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Novel PV device characterisation using biased photothermal deflection spectroscopy

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The development of new photovoltaic (PV) materials and cell structures requires detailed optical and electrical characterisation. Although a multitude of characterisation methods are presently used, data are often inconclusive and some properties remain difficult to measure. This is particularly true for materials and cells that are based on thin films: thinner layers interact weakly with light, making optical measurements challenging.

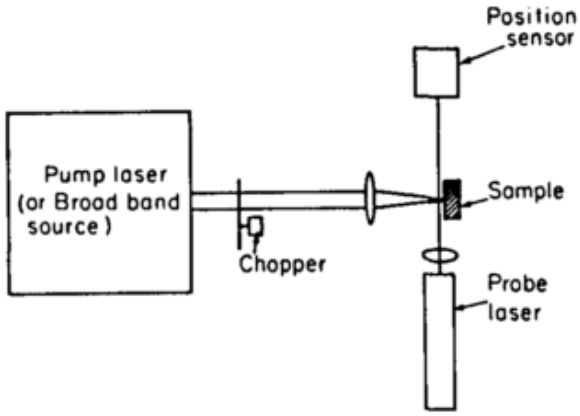
Ultra-sensitive characterisation methods that are especially suited to thin films have long been described in the literature. Unfortunately, most of these techniques are not commercially available and thus are not widely used. One example is photothermal deflection spectroscopy (PDS), one of the few methods available to directly measure the nonradiative recombination of excess carriers.

In this paper we report on our effort to develop a commercially-available PDS instrument and propose extensions of the technique to make it more useful for researchers. In particular, optical or electrical biasing during the measurement allows the excess carrier concentration in the material to be controlled, indirectly influencing the Fermi level and occupation of defects within the material. The effect on the absorption spectrum can then be observed with high sensitivity. Biased PDS has previously been investigated for PV devices [1–3] and photoelectrochemical cells [4] but here we demonstrate new directions for PV characterisation with the technique.

Setup and Methodology

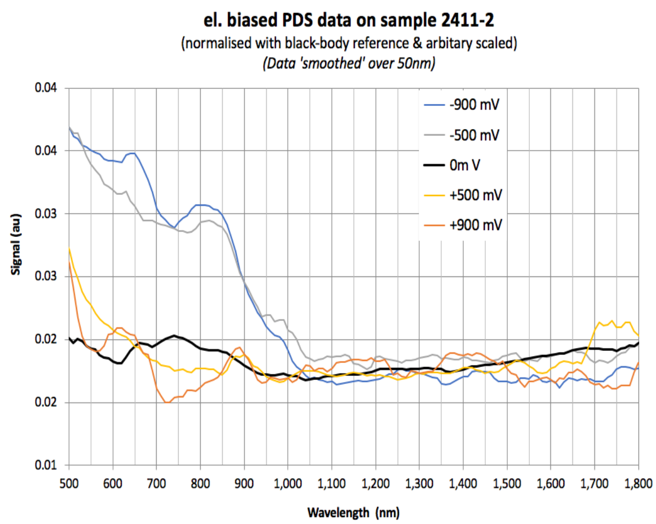
A prototype of our PDS setup is shown in the block diagram in Figure-1, taken from [5]. The pump beam from the monochromator is normally incident on the sample and the probe beam from a laser source passes parallel to the sample surface, near grazing incidence but not actually encountering the sample. The pump beam wavelength is scanned from 400 nm to 2000 nm to examine a range of energy levels in the material. The deflections in the probe beam (the PDS signal) due to thermal fluctuations near the sample surface are captured for each wavelength using a position detector. These thermal fluctuations result from nonradiative recombination in the material. The PDS signal is connected to a lock-in amplifier to increase the signal-to-noise ratio of the results. The pyro detector and the reference detector normalise the PDS signal with the input power.

The sample was electrically biased with a DC power source (not shown).



Results

A preliminary measurement on our experimental PDS setup is shown below. The tested cell was a III-V quantum well structure. The response of the PDS signal at various electrical DC bias voltages is shown. The electrically active band-gap regions are clearly indicated by the signal separation below 1000 nm. The main impact, as expected, is in the above band-gap regions which mainly contribute to the conduction mechanisms in the device. Further interpretation requires data with a better s/n ratio, on which we are working currently.



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