# Characterization of Nanoscopic Solar Cells

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Novel solar cell architectures are attracting increasing interest. In particular, various dye-sensitized cells[1] or polymer blend-based cells[2] demonstrate the possibility of attaining both, high power conversion efficiency and low production costs. A further development involves nano-structured solar cells comprising for example vertically aligned arrays of ZnO[3], $TiO_2$[4], Si[5] nanowires, or $TiO_2$ functionalized CNTs[6]. These arrays combine a high surface area with improved electron and hole transport characteristics. The achieved cell performance depends strongly on the material combination and the quality of the interfaces. Especially the interface between the sensitizer and the electrodes is crucial. Thus, gaining a thorough understanding of the charge separation and photocurrent generation mechanisms at these interfaces is a highly relevant goal. Here, we address this task by investigating nanoscopic solar cells, which differ from their bulk counterparts by the lateral alignment of all components on a substrate. While this configuration reduces the light harvesting efficiency, such nanoscale devices represent flexible and versatile test systems. Specifically, their spatially resolved photocurrent response enables a detailed study of the charge separation processes at each of the involved interfaces. It thus becomes possibly to identify the factors that limit the photo-conversion efficiency, in contrast to bulk cells, in which case only the net current is directly accessible. In the present work, we describe spatially resolved photocurrents in prototype nanoscale photovoltaic devices comprised of a carbon nanostructure (i.e., an individual graphene sheet) and an II-VI semiconductor nanostructure (i.e., an individual CdS nanowire).

## Methods and Device Architecture

The nanoscopic solar cells were studied by scanning photocurrent microscopy (SPCM), wherein a focused laser spot (with $\lambda_{exc}$ = 488 nm in the present experiments) is scanned across the sample surface, while the photocurrent is measured as a function of illumination position (see Figure 1a). The simultaneously recorded reflection image enables to correlate the spatially resolved photocurrent signals with sample structure.

Toward fabricating the nanoscopic graphene – cadmium sulfide (CdS) devices, first CdS nanowires (NWs) were randomly deposited on graphene sheets. The graphene sheet and CdS nanowire were then supplied with top contacts made of AuPd and Ti, respectively.

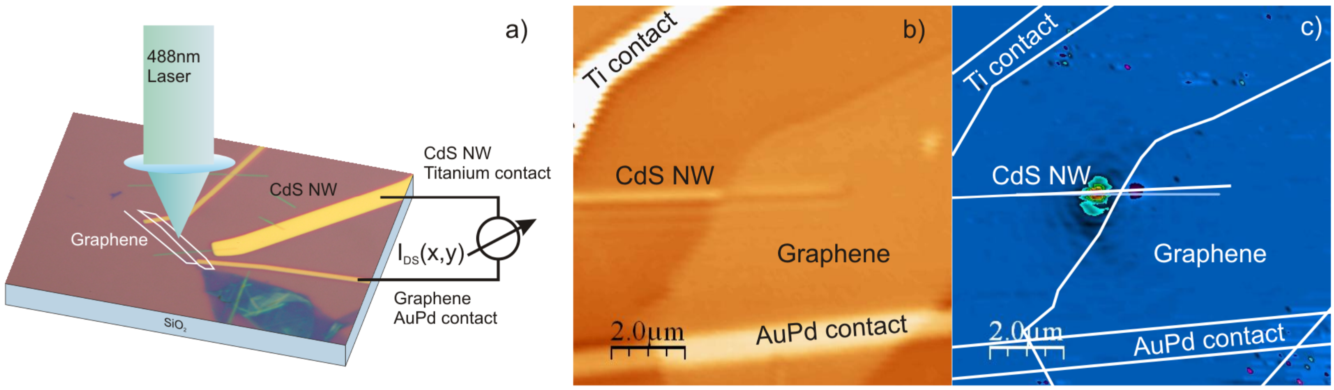


**Figure 1**. a) Schematic depiction of the SPCM method. SPCM reflection b) and photocurrent c) image of a graphene / CdS NW solar cell. Features in c) show where charge separation occurs.

An SPCM image acquired from such a device is shown in figure 1c. Combined with the reflection image (figure 1b), where the graphene sheet, the CdS NW and both electrodes can be identified, it is apparent that the main current is generated at the intersection of the CdS NW and the edge of the graphene sheet. The photocurrents, with magnitudes between 1-5 nA, can be attributed to electron-hole pair separation by the built-in electric field at the graphene-CdS interface.

## Surface plasmon coupling

The SPCM image in figure 2 displays a photocurrent signal at the edges of the titanium contact attached to the CdS NW. This signal extends along the edge up to the end of the wire, whereas further away it is absent. It is of a different sign than the photo contributions at the graphene / CdS interface and therefore probably arises from another effect. Most likely it originates from the excitation of surface plasmons at the edge of the titanium contact, which propagate perpendicular to the edge along the $SiO_2$/Ti and the Ti/air interface. Since the metal layer is less than 100 nm in height, the plasmons are expected to form coupled modes. Only those modes which propagate across the CdS NW can generate excitons and hence contribute to the photocurrent, explaining why not all edges of the titanium contact exhibit a signal.

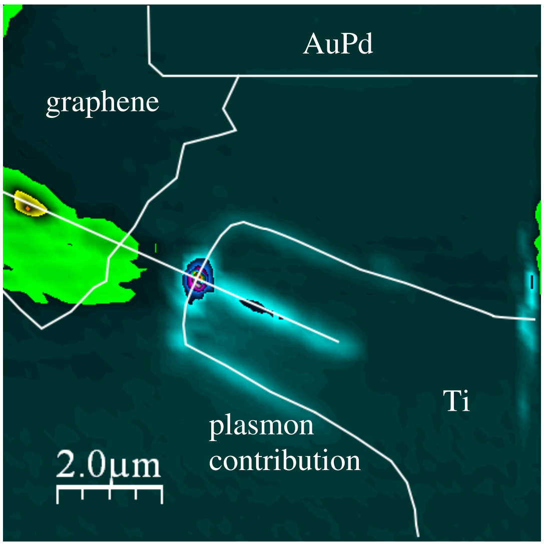


**Figure 2**. SPCM image revealing the contribution of plasmon excitation at the edges of the titanium contact to the CdS nanowire.

## Conclusion

The spatially resolved photocurrent generation, as determined by SPCM, provides valuable insights into nanoscopic solar cells. The photocurrent contributions arising from the graphene - CdS interface or plasmon coupling can be resolved. In the future, further cell configurations with different sensitizing materials and contact electrodes will be studied in order to identify means to improve their overall performance.

References:

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