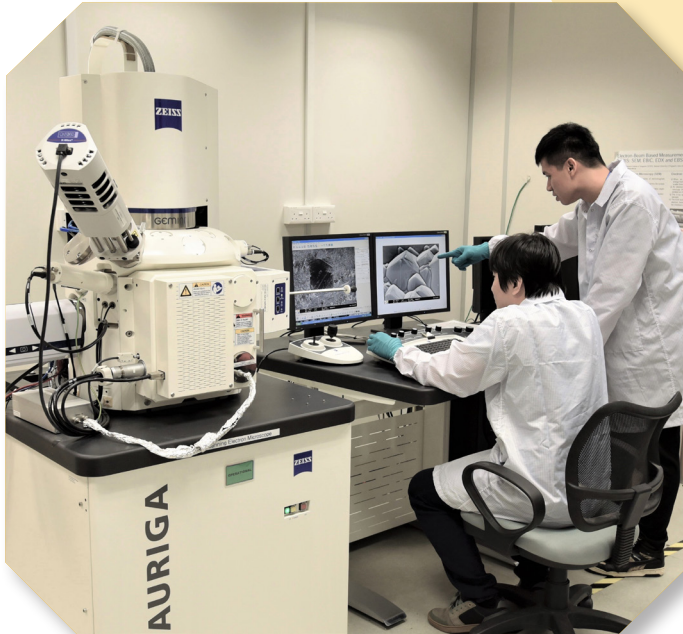




NUS
National University
of Singapore



PV Devices Characterisation

Solar Cell Doctor
Solar Cell Simulation Software
Characterisation of Solar Cells and Materials

NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
SINGAPORE



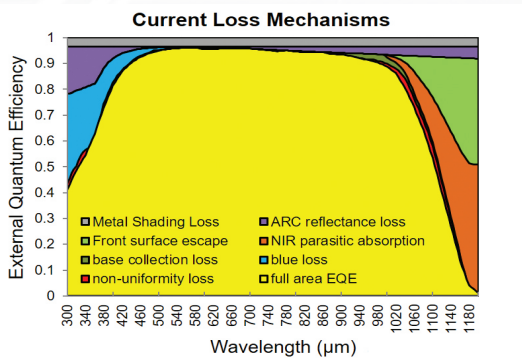
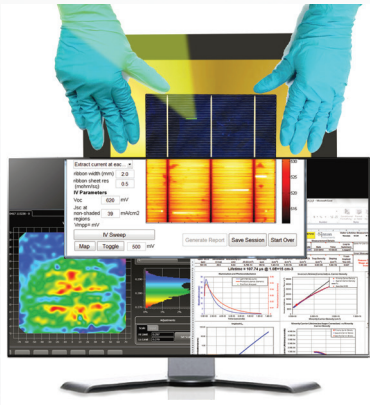
EDB:
SINGAPORE

SERIS is a research institute at the National University of Singapore (NUS). SERIS is supported by NUS, the National Research Foundation Singapore (NRF), the Energy Market Authority of Singapore (EMA) and the Singapore Economic Development Board (EDB).

SOLAR CELL DOCTOR - ADVANCED SOLAR CELL DIAGNOSTICS

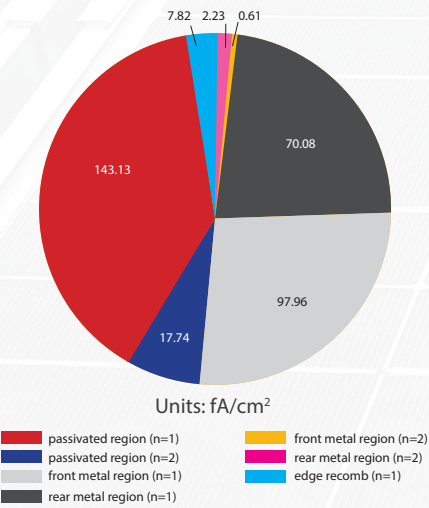
The Solar Cell Doctor enables solar cell researchers and production line engineers to:

- Accelerate continuous improvement programme
- Shorten product development time
- Improve the efficiency of their devices

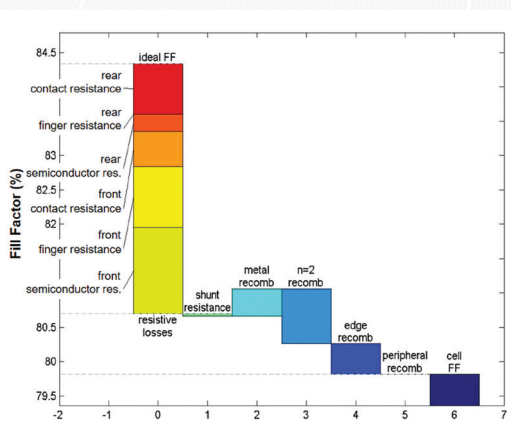


External quantum efficiency (EQE) of a silicon solar cell and the various contributions to current density loss.

By judiciously combining solar cell characterisation with sophisticated computational methods on easy-to-prepare test structures and solar cells, the Solar Cell Doctor provides comprehensive diagnosis of solar cells to delineate performance losses.

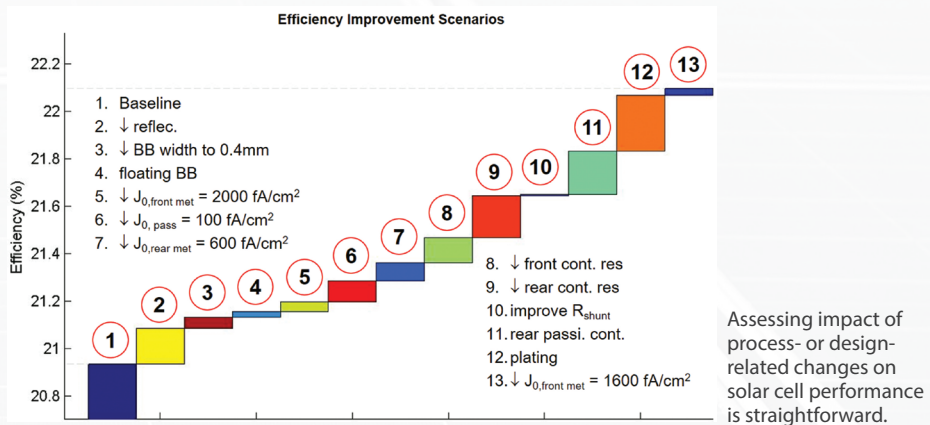


Equivalent first-diode saturation current density J_{01} values (in fA/cm²) at V_{oc} of a solar cell



Fill factor (FF) loss mechanisms and their contributions to the FF.

SOLAR CELL DOCTOR - EVALUATING PROCESS OR DESIGN CHANGES

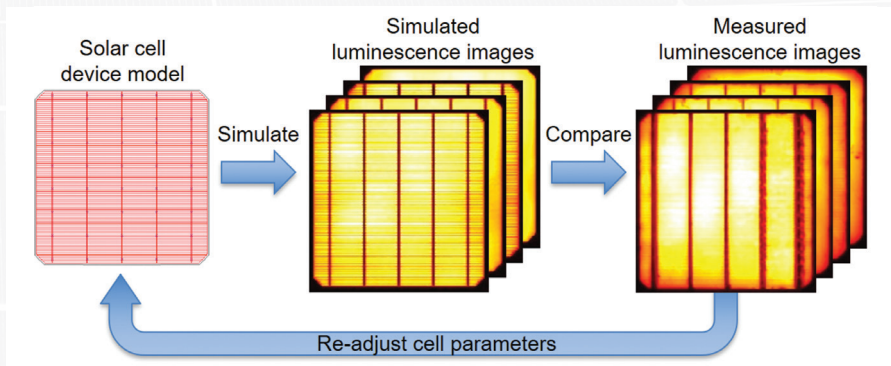


SOLAR CELL SIMULATION SOFTWARE (I) - GRIDDLER 2.5 SOLAR CELL MODELLING

Effective two-dimensional finite element modelling through Griddler 2.5 permits users to independently optimise cell design and explore efficiency improvements.

SOLAR CELL SIMULATION SOFTWARE (II) - SolarEYE AUTOMATED SOLAR CELL ANALYSIS

- SolarEYE is a luminescence imaging platform with automated analysis routines.
- Based on the Griddler two-dimensional finite element ecosystem, SolarEYE auto-fits to data on a detailed level.
- Analysis routine traces the sources of recombination and series resistance, down to process-related components.
- Automatically assesses the impact of factors which impact the V_{oc} and FF.
- Applicable to mono- and multicrystalline silicon BSF, PERC, heterojunction and passivated contact solar cells (p & n-type, monofacial & bifacial).



Automated fitting routine of luminescence images in SolarEYE

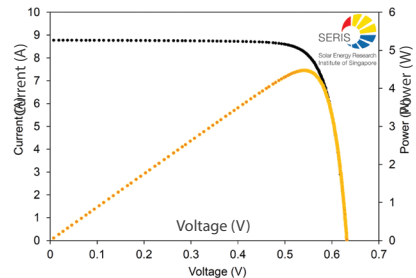
SOLAR CELLS AND MATERIALS CHARACTERISATION

SERIS combines state-of-the-art measurement tools for characterisation of material and device properties, optical and electronic activity, with powerful modelling techniques to improve the understanding of solar cells and materials.

Proprietary analysis techniques and an extensive range of characterisation tools in the laboratories deliver crucial data, ultimately linked to solar cell efficiency and cost.

Cell

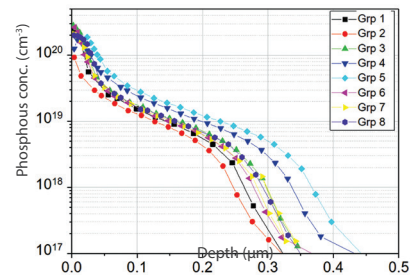
- Standard solar cell I-V testing using Xenon lamp and large-beam spectral response according to IEC 60904
- LED-based solar simulator with spectrum tunability
- Spot-area quantum efficiency & reflectance
- Suns- V_{oc} and multi-flash-based I-V testing
- Solar cell resistance measurement
- Light soaking system



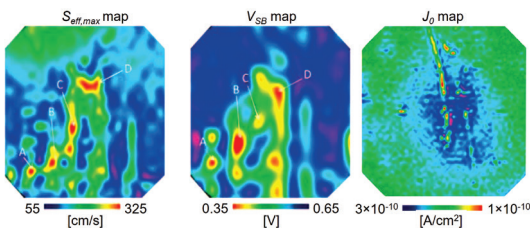
Calibrated solar cell I-V measurement

Wafer

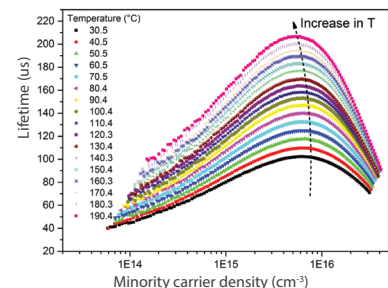
- Photoconductance-based carrier lifetime with temperature variation
- Contactless corona-voltage & μ -PCD lifetime mapping
- Electrochemical capacitance-voltage (ECV) profiling
- Sheet resistance, thickness and resistivity mapping
- Photoluminescence imaging
- Inductively coupled plasma mass spectrometry (ICPMS) for impurity analysis



Measurement of phosphorus dopant depth profiles in silicon via ECV profiling.



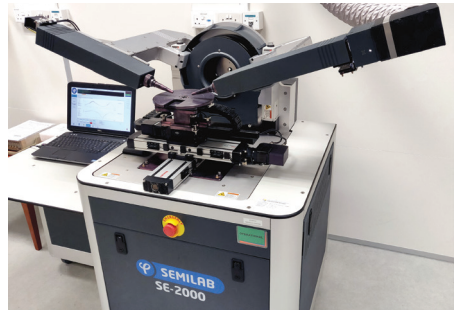
Spatial maps of surface recombination velocity S (left), surface barrier V_{SB} (middle), and J_0 (right)



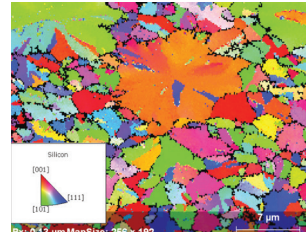
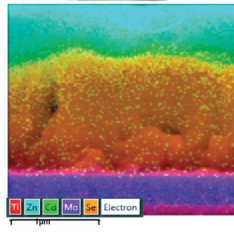
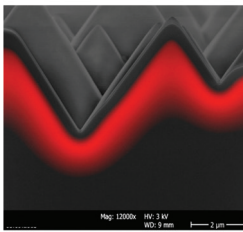
Temperature and injection dependent lifetime spectroscopy (TIDLs) of AlO_x passivated multicrystalline Si wafers

GENERAL-PURPOSE TOOLS

- UV-VIS-NIR spectrophotometry (angular-resolved capability)
- Time-resolved fluorescence spectroscopy
- Optical surface profiling
- High-precision dimension measurement
- SEM equipped with EDX spectroscopy
- Electron backscattered diffraction (EBSD)
- Electron beam induced current (EBIC)
- Spectroscopic ellipsometry
- FTIR and Raman spectroscopy



Spectroscopic ellipsometer for thin film optical characterisation



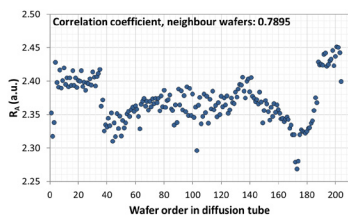
(Left) Cross-sectional EBIC image of a Si solar cell showing depletion region of p-n junction; (Middle) EDX elemental map of the cross-section of a thin-film solar cell; (Right) EBSD map of the crystalline orientation of a polycrystalline thin film.

ADVANCED DATA ANALYSIS FOR SOLAR CELL MANUFACTURING

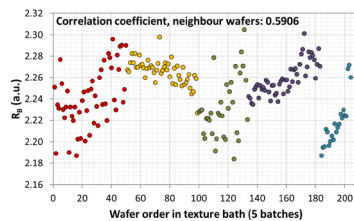
Advanced data analysis of solar cell manufacturing can provide valuable insights to

- Accelerate root cause analysis
- Enhance process optimization
- Increase process consistency
- Increase yield
- Drive down manufacturing cost

SERIS has researched and developed key enabling technologies for data collection and analysis.



In-line IR measurement for diffusion optimization



In-line IR measurement for root cause analysis

ABOUT SERIS

The Solar Energy Research Institute of Singapore (SERIS) is Singapore's national institute for applied solar energy research. SERIS is supported by the National University of Singapore (NUS), the National Research Foundation Singapore (NRF) and the Singapore Economic Development Board (EDB).

SERIS conducts research, development, testing and consulting on solar energy technologies and their integration into buildings and power systems. The institute's R&D spectrum covers materials, components, processes, systems and services, with an emphasis on solar photovoltaic cells, modules and systems. SERIS is globally active but focuses on technologies and services for tropical regions, in particular for Singapore and South-East Asia. SERIS collaborates closely with universities, research organisations, government agencies and industry, both locally and globally.

ABOUT PV DEVICES CHARACTERISATION GROUP

The PV Devices Characterisation Group at SERIS focuses on the research & development of innovative characterisation & analysis solutions for solar materials and cells. It is equipped with a raft of measurement, diagnostics and analysis tools that enable the group to perform both high-quality standard measurements (such as 1-Sun solar cell efficiencies) as well as detailed characterisations and analyses to determine efficiency-limiting factors or evaluate solar cell manufacturing processes.



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