サブnm のギャップを有する電極を用いた 単一分子のテラヘルツ分光

Terahertz Spectroscopy of Single Molecules Using Sub-Nm Scale Gap Electrodes

H28海自47

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海外における研究活動状況

研究目的

Terahertz spectroscopy is a powerful tool for clarifying electronic structures and vibrational dynamics of various kinds of molecules. However, it is a formidable challenge to greatly exceed the diffraction limitand perform single molecule spectroscopy. In order to investigate THz dynamics of single molecules, we need a new breakthrough to perform THz spectroscopy at single molecule level.

海外における研究活動報告

Conference overview

In the 8th International Conference on Molecular Electronics, 225 people joined it totally, including 16 invited lectures, 48 oral presentations, and 160 posters. There are totally 8 topics in a large room during Aug. 22nd- Aug. 26th, including Single Molecules & Quantum Dots, Organic Electronics and Spintronics, Organic Optoelectronics & Photonics, 2D materials, Nanotubes & Nanowires, Self-Assembly &Supramolecular Architectures, Scanning Probe Microscopies & Near Field Approaches, Molecular Theoretical Modeling, and Bioinspired Approaches & Biomimetic Devices. My research belongs to the first topic and it is related with other research fields.

Summary of my Presentation

My presentation was in the first day. The title is "Nanomechanical oscillation in single-C_{60} transistors investigated by time-domain terahertz spectroscopy". Three researchers ask me questions after my talk. Their questions were related with the sample structure, peak splitting, and THz source. All of them are the key points in my study. I believe my presentation impressed the audience. After the discussion in the conference, I roughly make sure three important results in the research.

1) Sub-nm gap electrode is a useful structure in THz spectroscopy of single molecules. The enhancement of E-field in the gaps increases at least 10^5 times when we use bow-tie antenna to improve THz coupling.
2) The mechanism of photocurrent is THz-induced vibron-assisted tunneling. Due to the resonance absorption between molecule and

THz photons, we create a vibron state between source and drain. It allows electron tunneling in the nanogap.

3) The origin of absorption peaks in single-C_{60} molecule is center-of-mass oscillation. From the spectrum, we can observe two sharp peaks around 2 meV and 4 meV with energy splitting. We think the mechanism of these absorption peaks is center-of-mass oscillation. It means the whole molecule vibrates against the gold surface. A possible reason of peak splitting is the vibrational frequency of the molecule may depend on the electron number.

Activities overseas

From other researchers' presentations and posters, I know some trends in the field of molecular electronics. Therefore I have some newideas for my future research plan.

1) The applications of 1D and 2D materials of fullerenes have a good potential development in THz spectroscopy. Many groups use carbon nanotube and graphene to perform nano devices. Since these 2 materials have some new feature, they may bring a huge revolution in physics, chemistry, biology, and nanoscience. Now I have performed THz spectroscopy on single fullerenes (0D material). I believe it should be interesting if I apply this technology onto carbon nanotube (1D material) and grapheme (2D material). Some new vibrational modes are expected to observe, which maybe depends on the size and shape of the materials.

2) The applications of THz spectroscopy in biomolecules may be possible at nano-meter scale. In ensemble measurement, the THz spectra of proteins always show a broadband peak which is very hard for us to analyze the vibrational modes in biomolecules. However some people found if they use 10-nm gap to capture a single biomolecule, they can observe sharp peaks in conductance spectra. This gives us a chance to perform THz spectroscopy of single biomolecule. It is expected to observe sharp vibrational peaks in THz spectra, including individual information of biomolecules.

3) Self-assemble molecule maybe becomes a useful tool in molecular electronics. Some groups show their technology on self-assemble molecule. It means we can control the features of molecules by change their shape, size, and structure. I think it is very helpful in molecular electronics devices because we can design different functional devices in ultra-small integrated circuit, which offers hope to keep Moore's Law. If we can combine THz spectroscopy and single self-assemble molecule, it is possible to develop a modulated THz-sensitive electronic device.

Summary & Acknowledgements

We believe our work will open new possibilities in the field of applications in biomedical research as well as medical diagnostics at single molecule-level. We will be put at the forefront in the field of THz nanoscience. Here we very thank for the support of The MurataScience Foundation. The journal paperof this work is being prepared and should be submitted and published soon.

この派遣の研究成果等を発表した著書、論文、報告書の書名・講演題目

The title of my presentation was slightly changed to "Nanomechanical oscillation in single-C60 transistors investigated by time-domain terahertz spectroscopy".