

Public Abstract

First Name:Linghui

Middle Name:

Last Name:Li

Adviser's First Name:Ping

Adviser's Last Name:Yu

Co-Adviser's First Name:

Co-Adviser's Last Name:

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Title:Development and Analysis of ZnO-based Semiconductor Photodetectors for UV Detection

Among direct bandgap semiconductors that are sensitive to photons in the ultraviolet (UV) region, ZnO is a promising photonic material because of its unique optical and electrical properties. At room temperature the exciton binding energy (about 60 meV) of ZnO is larger than that of GaN (20 meV) and ZnSe (26 meV), and is well above thermal ionize energy. ZnO has a very high breakdown electrical field () which is more than two times that of GaAs. ZnO also has a much larger saturation velocity () in comparison to GaN, SiC, and GaAs at room temperature. In addition, ZnO is more radiation-resistant than other semiconductors and is therefore a good candidate for fabricating photonic devices that can operate in extreme environments and conditions such as space and nuclear reactors.

The objective of this thesis is to develop ZnO-based semiconductor photodetectors for UV detection with low dark current, high responsivity, and fast response time. To achieve this objective, an understanding of carrier recombination and transport mechanisms of the devices is necessary by investigating their electrical properties and optical properties. The photoresponse under continuous wave excitation and pulse excitation along with the frequency photoresponse provide characterizations and useful mechanism information of the devices. These measurements are also helpful to the optimization of the structures in the UV detectors.

In this thesis, various ZnO UV detectors are investigated, including ZnO photoconductors, metal-semiconductor-metal (MSM) ZnO photodetectors with Ohmic contacts, post-processed MSM ZnO photodetectors with Schottky contacts, and p-i-n ZnO photodetectors. Experimental data and analysis give four unique results: (1) Very high photoelectric gain was confirmed in ZnO photoconductors. Persistent photoconductivity was observed in these detectors, which is due to carriers trapped in surface states. (2) A high gain and high speed photo-detection was validated in ZnO MSM photodetectors with Ohmic contacts. (3) A extremely low dark current and very high UV-Visible rejection was observed in ZnO MSM photodetectors with Schottky contacts. (4) Two photocarrier processes were found for the first time in ZnO p-i-n photodetectors. Photocurrent is due to the diffusion of carriers created from the top p-layer under lower biases, and comes from the avalanche effect in the i-layer under higher biases.

For most ZnO photodetectors, the photoresponse exhibits a high visible rejection, with an UV/visible contrast from 3 to 5 orders of magnitude. To investigate the photocurrent mechanisms, the photocurrents with respect to the incident light power were studied using a cw He-Cd laser at 325 nm (above the bandgap) and 442 nm (below the bandgap). The temporal photoresponse was determined by using the fourth harmonic generation of a short pulsed YAG: Nd laser (266 nm). The ZnO photodetectors display a fast pulse response with a very short rise time and relatively long relaxation time when a bias is applied. Our results show that semiconductor photodetectors based on ZnO are a promising candidate for UV detection.