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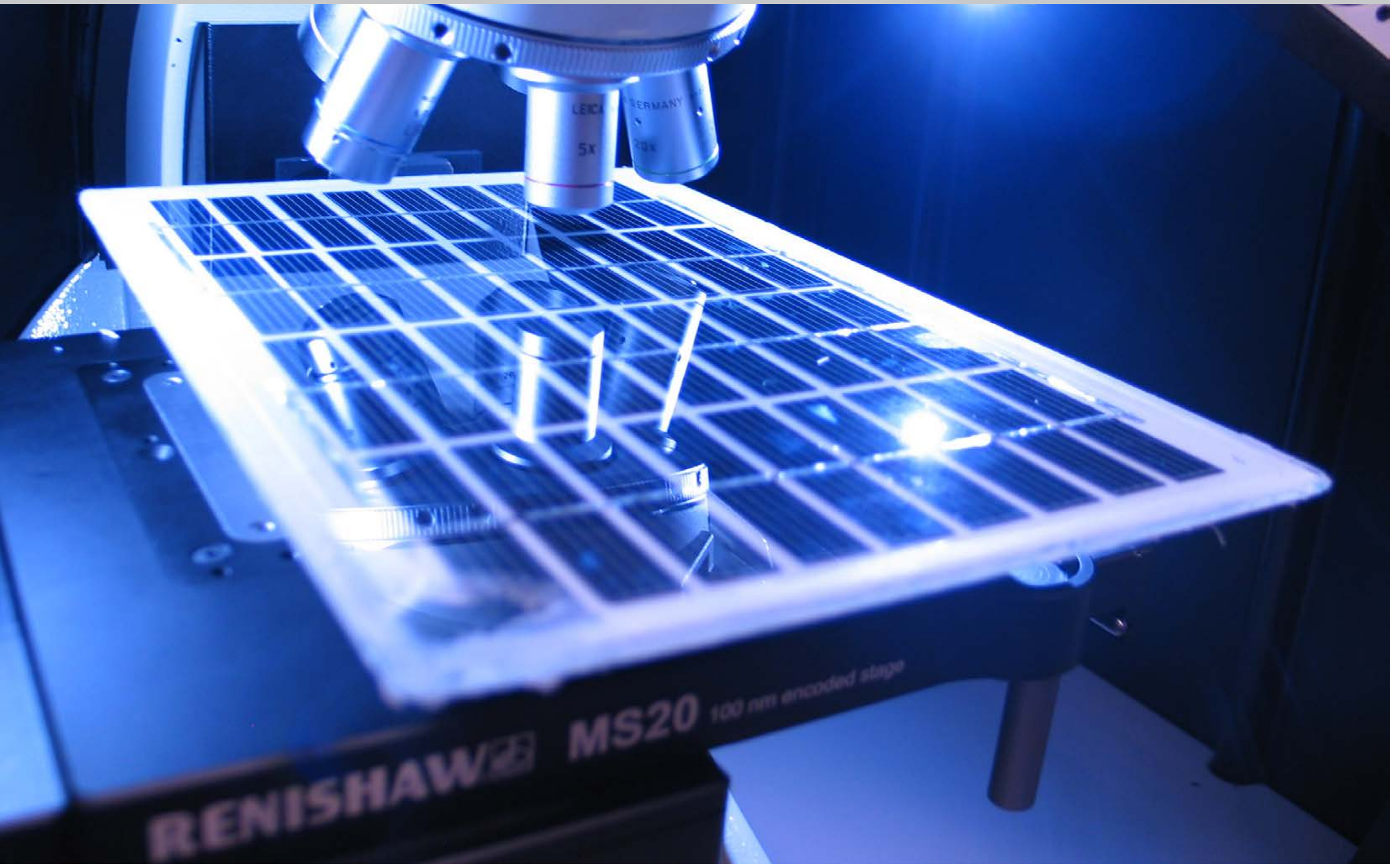
Photocurrent measurements on the inVia™ confocal Raman microscope



Introduction

When light interacts with semiconducting materials it can induce electrical currents ('photocurrents'). These currents carry information about the electronic, optical, and charge transport properties of the material. This information is complementary to that obtainable from Raman scattering, which can identify physical changes in the material properties.

You can equip your inVia confocal Raman microscope to measure and map photocurrents generated from the incident laser lighting and correlate the data with Raman information. This enables you to relate variations in photocurrent to changes in material properties. For example, current changes could be related to changes in strain, doping or crystal structure as determined from the Raman data.

This capability is particularly relevant to research on photovoltaics, perovskites, and 2D materials.

Photocurrent measurements using the inVia Raman microscope

Adding the photocurrent measuring capability to your inVia Raman microscope requires the addition of an external interface unit and trigger module which synchronise and measure the photocurrents via electrical connections on the semiconductor device. The interface unit feeds the current data to the computer running the inVia Raman microscope via USB.

Renishaw has fully integrated the external input into its WiRE™ software that controls the inVia Raman microscope. This enables the simultaneous collection of photocurrent and Raman data during both point and mapping measurements. In the latter, the motorised stage rasters the sample under the microscope and gathers both Raman and photocurrent data concurrently. You can then display the data as overlaid Raman, white light, and photocurrent images.

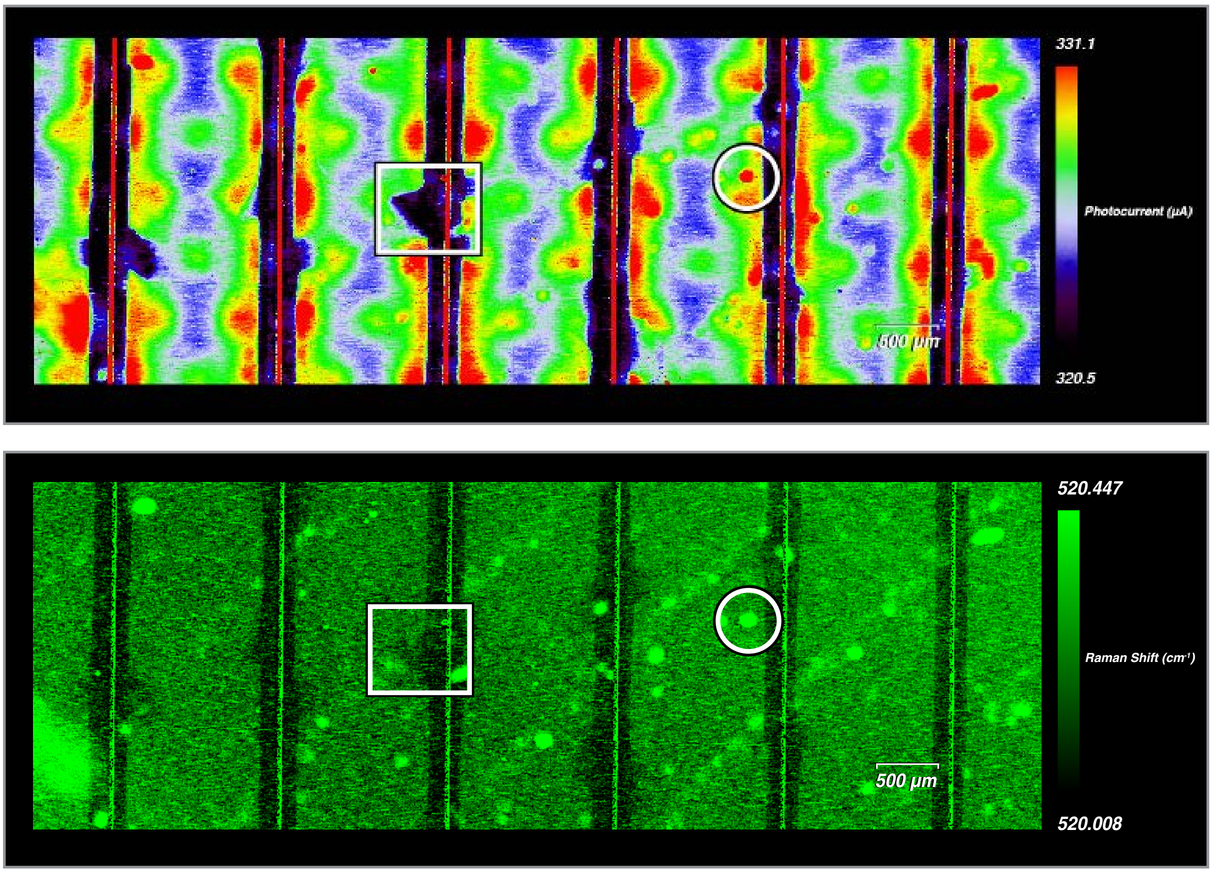


Figure 1. Photocurrent (top) and Raman band position (bottom) maps of an encapsulated silicon solar panel

The inVia Raman microscope rapidly generates Raman data, at over 1000 measurements per second, using its StreamHR™ Rapide fast acquisition mode. Photocurrent mapping is compatible with the LiveTrack™ focus-tracking of the inVia Qontor® system, so you can map not only flat, but also rough and uneven surfaces.

Example: PERC (passivated emitter and rear cell) silicon solar cell defect mapping

In this first example, we examined a single crystal silicon solar cell. Some regions gave lower photocurrents, indicating poor device performance (figure. 2). This corresponds to features on the image of Raman peak position (figure. 3), which shows that there is a corresponding downshift in peak position, when compared with the bulk. This is caused by local tensile strain.

It is likely that a change in local phosphorus dopant levels has caused this problem, resulting from an undesirable variation in the 'selective emitter' process used to manufacture PERC-type solar cells.

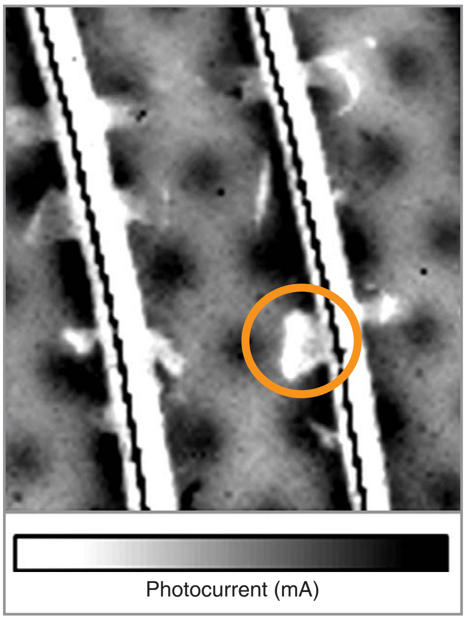


Figure 2. PERC photocurrent map

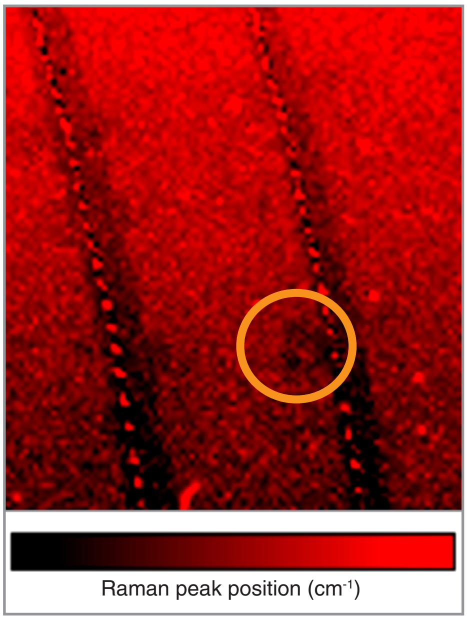


Figure 3. PERC Raman peak position map

Polycrystalline silicon solar cell response measurements

You can also use the system to measure the photocurrent response of materials, as a function of excitation wavelength.

We studied a polycrystalline silicon solar cell by illumining it with a super-continuum white light laser. This laser emits across a broad spectrum from 420 nm to 820 nm. We used filters (bandpass < 10 nm) to illuminate the sample sequentially with a narrow range of wavelengths and measured the response of the photocurrent as a function of wavelength.

The photo response (Fig. 4) is related to the quantum efficiency of the cell. It has a reduction in induced photocurrent at the blue end of the spectrum (420 nm to 500 nm). This is caused by absorption of the light by the cell's encapsulating material.

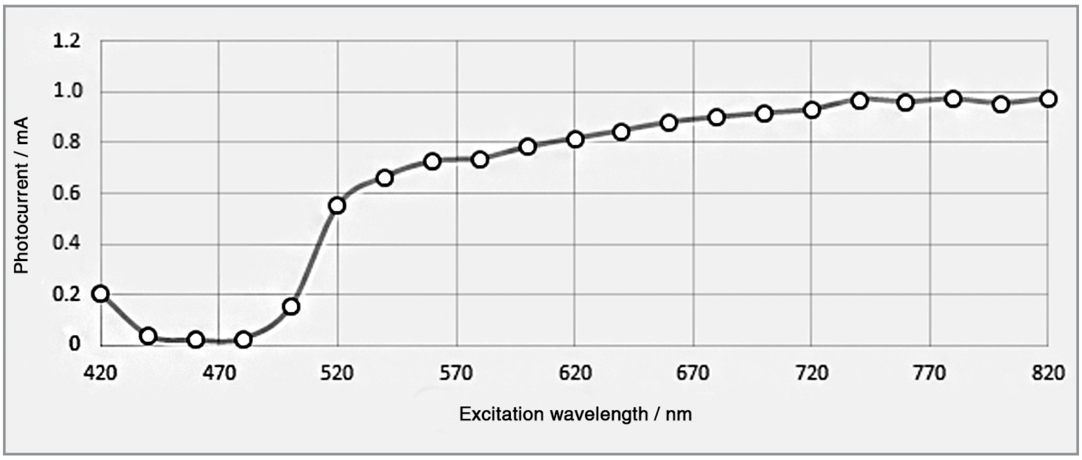


Figure 4. Graph of photocurrent produced by a polycrystalline solar cell versus the wavelength of light used to excite it

Polycrystalline solar cell defect mapping

We mapped, using both photocurrent and Raman data, a polycrystalline solar cell and analysed the Raman data to produce images of intensity and peak position.

The photocurrent image (Fig. 5) has a series of diagonal streaks of lower photocurrent running from bottom left to top right.

The Raman intensity (Fig. 6) shows changes correlated to these streaks. This change in intensity is caused by different orientations of silicon domains. Here the different orientations are shown in white, black, bright blue and dark blue.

The Raman peak position image (Fig. 7) has identical streaks on the edges of the crystal domains. From this combined information, we can see that the regions of lower photocurrent correspond to lower crystal quality material at the boundary of the domains with different orientations. This may be caused by variations in strain or doping.

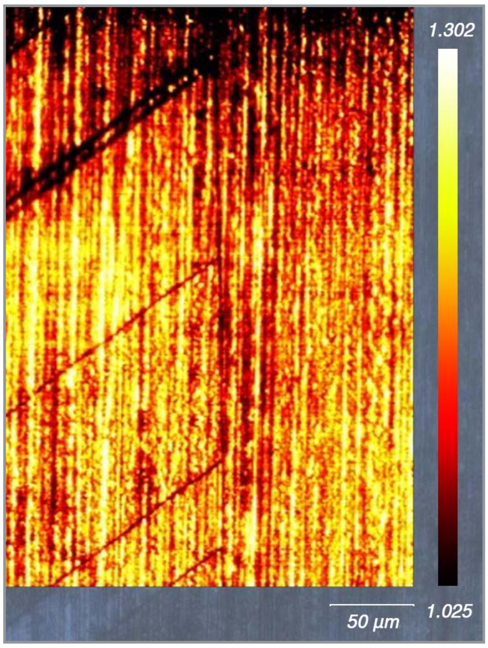


Figure 5. Photocurrent map of a polycrystalline solar cell

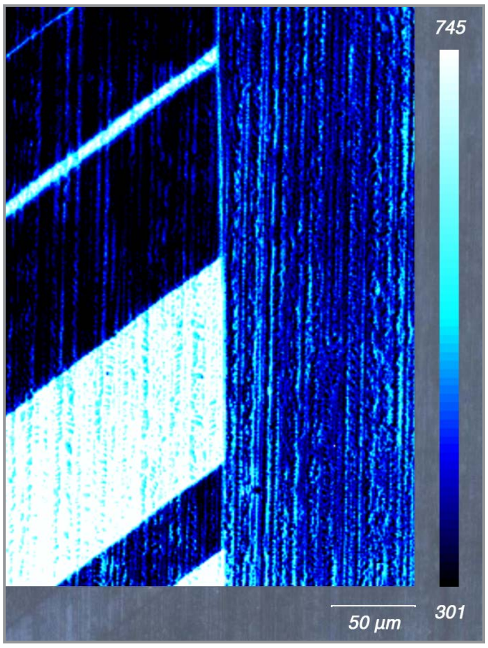


Figure 6. Raman intensity map of a polycrystalline solar cell

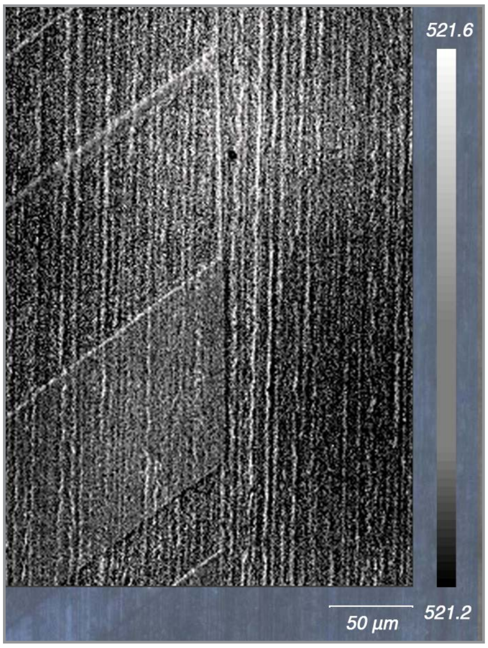


Figure 7. Raman peak position map of a polycrystalline solar cell

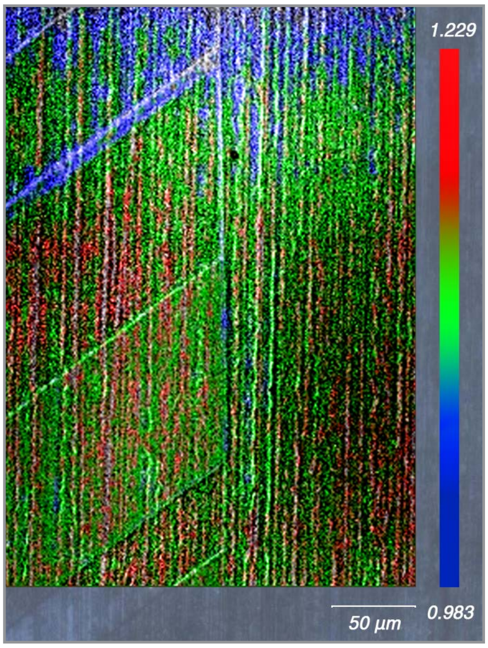


Figure 8. Photocurrent map split into high (red), medium (green) and low (blue) domains of photocurrent intensity, overlayed upon the peak position map

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Photocurrents and the inVia confocal Raman microscope

The inVia Raman microscope is highly customisable: you can easily equip it with modules to add additional capabilities. As illustrated in this study, the addition of photocurrent measuring makes the inVia Raman microscope an excellent tool for studying semiconductor materials.

Feature	Specification
Analogue-to-digital converter resolution	16 bit
Data read rate	up to 15 million/second
Maximum sample rate	200k samples/s
Nominal input (unipolar)	0 mA to 20 mA
Nominal input (bipolar)	±20 mA

Renishaw. The Raman innovators

Renishaw manufactures a wide range of high performance optical spectroscopy products, including confocal Raman microscopes with high speed chemical imaging technology, dedicated Raman analysers, interfaces for scanning electron and atomic force microscopes, solid state lasers for spectroscopy and state-of-the-art cooled CCD detectors.

Offering the highest levels of performance, sensitivity and reliability across a diverse range of fields and applications, the instruments are designed to meet your needs, so you can tackle even the most challenging analytical problems with confidence.

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