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Analyzing Solar Cell Material Properties with Confocal Raman Imaging

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Energy generation using photovoltaic devices is regarded as an important component in overcoming future energy shortages. This is reflected in a dramatic increase in photovoltaic production and demand. In the research and development of photovoltaic devices, the primary goals are to increase the conversion efficiency of the solar cells and to improve the production process. For these studies, a detailed knowledge of the micro- and nanostructures along with the chemical properties is essential for further improvements. A valuable tool for these investigations is Confocal Raman imaging, as it not only reveals optical information but also information regarding the 3D distribution of the chemical compounds, crystallinity and material stress. The aim of this contribution is to show how confocal Raman imaging can contribute to the analysis of the stress field around laser drilled holes in Si solar cell.

In a typical Si solar cell the contacts for discharging are located on top of the p- and n-doped material and block off a part of the sunlight, thus lowering the efficiency of the device. To increase the efficiency of these solar cells, holes need to be drilled through the cells in order to allow the contacts to be located at the bottom. These holes are typically drilled with lasers and can induce strain in the Si around the holes, which in turn lowers the efficiency of the solar cell. Various processing methods of minimizing the stress around drill holes will be presented. The following example shows how an etching with KOH after the drilling process influences the stress field. Fig. 1a shows a video image of the edge of a drill hole in a Si solar cell together with a typical scan area (red box) for confocal Raman imaging. In confocal Raman imaging, 2D arrays of Raman spectra are acquired. By evaluating spectral features such as peak intensity, peak position, etc, various Raman images can be extracted from the 2D spectral array, representing either the quantitative chemical distribution of material on the examined sample area or physical material properties. Fig. 1b sows the variation of the integrated intensity of the first order Si peak in the vicinity of a drill-hole. These intensity variations result from cracks of Si on the surface of the wafer, which are mostly not visible in optical images. The precise position of the first order Si peak reveals information about the stress state of Si. For each image, this peak was fitted using a Lorenzian curve and the exact peak position was then evaluated. An example of the stress field in the vicinity of a drill hole is shown in Fig. 2a. From such images, cross sections as shown in Fig. 2a were extracted and plotted as relative peak position vs. distance (note that the starting point relative to the edge of the hole varies for each line). Fig. 2b shows the results obtained from the samples processed with full laser drilling power and the different etching processes applied to the samples are indicated by colors. This graph clearly shows that the samples which had not been etched as well as the sample which had been etched for only one minute show a clear drop of the peak position before reaching the edge of the drill-hole. Already after two minutes etching, the stress filed around the drill-holes can be clearly reduced.

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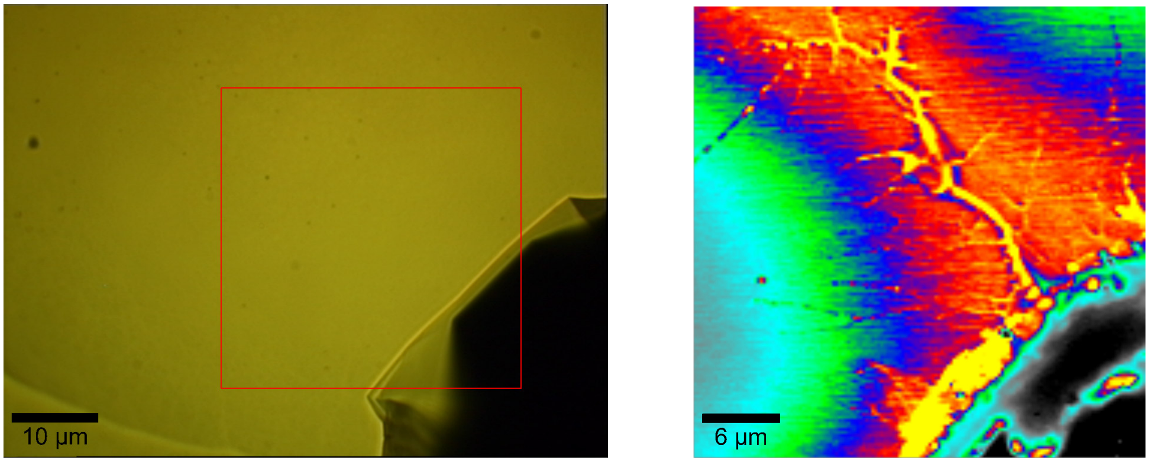

FIG. 1. (a) Video image of the edge of a laser drill-hole in a silicon solar cell. The scan area is marked with a red box. (b) Integrated intensity of the first order Si peak revealing a crack in the vicinity of a drill-hole on the Si surface. The laser drill-hole is at the bottom right.

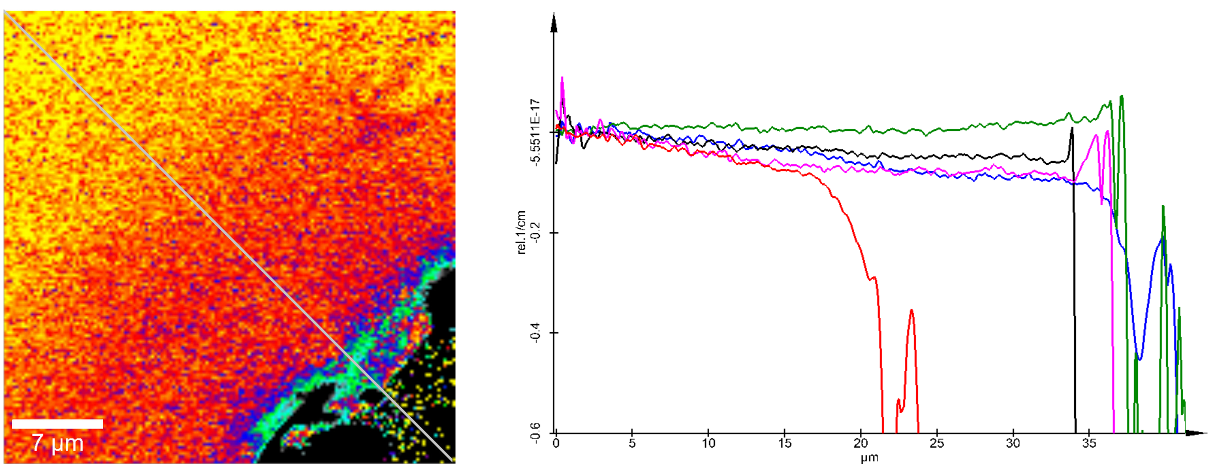

FIG. 2. (a) Typical stress image of the Si from the outside to the laser drill-hole (bottom right). Along the indicated cross section (gray line), the radial change of the stress field was evaluated.
(b) The cross sections of the various samples drilled with 100% laser power: no etching (red), 1 min etching (blue), 2 min etching (green), 4 min etching (black), 6 min etching (magenta).

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