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論 文 要 旨

THESIS SUMMARY

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学生氏名： Student's Name	鄧　湘穎	指導教員（主）： Academic Supervisor(main)	河野　行雄
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The spectral region of terahertz (THz) waves has been proven to have strong potential in various applications including security, medicine, food quality inspection, electronics, and astro-observation. The performance of THz systems in these areas strongly depends on the availability of high sensitivity THz detectors. However, existing commercial detectors in the THz region (especially above 1 THz) have limitations such as low sensitivity. In order to further promote THz technologies, high-performance detectors are in strong demand. Graphene has been demonstrated as a promising material for THz detection due to its unique band structure and high carrier mobility under room temperature. Ge-core-Si-shell nanowire also exhibits high hole mobility, which is potentially applicable to THz detection. However, the mismatch between the THz wavelength and the detection area of such nanomaterials leads to low coupling efficiency. Therefore, the use of plasmonic antennas that can obtain high concentration and extremely large enhanced transmission beyond the diffraction limit is a promising solution to this problem. However, the main limitation for a bull's eye (BE) shaped structure, one of plasmonic antennas, is its single resonant frequency. My research is aimed at optimizing the structure of the BE plasmonic antenna to overcome this limitation and expand its bandwidth, while maintaining its main advantages of enhanced transmission and high electric field concentration. Such modifications are expected to make it more useful in THz related studies.

In this work, I explored two different resonance modes to optimize the structure of the BE plasmonic antenna: cavity mode and groove mode.

For cavity-mode coupling, I introduced a double-frequency resonant plasmonic antenna, which overcame the limitation of conventional BE antennas and enabled multi-frequency applications. I further coupled the proposed double-resonant frequency BE antennas with photodetectors, and evaluated their performance. I proposed and fabricated a half-BE antenna-coupled graphene-based photodetector and a full-BE antenna-coupled graphene-based photodetector. The latter device is based on a chemical vapor deposition (CVD) grown monolayer graphene. The fabricated device was demonstrated to work under non-vacuum condition and room temperature. The nature of CVD grown graphene made it easy to determine the shape, size, location, and quantity of the graphene ribbons, which will allow large-scale integration in the future. This device is expected to be used in various fields

that require frequency-selective, room-temperature sensitive photodetection.

For groove-mode coupling, I proposed two designs of BE antennas using the groove-mode resonance, which enabled multi-band THz transmission and arbitrary frequency selection. The split-joint BE (SJBE) structure consists of slices from single-frequency BE antennas. The spiral BE (SBE) structure, which is derived from the SJBE structure, contains infinitely small slices of single frequency BE structures, making connections between grooves continuous. In contrast to conventional single resonant frequency BE antennas, the two proposed BE antennas have the capability of providing a wider transmission band without large sacrifice on overall transmission. These designs can be readily applied to wider or different frequency domain by simply changing structural parameters. This advantage is anticipated to make the BE structure a useful tool for multiple frequency investigations in a sub-wavelength region, which is potentially applicable to fields including nanomaterials and nanodevices characterization and molecular research. Compared to other tunable transmission devices that require either a change in the lattice constant or the Fermi level of materials, the SBE plasmonic grooves allowed frequency selection in a more convenient manner. Moreover, this structure does not only work as a tunable THz device, but also increases the transmitted intensity and enhances the electric field intensity at the aperture. I further utilized the SBE in medical examination by measuring THz transmission of tablets and organ tissues. The results confirmed the enhanced sensitivity through the use of the SBE. Mapping of mouse organs further verified that the SBE allowed sensitive and effective measurements with high resolution. This structure can also be modified to fit most frequency ranges for surface plasmons by changing the period and depth of the grooves, and therefore can be employed in future multi-resonance, frequency-selective applications.

A nanowire-based field-effect transistor (FET) is one of the promising device for THz detection. Ge has a high hole mobility and thus is suitable as a material for a nanowire-based FET. The Si-shell can protect the Ge-core from oxidization, and ensure the quality of the device for a long term. Therefore, I chose to use the Ge-core-Si-shell nanowire integrated with a bow-tie antenna as another type of THz detector. The fabricated detector exhibited improved responsivity of about 109.6V/W in the THz spectral range.