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SURFACE ROUGHNESS AND FEATURES OF A SOLAR CELL

Prepared by

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Introduction

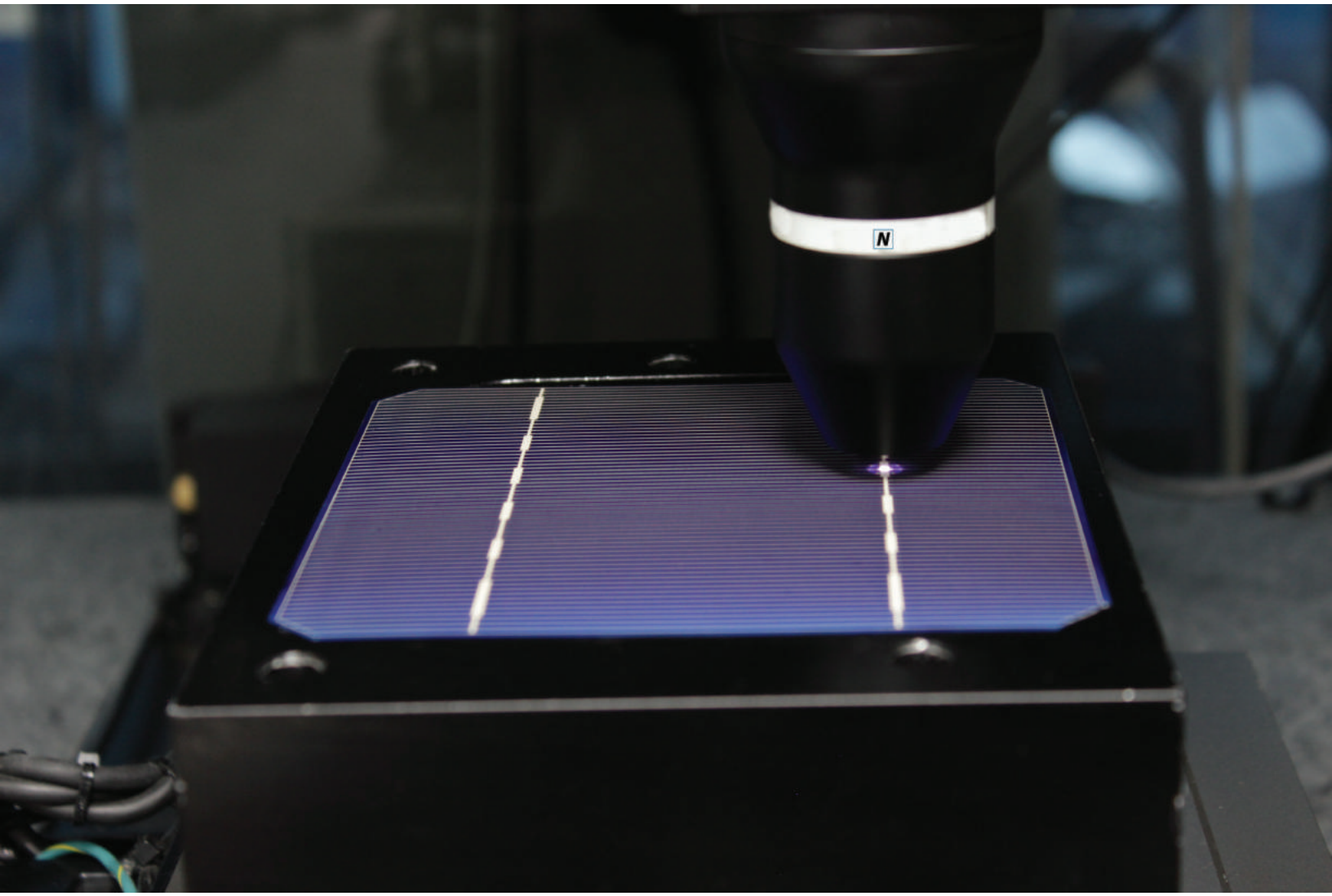
Maximizing a solar cell's energy absorption is key for the technology's survival as a renewable resource. The multiple layers of coating and glass protection allow for the absorption, transmittance, and reflection of light that is necessary for the photovoltaic cells to function. Given that most consumer solar cells operate at 15-18% efficiency, optimizing their energy output is an ongoing battle.

Importance of Solar Panel Testing

Studies have shown that surface roughness plays a pivotal role in the reflectance of light. The initial layer of glass must be as smooth as possible to mitigate reflectance of light, but the subsequent layers do not follow this guideline. A degree of roughness is necessary at each coatings interface to another to increase the possibility of light scattering within their respective depletion zones and increase the absorption of light within the cell[1]. Optimizing the surface roughness in these regions allows the solar cell to operate to the best of its ability and with the Nanovea HS2000 High Speed Sensor, measuring surface roughness can be done quickly and accurately.

Measurement Objectives

In this study we will display the capabilities of the Nanovea HS2000 High Speed Sensor by measuring the surface roughness and geometric features of a photovoltaic cell. For this demonstration a monocrystalline solar cell with no glass protection will be measured but the methodology can be used for various other applications.



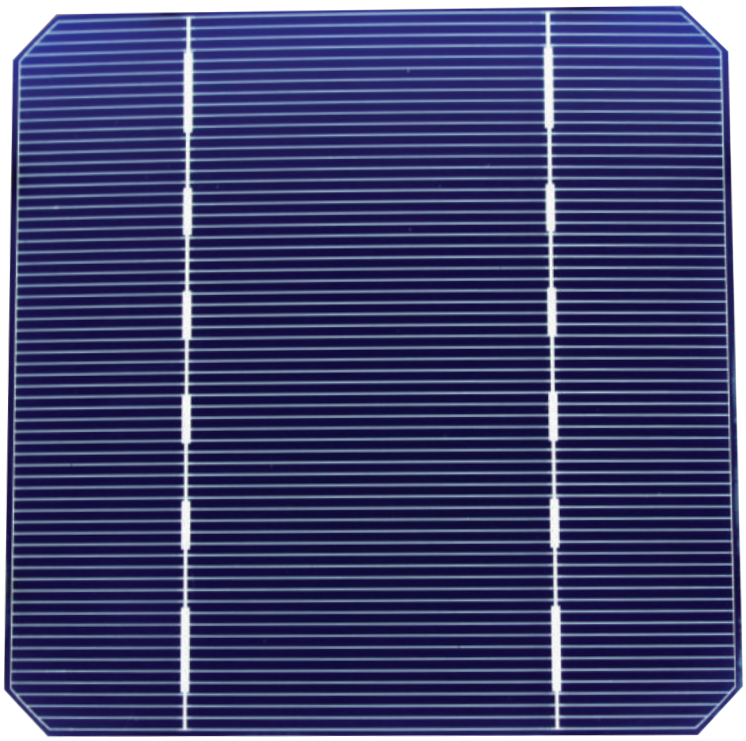
Solar Cell sample on Nanovea HS2000L Profilometer

Measurement Parameters

The following test parameters were used to measure the surface of the solar cell.

Solar Cell	
Optical Pen	L1
Acquisition rate	100 pps
Averaging	1
Measured surface	30mm x 10mm
Step size	5µm x 5µm
Measurement Time (h:m:s)	00:13:43

Table 1: Test parameters used



Sample of solar cell analyzed

Results and Discussion

Depicted below is the 2D false color view of the solar cell and an area extraction of the surface with its respective height parameters. A gaussian filter was applied to both surfaces and a more aggressive index was used to flatten the extracted area. This excludes form (or waviness) larger than the cut-off index, leaving behind features that represent the solar cell's roughness.

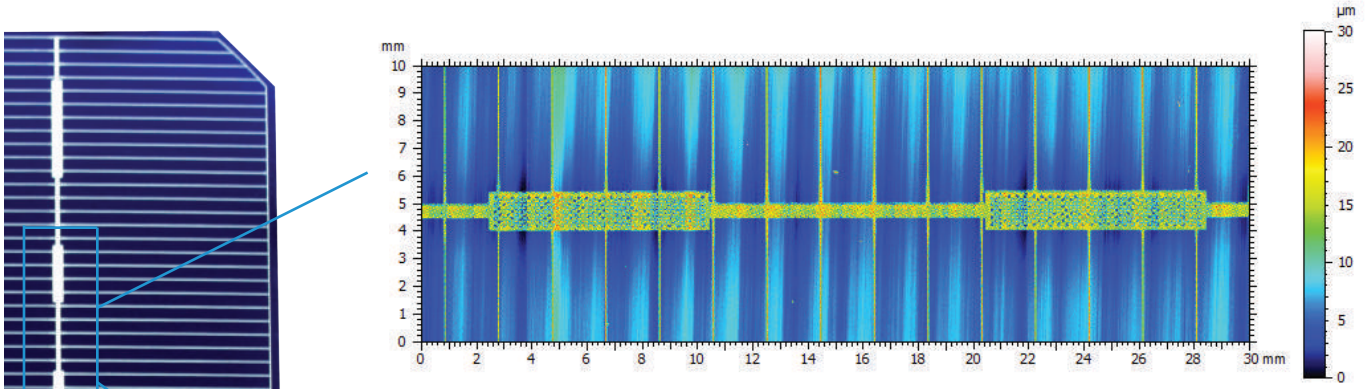


Figure 1: False color view of the photovoltaic cell

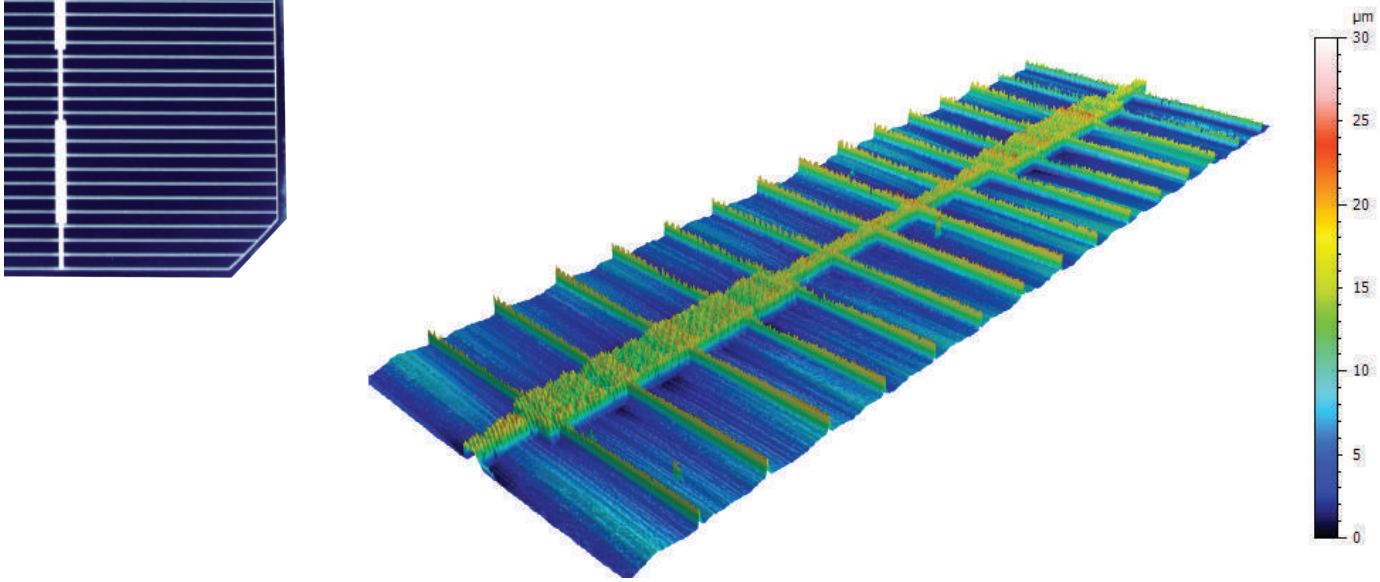


Figure 2: False color view of the photovoltaic cell

Results and Discussion

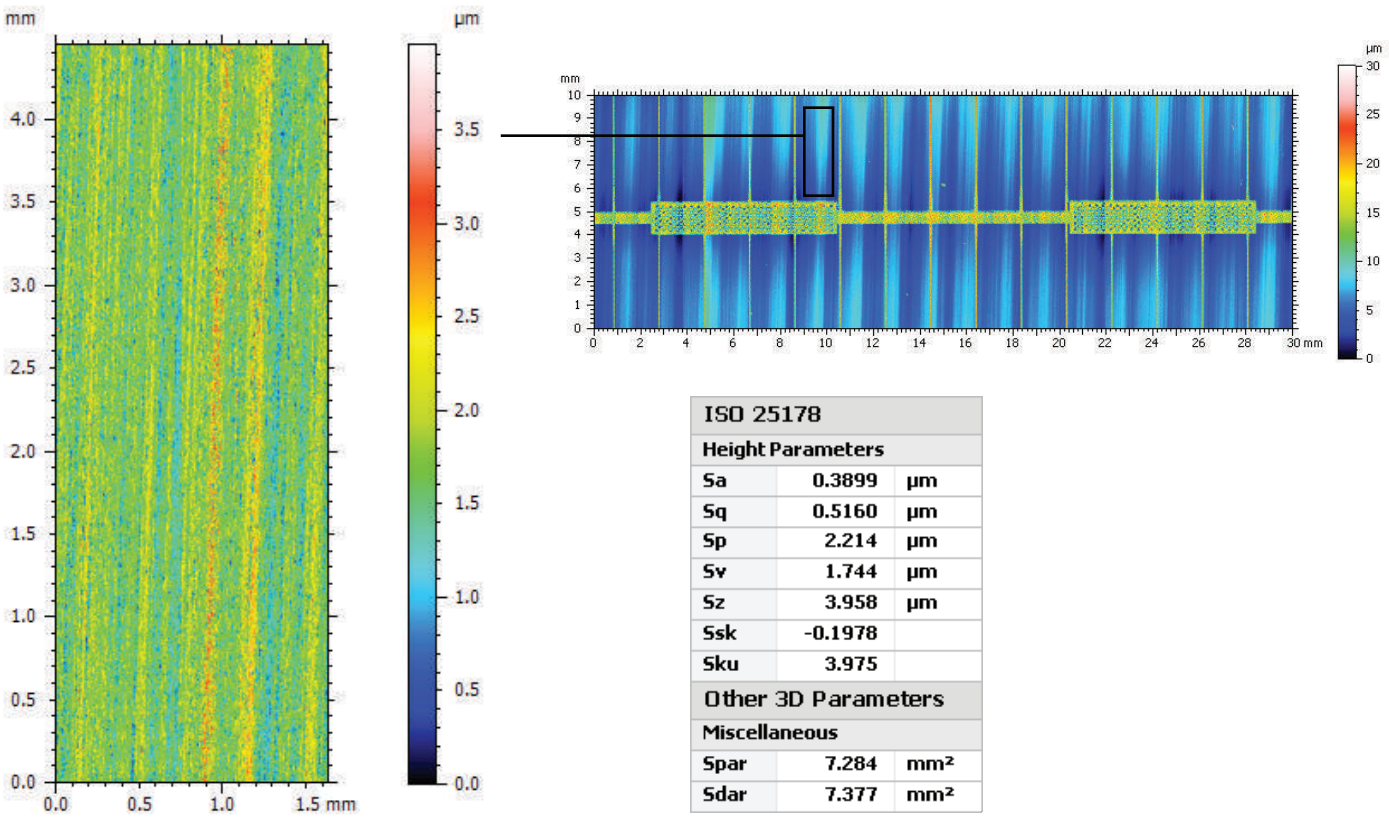


Figure 3: Surface roughness of the first layer of the photovoltaic surface

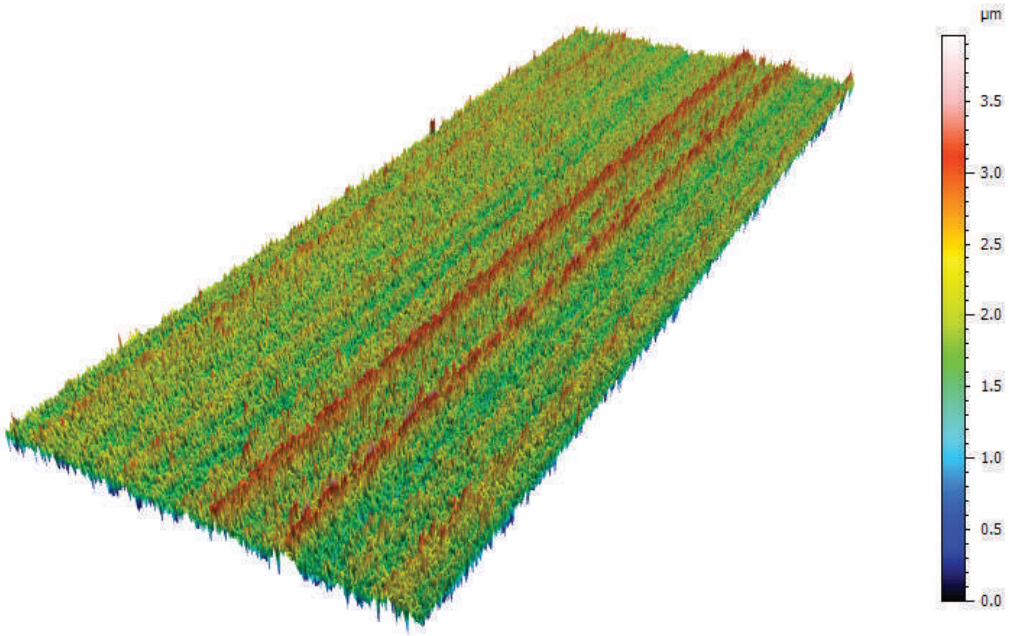
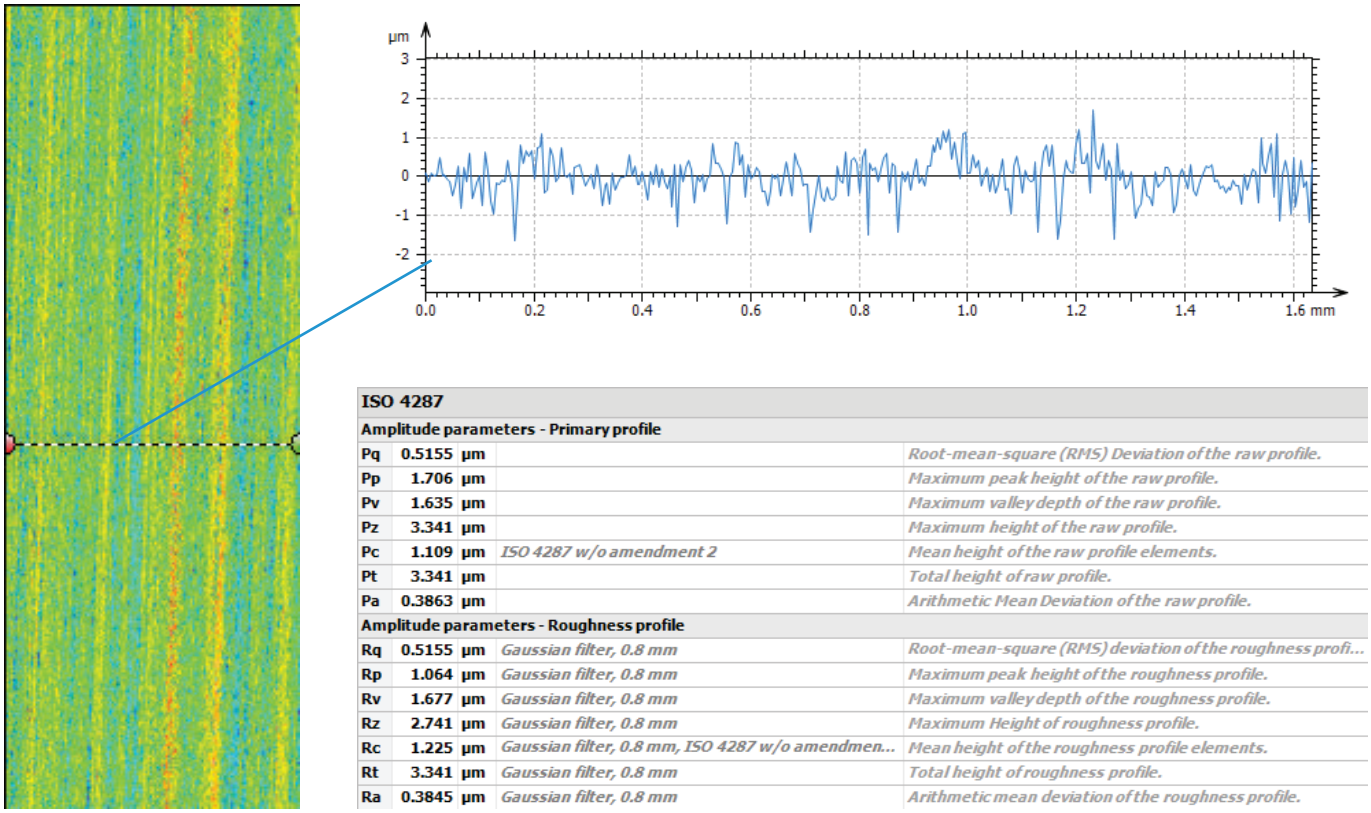


Figure 4: 3D view of the first layer of the photovoltaic surface

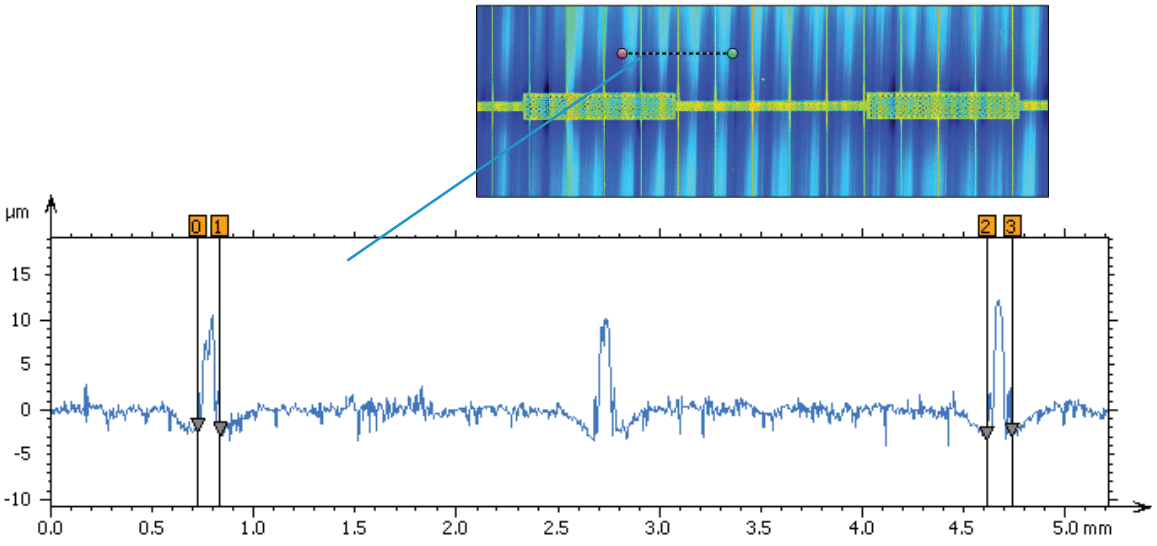
Results and Discussion



ISO 4287			
Amplitude parameters - Primary profile			
Pq	0.5155 µm		*Root-mean-square (RMS) Deviation of the raw profile.*
Pp	1.706 µm		*Maximum peak height of the raw profile.*
Pv	1.635 µm		*Maximum valley depth of the raw profile.*
Pz	3.341 µm		*Maximum height of the raw profile.*
Pc	1.109 µm	*ISO 4287 w/o amendment 2*	*Mean height of the raw profile elements.*
Pt	3.341 µm		*Total height of raw profile.*
Pa	0.3863 µm		*Arithmetic Mean Deviation of the raw profile.*
Amplitude parameters - Roughness profile			
Rq	0.5155 µm	*Gaussian filter, 0.8 mm*	*Root-mean-square (RMS) deviation of the roughness profi...*
Rp	1.064 µm	*Gaussian filter, 0.8 mm*	*Maximum peak height of the roughness profile.*
Rv	1.677 µm	*Gaussian filter, 0.8 mm*	*Maximum valley depth of the roughness profile.*
Rz	2.741 µm	*Gaussian filter, 0.8 mm*	*Maximum Height of roughness profile.*
Rc	1.225 µm	*Gaussian filter, 0.8 mm, ISO 4287 w/o amendmen...*	*Mean height of the roughness profile elements.*
Rt	3.341 µm	*Gaussian filter, 0.8 mm*	*Total height of roughness profile.*
Ra	0.3845 µm	*Gaussian filter, 0.8 mm*	*Arithmetic mean deviation of the roughness profile.*

Figure 5: Profile roughness amplitude parameters of the first layer of the photovoltaic surface

A profile was taken perpendicular to the orientation of the gridlines to measure their geometric characteristics which is shown below. The gridline width, step height, and pitch can be measured for any specific location on the solar cell.



Parameters	Unit	0-1	2-3
Horizontal distance	mm	0.1100	0.1252

Figure 6: Width measurement of the gridline

Results and Discussion

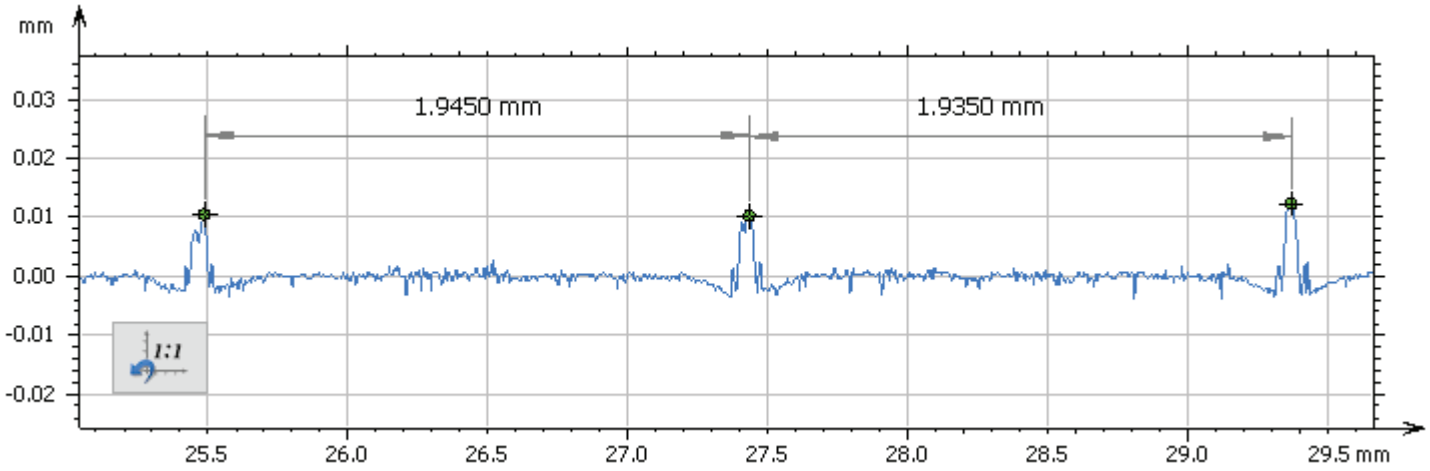
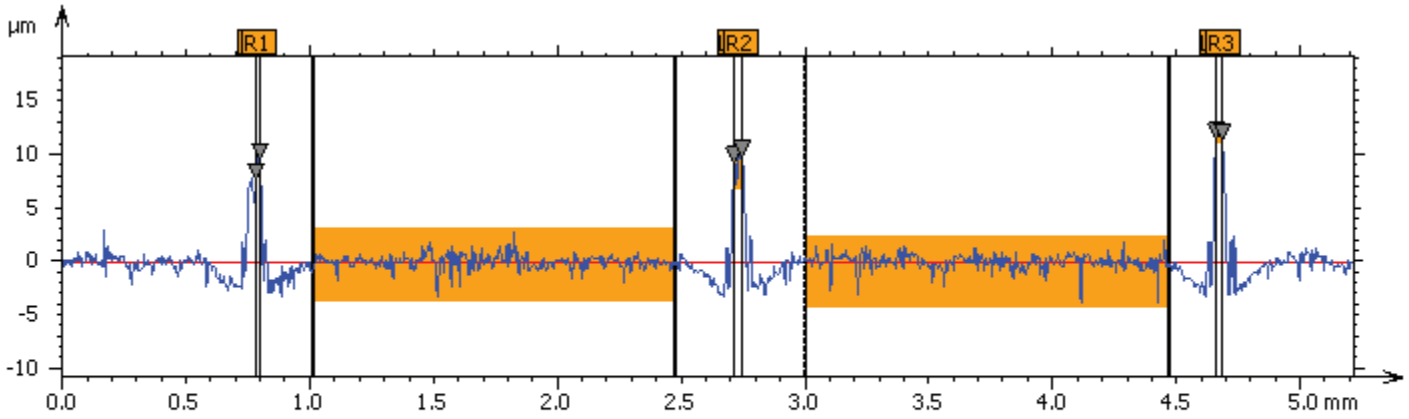


Figure 7: Pitch measurement of the gridline



Parameters	Unit	Step 1	Step 2	Step 3
Maximum height	µm	10.48	10.24	12.30
Mean height	µm	9.130	8.972	11.75

Figure 8: Step height measurement of the gridline

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Conclusion

In this study we were able to display the Nanovea HS2000 Line Sensor's ability to measure a monocrystalline photovoltaic cell's surface roughness and features. With the ability to automate accurate measurements of multiple samples and set pass fail limits, the Nanovea HS2000 Line Sensor is a perfect choice for quality control inspections.

To learn more about Nanovea Profilometer or Lab Services.

Reference

1 Scholtz, Lubomir. Ladanyi, Libor. Mullerova, Jarmila. "Influence of Surface Roughness on Optical Characteristics of Multilayer Solar Cells " Advances in Electrical and Electronic Engineering, vol. 12, no. 6, 2014, pp. 631-638.

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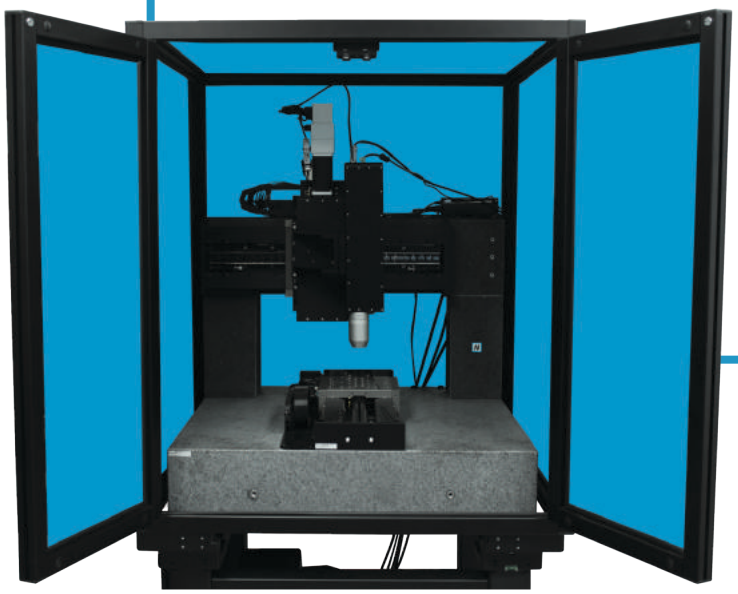
HS2000
Profiler



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