

Raman Microspectroscopy of Thin Film Silicon for the Application in Solar Cells

F. Köhler, S. Muthmann, Forschungszentrum Jülich (May 2010)

Application Note

Introduction

The Institute of Energy Research 5 (Photovoltaics) at the Forschungszentrum Jülich is working on the development and improvement of thin film silicon solar cells. Such solar cells make use of two different kinds of silicon material, namely purely amorphous (disordered) silicon and so-called microcrystalline silicon which is a mixture of a crystalline phase and an amorphous phase. Raman spectroscopy is one important technique for the characterisation of the microstructure composition as the Raman spectra of the amorphous and microcrystalline phase can be easily distinguished and semi-quantitatively evaluated. This is important, because different structural phases show a significantly different behaviour in the electronic properties and hence in the efficiency of a solar cell. Using a set-up with a microscope spatial inhomogeneities can be probed down to μm lateral resolution.

Due to the small scattering cross section of silicon the intensity of the Raman scattered light is typically eleven orders of magnitude lower than that of the exciting laser beam. Often the power of the excitation light has to be reduced to avoid detrimental heating of the thin film samples. So, it is necessary to use an optimized optical setup with a CCD detector providing high quantum efficiency, high flexibility as well as an excellent signal to noise ratio.

Experimental Setup

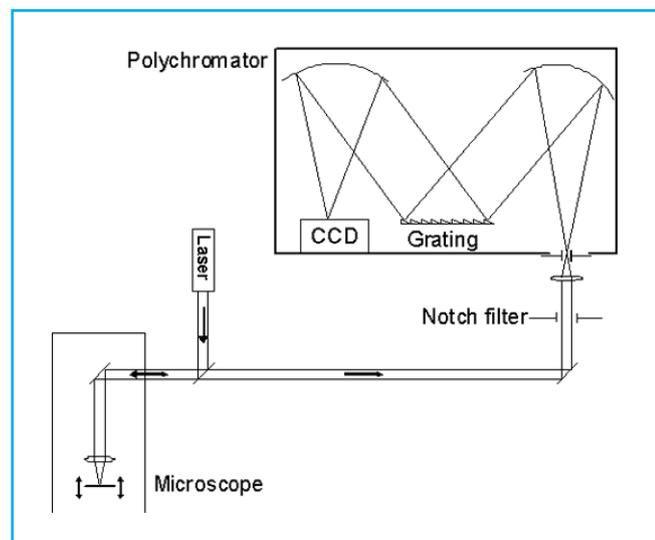


Figure 1: Schematic view of the Raman microscopy setup

We are using an argon-ion laser (488 nm, 330 μW) as excitation source. The laser beam is focussed within an Olympus BX 51 microscope (magnification = 50, NA = 0.9) on the probed sample, leading to a spot size of around 2 μm . The scattered light is collected with the same lens passing a notch filter to block the excitation wavelength and is guided into a Horiba

Spex 270 m polychromator with a 2400 l/mm grating. There it is detected with the Andor back illuminated CCD detector iDus DU420A-BU (see Figure 1). In this configuration, the spot on the CCD illuminates only around ten pixel rows. The flexibility of the camera, in our case the binning of the pixel of interest is used to obtain a better signal to noise ratio.

Results

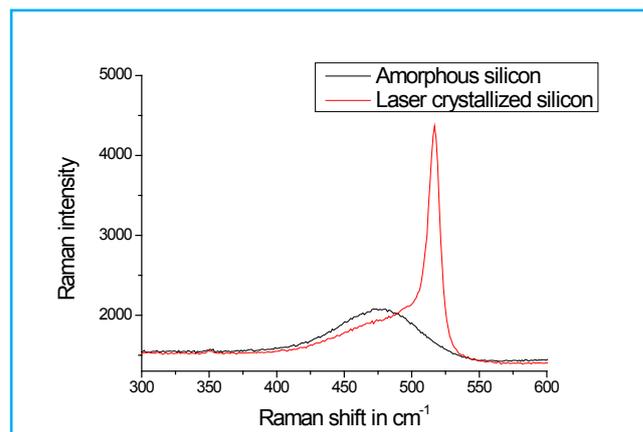


Figure 2: Raman spectra of amorphous (black line) and microcrystalline silicon (red line) in the range of 300 cm^{-1} to 600 cm^{-1}

In Figure 2, we see two spectra of a thin film silicon sample to demonstrate the difference in the Raman-spectrum of amorphous and microcrystalline silicon. The integration time was 30 s, adding up 5 accumulations. The first one was taken of an as deposited sample (black line). A broad peak is visible at 480 cm^{-1} , that is typical of amorphous silicon. The second spectrum was taken at the very same position after a laser illumination of 2 mW for a few seconds (red line). A sharp peak arises at around 520 cm^{-1} which is characteristic for the presence of a crystalline phase. This means that the heat dissipated in the sample through illumination with 2 mW resulted in the formation of a crystalline phase [1].

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However, there is still a visible signal in the amorphous region around 480 cm^{-1} , indicating that the crystallization did not take place completely within the measured spot size. Due to the good signal, a deconvolution into an amorphous and a microcrystalline part is easily possible. This leads here to a quantitative estimation of the crystalline volume fraction of around 54% [2] after the high intensity illumination (deconvolution is not shown).

Without the good performance of this camera, these clear signals could not have been obtained within such a short time. Furthermore, the thermoelectric cooling and the possibility of an additional water cooling spares the cost demanding use of liquid nitrogen to achieve the reduction of dark current necessary for the detection of the weak signals.

References

- [1] Carius R, Wohllebe A, Houben L, Wagner H, Physica Status Solidi A, Vol. 166, 635-641(1998)
- [2] L. Houben, M. Luysberg, P. Hapke, R. Carius, F. Finger, H. Wagner, Philosophical Magazine A, 1447-1460(1998)

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