Photovoltaic Calibration and Measurement Capabilities at NMC- A*STAR

The National Metrology Centre (NMC), a research institute of the Agency for Science, Technology and Research (A*STAR), has set up the first specialised metrology laboratory in South East Asia capable of providing one-stop services for solar photovoltaic (PV) cell calibration, testing and characterisation to local and neighbouring solar cell research community and industry users since June 2012.

The solar PV cell calibration and measurement laboratory from the Optical Metrology cluster houses facilities that have been designed and built by NMC’s own experts. The differential spectral responsivity measurement facility is able to perform primary calibration of critical spectral parameters of reference solar cells, with high accuracy and an uncertainty of less than 1%, which only a few leading laboratories in the world such as the National Metrology Institute of Germany (PTB), the National Renewable Energy Laboratory (NREL) in the United States and the National Institute of Advanced Industrial Science and Technology (AIST) in Japan can achieve.

Another major facility, a super solar simulator based automatic current-voltage measurement facility measures full electrical characteristics of solar cells of different sizes up to 156mm x 156mm, including the most critical quality indicators of solar PV cells – maximum electrical power and energy conversion efficiency. The high precision spectroradiometers in the laboratory can measure the optical power and spectrum of either continuous or pulsed solar simulator - a critical equipment for all testing laboratories. In addition, the laboratory is also equipped with advanced equipment capable to measure the spectral properties of small, non-regularly shaped solar cell samples for R&D on new types of PV devices. The laboratory has been collaborating with other research institutes such as Solar Energy Research Institute of Singapore (SERIS) and Institute of Materials Research and Engineering (IMRE) of A*STAR, Singapore, on high accuracy measurements of solar cells.

For more information, please visit NMC website: www.a-star.edu.sg
Primary Calibration Facility - Differential Spectral Responsivity Measurement System - for Calibration of Reference PV Cells

- Direct traceability to NMC’s cryogenic radiometer based spectral responsivity scale
- A multi-functional measurement system for spectral properties of solar cells
  - Absolute & relative spectral responsivity
  - Differential spectral responsivity
  - Quantum efficiency
  - Nonlinearity
  - Spatial uniformity
  - Temperature coefficient
- A powerful tool for solar cell characterisation of spectral properties (mono- or poly Si, Ge, dye-sensitised, thin film solar cells etc)
- Primary calibration of short-circuit current ($I_{sc}$) of reference solar cells with high accuracy (uncertainty < 1%)
- Able to support all secondary cal/testing labs for reference cell calibration

1. Automatic Current - Voltage Tester

- Based on a super-class solar simulator
  - Able to accommodate two reference cells (20 mm x 20 mm) and two 6” single cells (156 mm x 156 mm) simultaneously
  - Motorised x-y sample stage enables I-V scan w/o removing the ref cell
  - First in the world with integrated capability for solar simulator characterisation: spectral irradiance and spatial uniformity
  - Automatic measurement of both static ($I_{sc}$, $V_{oc}$) and dynamic (full I-V scan) parameters of solar cells: $I_{sc}$, $V_{oc}$, $P_{max}$, FF, Efficiency etc

2. Spectroradiometry for Solar Simulator

- Characterisation and measurement of solar simulator
  - Spectral irradiance of CW and pulsed solar simulator measured by spectroradiometer and compact spectroradiometer for site work
- Classification of CW and pulsed solar simulator according to IEC standard 60904-9:
  - Spectral power distribution;
  - Non-uniformity of irradiance (CW);
  - Short term and long term instability of irradiance
# Calibration Capabilities for PV Cell and Solar Simulator at NMC-A*STAR

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<th>S/N</th>
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| 1   | Primary calibration of WPVS reference solar cell using differential spectral responsivity (DSR) method with I-V tester under standard testing conditions | Calibration of WPVS reference cells using DSR facility and I-V tester with following reported values:  
1) Absolute spectral irradiance responsivity & differential spectral irradiance responsivity values of the test cell (285 nm - 1195 nm, every 5 nm) at 6 bias irradiance levels;  
2) Short circuit current of the test cell under IEC standard testing conditions with uncertainty ~ 1%;  
3) full I-V parameters including $V_{oc}$, $P_{max}$, $I_{max}$, $V_{max}$, FF, Efficiency etc in addition to $I_{sc}$;  
4) I-V scan curve with data  
5) Sensitive area of solar cell | ![Absolute spectral irradiance responsivity](image1.png)  
![Differential spectral responsivity at 6 bias irradiance levels](image2.png)  
![Full I-V scan curve](image3.png) |
| 2   | Calibration of 6” cell using I-V tester under standard testing conditions | Calibration of 6” single solar cells (mono-crystalline or multiple crystalline silicon based) by a DSR calibrated cell using I-V tester with following reported values:  
1) Relative spectral responsivity values of test cell (285 nm - 1195 nm, every 5 nm);  
2) $I_{sc}$, $V_{oc}$, FF and other full I-V parameters of the DUT under standard testing conditions (STC);  
3) I-V scan curve with data | ![Relative spectral responsivity](image4.png)  
![Full I-V scan curve](image5.png) |
| 3   | Measurement of solar simulator by spectro-radiometer | Measurement of CW and pulsed solar simulator according to IEC standard 60904-9:  
1) Spectral power distribution;  
2) Non-uniformity of irradiance; Short term and long term instability of irradiance | ![Spectral power distribution](image6.png) |