KPTechnology

KPAN009: Application – Surface Photovoltage Research

"Surface photovoltage study of photogenerated charges in ZnO nanorods array grown on ITO" -

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Keywords

Work Function, WF, Kelvin Probe, Surface Photovoltage, SPV, ZnO Nanostructures

Abstract

A well-aligned nanorods array of ZnO was chemically grown on conductive ITO substrate at low temperature. The photogenerated charges at surface and interface were examined by surface photovoltage techniques based on both Kelvin probe and lock-in amplifier with dc bias. The photovoltage response bands related to band-to-band transition and bound excitons were discriminated. We demonstrated the spectrum-dependent transfer characteristic of photogenerated charges at the surface of ZnO nanorods array and the interface between ZnO and ITO.

Figure 1. KP Technology SPS040 System

Research Area

Recently, many efforts have been devoted to the fabrication of ZnO nanostructures, which is greatly inspired by its multiple functional properties, such as direct wide bandgap (E.g. ~ 3.3 eV at 300 K) and a large exciton binding energy (~60 meV), near UV emission and transparent conductivity, etc. For ZnO systems with diverse nanostructures, shape and dimension effects on surface related properties are significant. For example, ZnO nanoparticles with similar size but different morphologies are discrepant on the properties of field emission. To date, nanorods array of ZnO has been utilised in many photoelectric applications, such as nanolaser, photodiode, solar cell, bio-sensor, p–n junction, and photo catalysis, which are much dependent on the understanding of the mechanisms of photoelectric response and charges transport in the material. However, the mechanisms that are essential to design and improve the material-based devices, such as how the surface or interface potential will change under different wavelengths of light excitation have not been addressed in these reports. This report aims to readdress this omission.

KPAN009: Application – Surface Photovoltage Research

Use of Kelvin Probe

The surface photovoltage (SPV) method is a well-established technique for the characterisation of semiconductors, which provides both optical and transport properties of different regions in the material under study, with high sensitivity to defect states in the sample at its surface, bulk, or any buried interface. The Kelvin probe (KP), which measures surface work function and follows the change on surface potential, combined with a light source is commonly utilised.

The KP SPV techniques was employed to characterise the transfer behaviour of photogenerated charges at surface and interface of the nanorods array, with illumination directly on top of the ZnO nanorods. The feature of spectrum-dependent generation and transfer of photogenerated charges was demonstrated based on the analysis of SPV measurements.

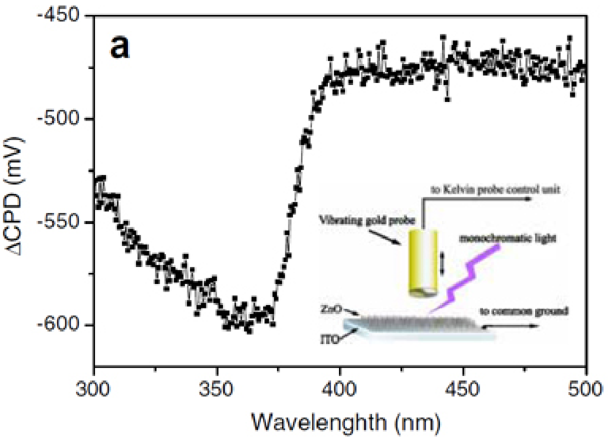

Figure 2. SPV spectrum of ZnO array with top illumination taken on KP. Inset: Schematic setup of KP SPV measurement

Four cleaned and treated ITO glass plates with ZnO seeds were put into fresh aqueous solution of an 0.1 M equimolar zinc acetate, $Zn(Ac)_2$ Æ $2H_2O$, and methenamine, $C_6H_{12}N_4$ and heated to produce the ZnO film. KP based SPV Measurements were carried out on a commercial KP system (KP Technology, Scotland, UK). The width of the gold reference probe is 1.8 mm. Work function of the probe is employed as 5.1 eV after the manufacturer. The SPV was measured by tracking the change of contact potential difference (DCPD) between sample and the probe. A 500 W Xenon lamp and a double prism monochromator provided monochromatic light. The SPV spectra were obtained by scanning the wavelength of the incident light through the visible and UV range (500– 300 nm) with the rate of ~30 nm/min. The work function of blank ITO was measured as 5.01 eV.

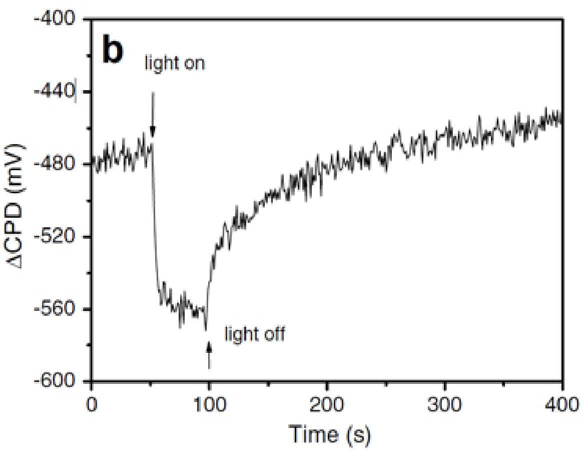

Figure 3. SPV response with 350 nm light on and off.

All the SPV measurements were operated under ambient conditions and the raw data are not treated further. Constant light intensity (at each wavelength) was not used in the KP and ac SPV measurements, and the monochromic light intensity depended on the Xenon lamp spectral energy distribution. The excitation light intensity smoothly declines from 450 to 300 nm, which cannot induce any extra peak on SPV spectra.

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KPAN009: Application – Surface Photovoltage Research

Conclusion

We demonstrate by SPV measurements that in nanorods array of ZnO synthesised chemically, the spectral characteristics of photovoltage response depend on the absorption coefficient varying from sub-bandgap to super-bandgap. When excited directly at ZnO surface with photons of larger energy than bandgap, the photocarriers are generated in the SCR, causing super-bandgap photovoltage response. When excited at interface with photons of smaller energy than bandgap, the system will generate excitons, and it follows that electrons are trapped by hollow interface states, yielding excitonic photovoltage response. Optimising the length and width of ZnO nanorods and modulating the spectrum dependent SPV response are expected to promote the performance of the devices based on the ZnO nanorods array.

Reference

1. Original publication: *"Surface photovoltage study of photogenerated charges in ZnO nanorods array grown on ITO"* - Qidong Zhao, Dejun Wang , Linlin Peng, Yanhong Lin, Min Yang, Tengfeng Xie

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