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# Identification and classification of contaminations on wafers using hyperspectral imaging

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**Abstract**

We present a new characterization technique based on hyperspectral imaging applied to silicon wafers. It combines the measurement of spatially and spectrally resolved reflection features and a dedicated subsequent data analysis. This method allows for a rapid localization and classification of defects and contaminations on wafers. Thus, it complements standard imaging techniques such as infra-red or luminescence imaging. In our work, we show that hyperspectral imaging is capable of separating clean and contaminated regions including a classification of the contamination type and a quantification of the coverage.


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*Keywords:* hyperspectral imaging; quality control; silicon wafer

## 1. Motivation and introduction

A number of imaging techniques have been established both in research and development and in quality control in the photovoltaic industry. These methods include optical and infrared imaging as well as luminescence imaging such as photo-luminescence (PL) and lock-in-thermography (LIT). Another common approach is to apply scanning methods based on local measurements, for example measuring the light beam induced currents (LBIC) on solar cells. Typically, in all of these cases, very limited information is available on the spectral properties of the signal. On the other hand, a number of spectrally resolved methods have been established such as quantum efficiency, reflection, or

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spectral luminescence measurements. In almost all cases, these techniques provide no or very limited spatial information. In order to gain this additional spatial information for the spectrally resolved methods, a multiple measurement at individual spots on the sample is necessary which significantly increases the measurement time.

In contrast to these established characterization methods, hyper-spectral imaging yields both spatial and spectral information with high resolution and in short time. While this approach is widely used in other fields such as remote sensing or quality control, its applications in the PV-industry are very limited. Recently, there have been studies on the identification of defects in solar cells [1], the local electrical properties of solar cells [2], the analysis of spectrally and spatially resolved luminescence imaging of wafers [3], the mapping of local wafer properties [4] and solar cell saturation currents [5], and the Fermi level splitting [6]. Quite generally, hyperspectral imaging provides two major advantages: i) a high number of sample positions is spectrally characterized yielding enough data points for a statistical analysis in a short time; ii) the spectral foot-print of a certain defect or contamination needs not to be known in detail as it can be extracted from the data. On the other hand, this approach using a large amount of simultaneously collected data requires dedicated numerical data analysis algorithms which allow for a fast extraction of the relevant information.

In our work, we show how hyperspectral imaging can be employed to localize and classify contaminations on wafers. In contrast to other methods, such as a chemical analysis, our approach is non-destructive, locally resolved, and allows measurement times in the range of a few seconds. The interpretation of the measured data does not rely on a detailed analysis of individual spectral properties but rather on a self-adjusting numerical algorithm which consists of an initial training phase and a subsequent application phase. Hence, it is a promising candidate for an implementation as a quality control tool in a production environment.

## 2. Experimental setup and data analysis

### *2.1. Sample preparation and experimental setup*

We have prepared silicon wafers by applying an intentional contamination on two parts of the wafers. While one region has been subject to organic contaminations the other one has been treated with a solution containing inorganic elements. An optical image as well as a photoluminescence image is shown in Figure 1. It can be observed that these methods do not allow for a distinction of the two different types of contaminations. In particular, a process optimization which requires the reduction of one of the two contamination types only would not be possible.

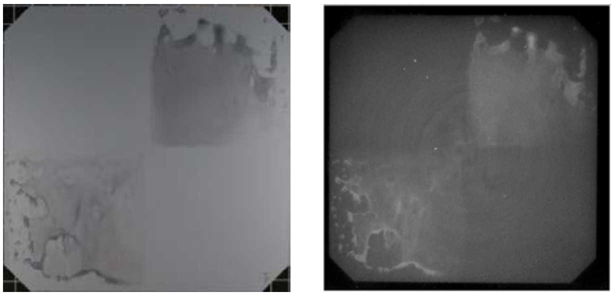

Fig. 1: Optical and photoluminescence imaging of the wafer: While the upper right corner has been subject to an organic contamination the lower left corner shows the inorganic contaminations. Neither imaging technique provides a mean of classifying the contamination type.

After the initial inspection, a hyperspectral image using a short-wave infrared (SWIR) camera (HySpex SWIR-384, Norsk Elektro Optikk A/S) has been measured. This camera provides a spectral range from 1000nm to 2500nm with a spectral resolution of about 5nm. The spatial resolution has been about 0.5mm. The measurement time for a single image is in the range of a few seconds. As a result, a three-dimensional data set with two spatial and one spectral dimension is obtained. Due to the spatial and spectral resolution, the size of the data set is about 320x320x300 data points. Each wafer was recorded together with a common optical Polytetrafluoroethylene (PTFE, SphereOptics) calibration standard in order to obtain relative reflectance measurements.