THz GaAs/AlGaAs Quantum Well Detector

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***Abstract* - We have designed and tested basic operation of a GaAs/AlGaAs quantum well photodetector in THz range of spectrum (3 THz, 100 μm). Responsivity of a few mA/W was measured, however achieving of the background-limited performance was not feasible because of high level of the dark current. Suitability of the device for practical applications will depend on further improvements of the design. We believe that better performance can be attained by optimizing the doping levels in the quantum wells. To evaluate suitability of the quantum well detectors for THz imaging, a small (up to 32 elements) prototype array will be tested.**

In recent years, there have been continuing efforts in developing practical semiconductor based sources and detectors of terahertz (THz) radiation. Most of the existing and emerging applications will utilize direct or heterodyne detection techniques for THz imaging, spectroscopy and communications, and their successful implementation will depend on availability of fast and sensitive multi-element detectors. A quantum well (QW) photodetector based on intersubband absorption in the quantum well, with well's geometry and alloy composition appropriately tuned to THz range, is one of the possible candidates to meet these requirements.

Optimal design of the QW photodetector with minimal level of the dark current corresponds to condition when the first excited state in the quantum well is aligned with the top of the barrier (bound to quasi-bound configuration). We have designed GaAs/AlGaAs structure with targeted peak frequency of 3 THz (100 microns), whose parameters correspond to QW width of 18 nm and the aluminum alloy fraction of 2%. Electrical and other properties of the detectors with different barrier widths and doping concentrations were numerically simulated, and several samples with 60 nm and 80 nm barriers and doping concentrations in the range of 5×10^{16} – 2×10^{18} cm^{-3} have been fabricated. The samples were grown by molecular beam epitaxy on semi-insulating GaAs substrates. A typical fabrication process consisted of the following steps. On top of 800 nm thick n-doped (Si, 2×10^{18} cm^{-3}) GaAs contact layer, 20 periods of 80 nm $Al_{0.02}Ga_{0.98}As$ barrier and 18 nm n-doped (Si, 1×10^{11} cm^{-2}) GaAs well were grown. After the last 80 nm $Al_{0.02}Ga_{0.98}As$ barrier, 300 nm n-doped (Si, 2×10^{18} cm^{-3}) GaAs top contact layer was deposited. X-ray diffraction, SEM/EDS and PL measurements were used to verify the composition, period and energy level structure of the superlattice. Only minor deviations from the designed parameters have been observed.

The samples were processed into single-element or multi-element square shaped mesas of different sizes (1000, 710, 500, 350, 250, 180, 130 μm) using standard photolithography and wet etching with H_2SO_4:H_2O_2:H_2O. Top and bottom ohmic contacts and grating coupler on top of the mesas were made by thermal deposition of 100/300 nm GeAu/Au and annealed at 360°C for 120 s.

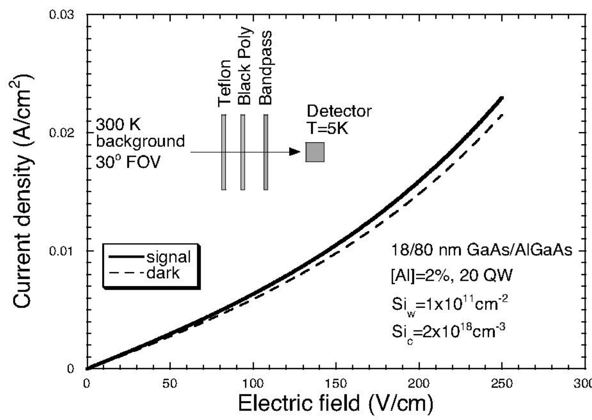

Fig. 1. Bias dependence of the photocurrent under dark condition and under a 300 K background. THz photon flux is defined by the field of view of the detector and a combination of filters that keep the incoming radiation within the targeted spectral range.

Responsivity of the detector at the temperature 5 K was measured by comparing current-voltage characteristics under dark condition and under a 300 K background. Example of the curves is shown in Fig. 1. Responsivity of a few mA/W was measured, however achieving of the background-limited performance was not feasible because of high level of the dark current. We believe that better performance can be attained by optimizing the doping concentrations in the quantum wells.

In summary, we have demonstrated basic operation of the GaAs/AlGaAs quantum well photodetector in THz range of spectrum (3 THz, 100 μm). To evaluate suitability of quantum well detectors for THz imaging, a small (up to 32 elements) prototype array will be tested.

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