Test report ID: BOSCH201212-01-R1
18 JAN 2013

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BRTD measurement report

Goniophotometer Laboratory
Silicon Photovoltaics Cluster

ACCREDITED LABORATORY
SAC-SINGLAS
Cert No: LA-2012-0526-E

Purchase Order Reference No: 2012-181-Rev1

Report prepared for

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by

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The results reported herein have been performed in accordance with the laboratory's terms of accreditation under the Singapore Accreditation Council–Singapore Laboratory Accreditation Scheme.

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1. Measurement Overview

Contact Information	
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Order Details			
Total Number of Samples: 3		No. of Measurements requested: 06	
Type of sample: PV module exemplary, Red roof tile and Black roof slate.			
Date on which samples received at SERIS: 03 Dec 2012			
#	**SERIS Sample ID**	**Sample Name/ description**	**Measurement ID**
1	2012.12.04.001	PV module exemplary	5204 & 5205
2	2012.12.04.002	Red roof tile	5190 & 5191
3	2012.12.04.003	Black roof slate	5164 & 5165

Terms of subsequent use of data and samples	
(x) Samples to remain at SERIS (x) Samples can be displayed at SERIS ( ) Samples to be destroyed (x) Results to be kept confidential	( ) Samples to be returned to:

2. Introduction

2.1. Measurement setup

The PAB-PGII goniophotometer operated at SERIS is a device for the measurement of the bidirectional reflectance and transmittance distribution (BRTD) of samples with dimensions ranging from 50mm x 50mm up to 900mm x 1000mm, with a maximum thickness of 50mm and a weight limitation of 50kg. The measurement is angular resolved. The device consists of three main components:

- The light source, which is used to illuminate the sample by a converging beam. The spectral range of the emitted light can be restricted using filters. Two sources are currently in use, a halogen and a xenon lamp.
- The sample holder, which can be rotated to vary the incident angle.
- The detector, which is mounted on an arm and rotates at a constant distance around the center of the sampled area. The detector is always facing the sample.

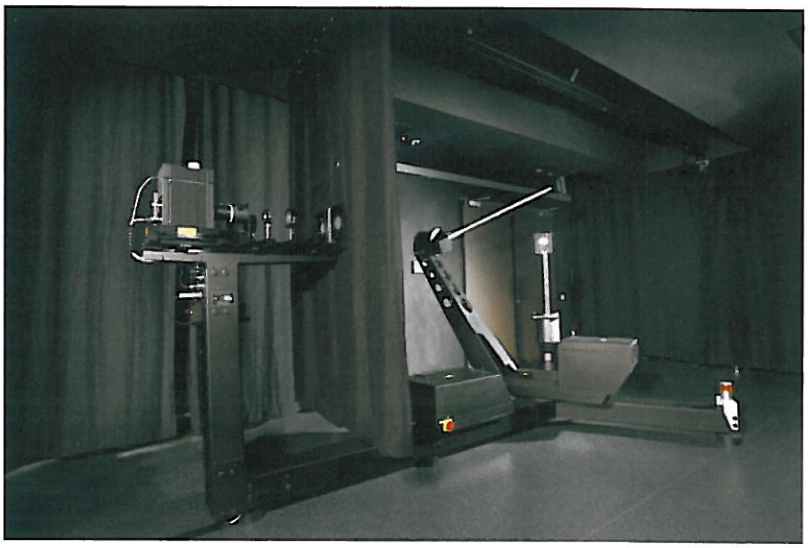

Fig 1. The Goniophotometer

Compliant with measurement method described in ASTM 2387-05 (2011)

BRTD*cos (theta_out) signal below 10^{-3} sr^{-1} is in the range of noise of the equipment as determined by the manufacturer; features and speckle in this range should be ignored.

2.2. Data presentation format

Figures:

- Polar plots of BRTD multiplied by $\cos(\theta_{out})$ [identified as DSF in ASTM2387] in decadic logarithmic scale for the scatter plane overlaid for all measured angles. θ_{out} is the same as θ_s (scattering angle). BRTD includes BRDF (bidirectional reflectance distribution function) and BTDF (bidirectional transmittance distribution function)

Tables:

- Integrated reflectance or transmittance values for the samples at all incident angles

2.3. Measurement uncertainty

The results reported here have a relative expanded uncertainty of 5.6% with a 95% confidence level and a coverage factor of k =2.

2.4. Disclaimer, Limitation of Liability

This report represents the personal opinions of the members of the evaluation team. The evaluation team members, SERIS, and the National University of Singapore (NUS) exclude any legal liability for any statement made in the report. In no event shall the evaluation team members, SERIS, and NUS of any tier be liable in contract, tort, strict liability, warranty or otherwise, for any special, incidental or consequential damages, such as, but not limited to, delay, disruption, loss of product, loss of anticipated profits or revenue, loss of use of the equipment or system, non-operation or increased expense of operation of other equipment or systems, cost of capital, or cost of purchase or replacement equipment systems or power. The results apply only to the samples tested.

3. Measurement information

1	Description of the sample (size, shape, color, finish)	PV modules of size 540X360X50 mm Red roof tile of size 420X335X10 mm Black roof slate of size 200X200X4 mm
2	Any treatment or cleaning performed on the sample before measurement	Wipe with optical cleaning tissue
3	Angle of incidence	Zero and 10 degrees
4	Incident azimuth angle	Fixed at zero
5	Scatter polar angle	Available as raw data
6	Scatter azimuth angle	Available as raw data. Scatter plots are at phi = 0
7	Location of measurement on sample	One spot per sample. As shown in photo
8	Spectral range	(x) 350 -750 nm ( ) 350 -1100 nm
9	Incident polarization	Not polarized
10	Incident light source	(x) Halogen ( ) Xenon
11	Detector	( ) Si (x) Vλ

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4. Sample measurement results

4.1) PV module exemplary

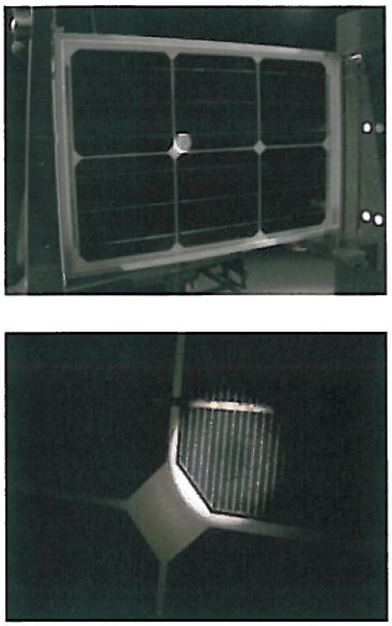

Fig 2. Photo of PV module exemplary sample: location of light spot on cell.

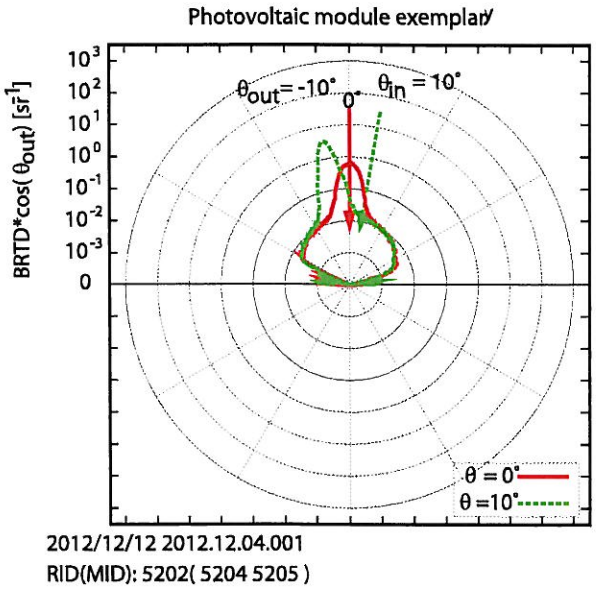

Fig 3. Polar plot of reflectance distribution at zero* and 10 degrees.

NOTE: The PV module exemplary in this test report refers to the following module type:

Foil laminate with

- Structured front glass
- Mono crystalline Bosch Solar cells
- Weather-resistant white backsheet
- Blanc anodized aluminum frame

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4.2) Red roof tile

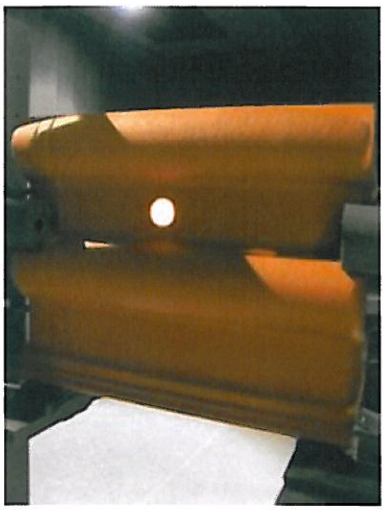

Fig 4. Photo of sample 2: location of light spot on sample.

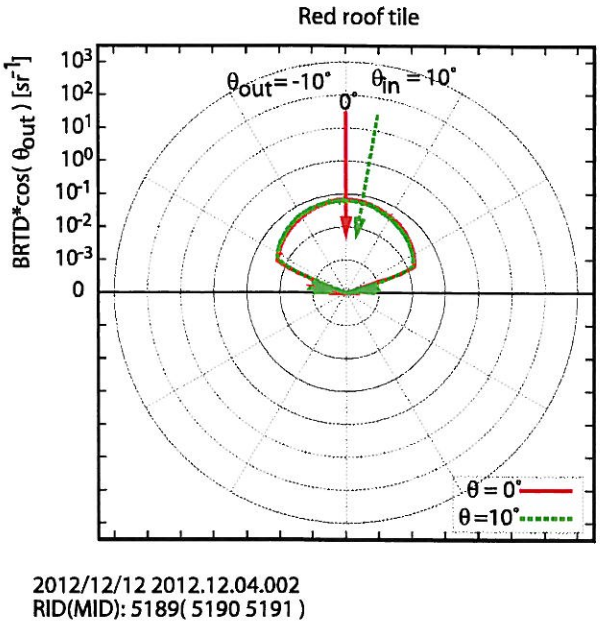

Fig 5. Polar plot of reflectance distribution at zero* and 10 degrees.

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4.3) Black roof slate

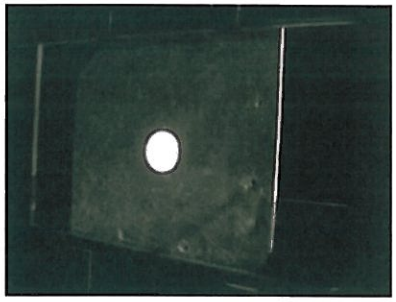

Fig 6. Photo of sample 3: location of light spot on sample.

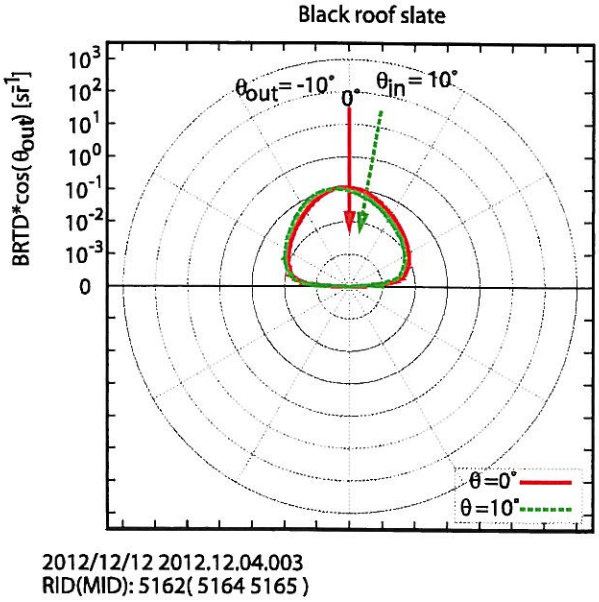

Fig 7. Polar plot of reflectance distribution at zero* and 10 degrees.

4.4) Table of integrated reflectance

Reflectance (%) of the 3 samples			
Incidence angle (deg)	PV module (%)	Red roof tile (%)	Black roof slate (%)
0*	6.1	14.0	11.7
10	8.7	13.5	11.2

*For 0° incidence only, peak reflectance at $\Theta_{out} = 0°$ may be incorrectly estimated when the detector shades the light source; data correct at other Θ_{out}