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Photoresponse of a single ZnO nanowire illuminated by modulated light

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1. Introduction

One-dimensional nanomaterials including nanotubes and nanowires have high surface to volume ratios and nanoscale diameters. Because of these advantages, many studies about potential applications such as UV-lasers, light-emitting diodes, gas sensors, field effect transistors, and UV photodetectors have been reported.[1-5]

Photoconduction has been investigated by many research groups for various types of ZnO; single crystals, crystalline films, and polycrystalline films.[6-11] Recently, photocurrent of a single ZnO nanowire under UV light illumination was first reported by *Yang et al*.[12] Nevertheless, the photoconduction mechanism of ZnO nanowires has not been currently understood well. Moreover, the fabrication of electrodes using photolithography process is necessary for application to Si-based fabrication processes.

In this study, ZnO nanowires were first synthesized, patterned by photolithography process, and then photoresponse, photoresponse spectrum, current vs. voltage characteristics, and photoluminescence (PL) of a single ZnO nanowire were investigated. Finally, the photoconduction mechanism is discussed in this study.

2. General Instructions

Experimental Method

ZnO nanowires were synthesized by thermal CVD methods,[13] immersed in ethanol solution, and dispersed via sonication. The dispersed ZnO nanowires were deposited on thermally grown SiO_2/Si substrates. To form electrodes, a single ZnO nanowire was patterned by mask aligner. Ti(20nm) and Au(100nm) layers were deposited by thermal evaporation and lift-off processes. Microscope image of a single ZnO nanowire patterned by photolithography process is shown in Fig. 1.

The current vs. voltage characteristics, photoresponse, and photoluminescence of the single ZnO nanowire was taken. The photoresponse of a single ZnO nanowire was measured under the continuous illumination of light. The light source was the 325-nm wavelength line from a He-Cd laser. The excitation source for photoresponse spectrum was light from a Xe lamp dispersed by a monochromater. To modulate light, a chopper was placed between the light sources and samples, and the cut-off filter was mounted on a monochromater.

Results and Discussions

Current vs. voltage characteristics for a single ZnO nanowire is ohmic, shows in inset of Fig. 2. Figure 2 shows the photoresponse for a single ZnO nanowire under the continuous illumination of 325nm wavelength light in air. The observed slow photoresponse indicates that the creation of holes by the illumination of light allows chemidesorption of oxygens to happen and that excited electrons contribute to photoconduction.

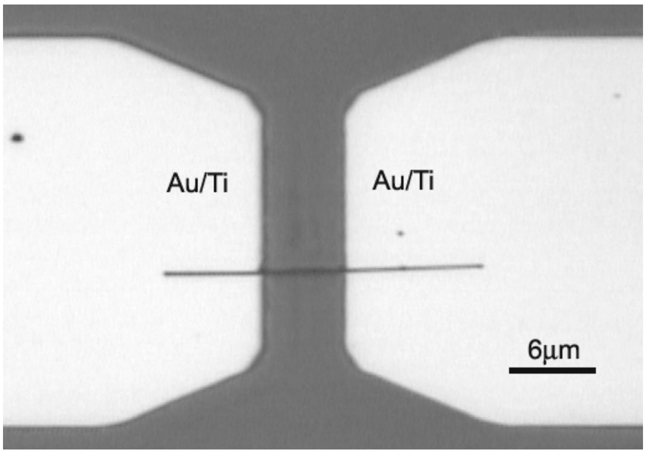

Fig. 1 Microscope image of a single ZnO nanowire patterned by photolithography process.

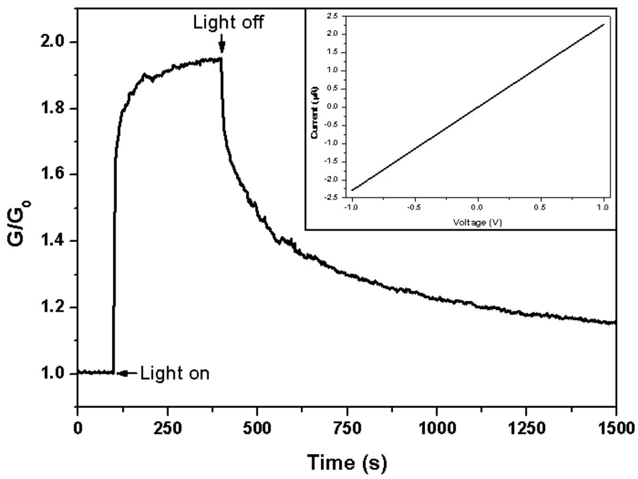

Fig. 2 Photoresponse and current vs. voltage characteristics(inset) of a single ZnO nanowire in air. G is a conductance and G_0 is a dark conductance.

Figure 3 shows photoresponses of the single ZnO nanowire under modulated illumination of 325nm wavelength light. The photoresponses of the nanowire under the illumination modulated at frequencies of 10, 20, and 30Hz illustrate that the intensity of the photoresponse is independent of the illumination time. The illumination-time-independent intensity of the photoresponse implies that the constant number of electrons reaches the electrodes per unit time during the illumination modulated at a fixed frequency.

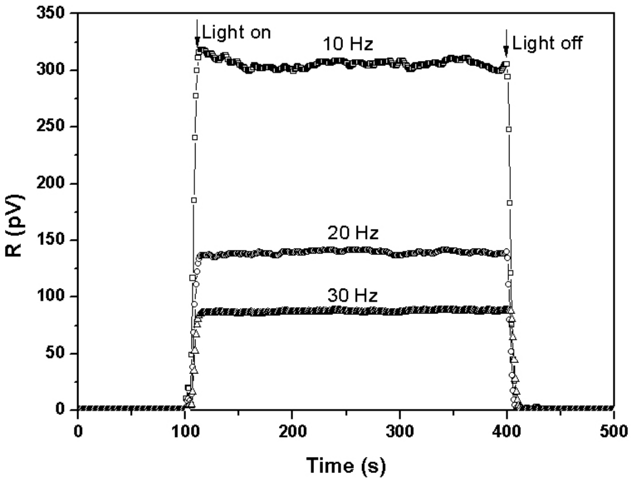

Fig. 3 Photoresponses of the single ZnO nanowire under the illumination of 325-nm wavelength light modulated at frequencies of 10, 20, and 30Hz.

Figure 4 shows a photoresponse spectrum of a single ZnO nanowire under modulated illumination and a photoluminescence spectrum of ZnO nanowires. The photoresponse spectrum represents the above- and below-bandgap absorption bands for the photocurrents. In the PL spectrum, the excitonic band is absent in the photoresponse spectrum. This observation implies that excitons excited by the above-bandgap light in the ZnO nanowire do not contribute to the photoconduction, but that the excitons participate in the recombination to emit the PL signal.

3. Conclusions

The current vs. voltage characteristics of a single ZnO nanowire was ohmic for Ti contact. The creation of holes excited by above-bandgap light chemidesorbs oxygens on the surface of ZnO nanowire, and then excited electrons contribute to photoconduction. In the photoresponse spectrum, the peak position of photocurrent was at 366 nm(3.39eV; this wavelength was somewhat higher than the bandgap(3.3eV) of ZnO. These results indicate that excitons excited by near bandgap light participate in the recombination to emit, but that electrons excited by higher energy than bandgap contribute to the photoconduction.

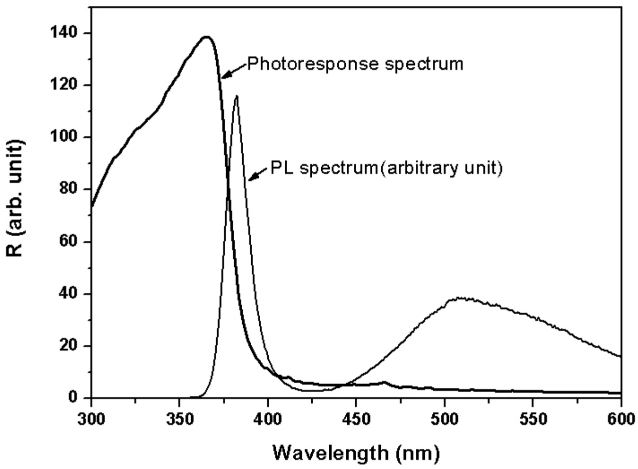

Fig. 4 Photoresponse spectrum of a single ZnO nanowire under modulated illumination; PL spectrum taken for nanowires was added in this figure.

Acknowledgements

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