Wafer and Solar Cell Characterization by GT-PVSCAN6000

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Introduction

The PVSCAN is an instrument designed to characterize silicon solar cell materials and devices. It performs a host of measurements that yield spatial maps of dislocation density, grain distribution, reflectance, and photoresponses from near-junction and the bulk of a solar cell. The information it generates helps in both crystal growth and solar cell process design. It provides insight for developing better crystal growth conditions for minimizing defects, establish database on how substrate defects degrade the performance of the electronic devices, and examining the influence of various device fabrication processes on the device performance. It therefore leads to processes that can ameliorate the impact of defects and impurities on device performance. The PV industry recognized the importance of this instrument for solar cell processing development. Therefore, NREL has decided to upgrade the instrument to include commercial features such as large-area scanning capability, high-speed scanning, user-friendly/menu-driven operation, and automated data analysis. More features are now being added to the new version of the software to accommodate the needs of industry.

PVSCAN was available from NREL for many years. Recently, it has been licensed for commercial manufacture to GTSolar, Nashua, NH. PVSCAN6000 has a fully menu-driven operation with many upgraded features suitable for high-speed analyses. These features include:

- Larger scanning area (8 x 8 in. vs. 4 x 4 in.) with a resolution up to 25 μm
- Reduced the scanning time. PSCAN6000 is typically operated at 4 ips. This high-speed reduces the scanning time for most commercial Si solar cells to about 30 min.
- Display of distribution-plots of the measured parameters.

User Requested Capabilities

In addition to these, we have had requests from various users. In response, we are currently implementing several improvements as described below.
Capability of exporting data for all scans as text/csv files of position (X, Y) and intensity (Z) data. The updated software saves an additional set of scan files as text files in the SDMS folder for each scan type. These files can be renamed after the scan is completed.

Figure 1 shows line-scan plots of a defect-etched wafer taken from three different maps (at the same position of the wafer) using data-export capability. The three plots correspond to defect, grain boundary, and reflectance maps. It is seen that defect and reflectance maps have excellent correlation. Furthermore, one can decipher segmentation of intragrain defect density, representative of grains with high and low densities. Also notice the occurrence of grain-boundary signals at the edges of each defect density segmentation.

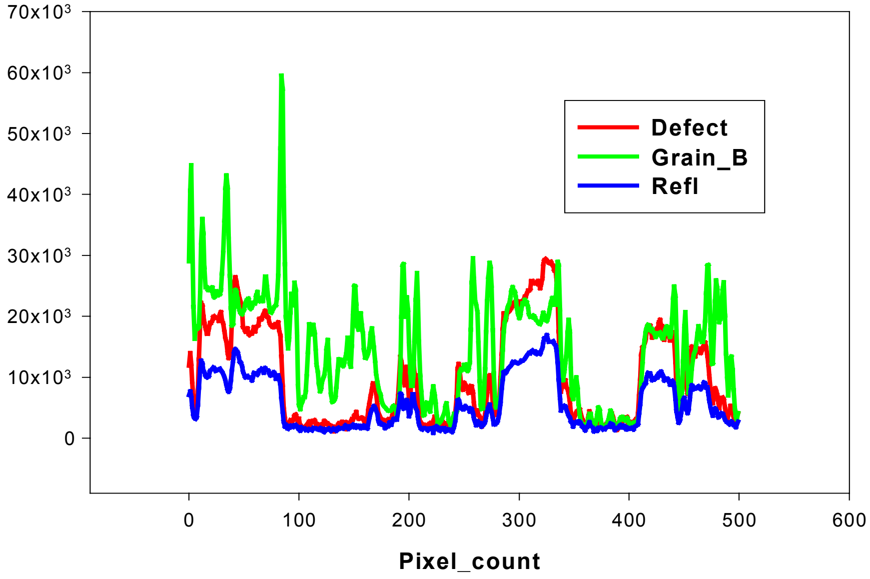


Figure 1. Line scans generated from cvs files of defect, grain boundary and reflectance files. The data are selected from the saved text files that contain data of the entire scan.

The size of the cvs file can be quite large for a large-area sample. To avoid handling excessive amounts of txt-data and save plotting time, we also save a txt file that contains data for one line scan. This line scan is selected to correspond to the central row of data (along Y direction) scan. Figure 2 shows a line scan, transposed to the map via any graphical package, and imposed on a defect map.

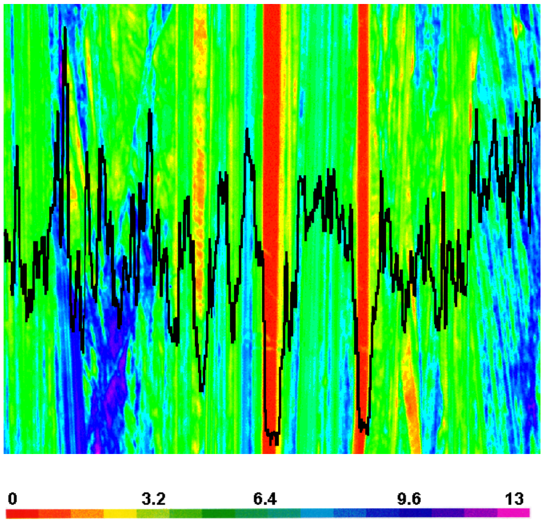
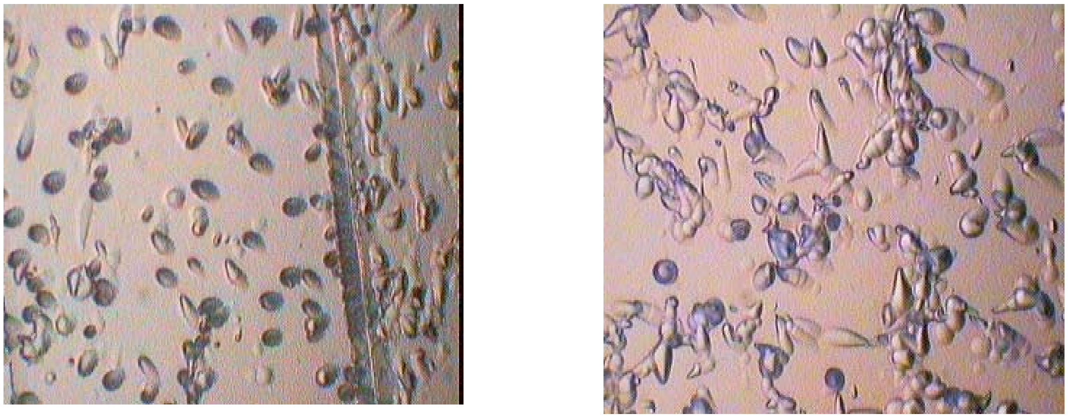


Figure 2. A line-scan superimposed on a defect map. The data for the central line are stored in a file that only saves information for the central row.

One of the recent improvements in the PVSCAN analysis is the ability to make defect maps without chemical-mechanical polishing. We are following two approaches to do this: one is for ribbon samples and the other for wire-sawn samples. For ribbon samples, we have adjusted our etching conditions to provide better defect delineation on striated surfaces of ribbons. Figures 3a and 3b compare etch pits generated on polished and as-grown ribbon samples. For wire-sawn samples, we are trying to identify a polishing chemical etch that can yield a smooth surface.



(a) (b)

Figure 3. Defect delineation on EFG ribbon samples using Sopori etch: (a) sample was polished before defect etching, and (b) as-grown sample.

Because the as-grown surface of ribbons is not smooth, the defect-etched samples result in some extraneous scattering that can produce an error. We have compared average defect density of as-grown and polished samples to determine the error caused by lack of polishing. Figures 4, 5, and 6 show defect maps of three EFG ribbon samples. The sample in Figure 4a was polished and defect-etched, whereas samples in Figure 5a and 6a were only defect-etched. The defect distributions corresponding to Figures 4a, 5a, and 6a are shown in Figure 4b, 5b, and 6b. The average density of defects for samples of Figures 4, 5, and 6 are: 5.82 cm^{-2}, 6.65 cm^{-2}, and 4.77 cm^{-2}, respectively. Considering these numbers, there appears to be insignificant error resulting from a lack of polishing.

Higher sensitivity is needed for reflectance mapping so that low-reflectance, AR-coated cells can be mapped. In response to this, we have developed a new procedure for reflectance mapping that will enable mapping of total reflectance or as three different reflectance components, i.e., specular, near-specular, and diffuse component, either individually or in any combination.

SUMMARY

PVSCAN is now commercially available from GT Solar. It has many upgraded capabilities, such as ease of data handling and export, less sample preparation for defect mapping, separation of reflectance into specular, near-specular, and diffuse components, and higher sensitivity for reflectance to accommodate very low-reflectance AR coatings.

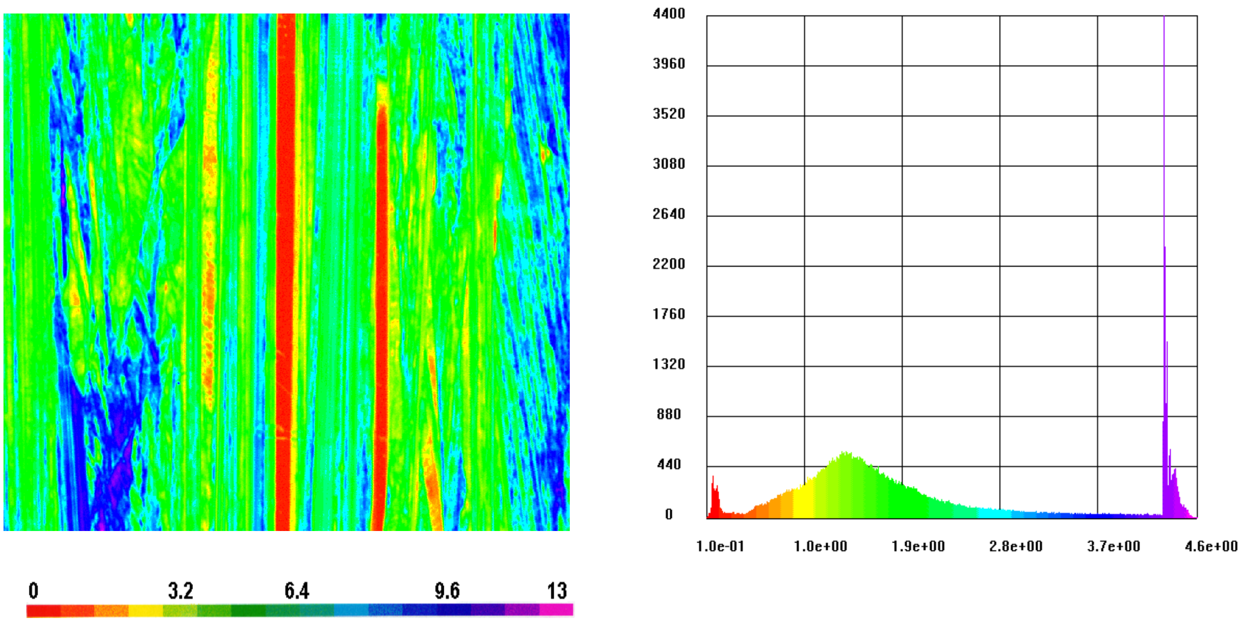
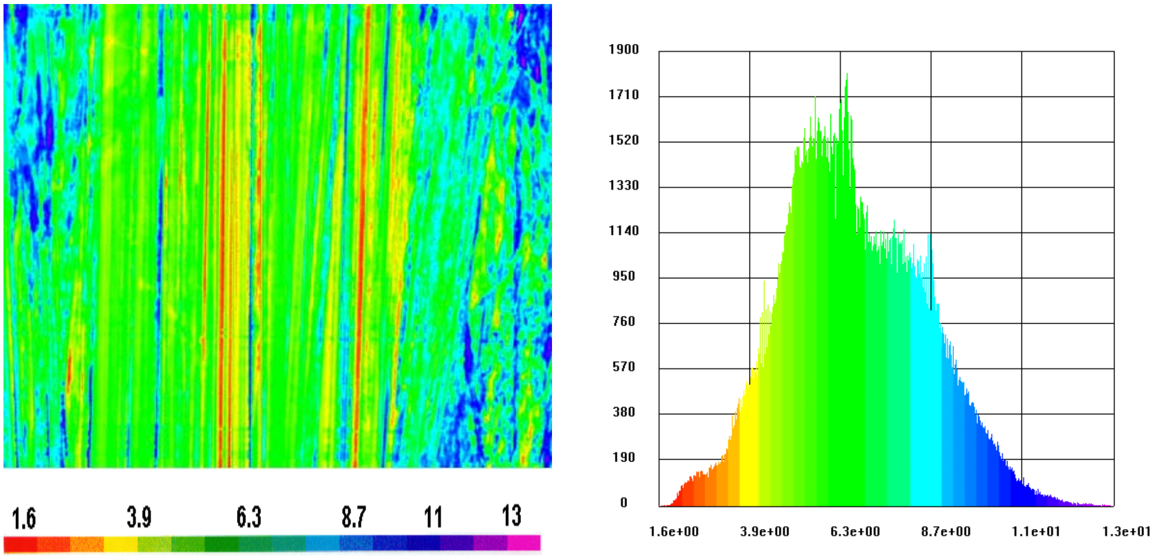


Figure 4. Defect map (a) and defect distribution (b) of a polished sample ribbon sample. Average defect density = 5.82 cm^{-2}. Scan area = 3.5 x 3 in.



(a)

(b)

Figure 5. Defect map (a) and defect distribution (b), of an unpolished ribbon sample Ave defect density = 6.65 cm^{-2}. Scan area = 3.5 x 3 in.

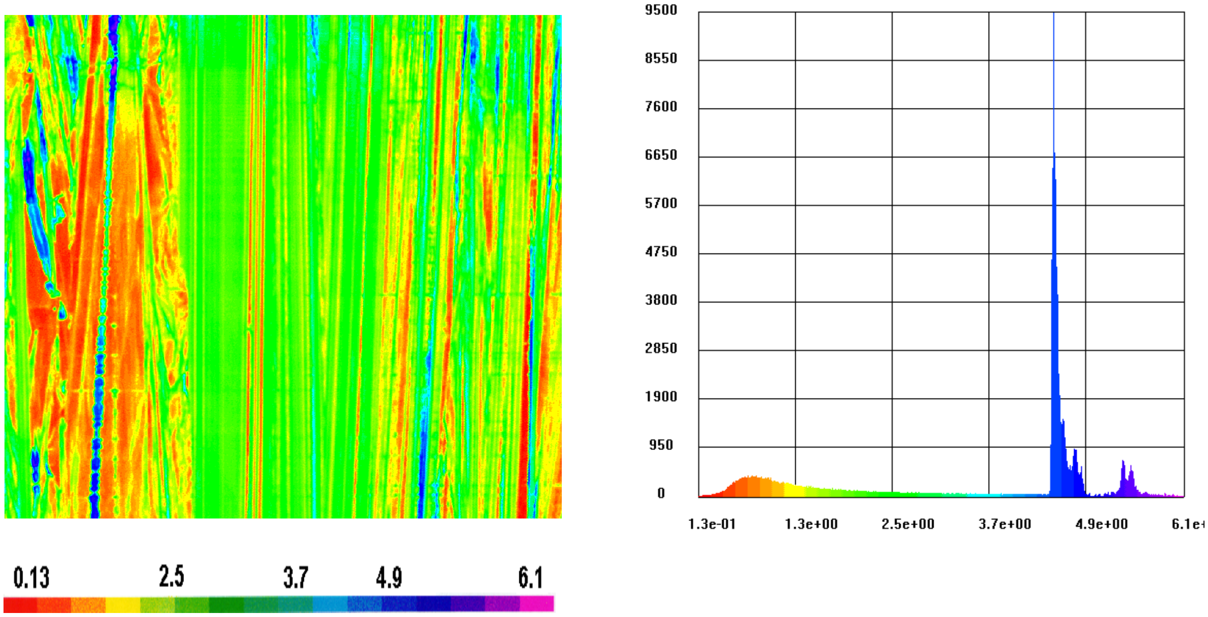


Figure 6. Defect map (a) and defect distribution (b) of an unpolished ribbon sample. Average defect density = 4.77 cm^{-2}. Scan area = 3.5 x 3 in.