【Grant-in-Aid for Specially Promoted Research】

Science and Engineering (Mathematics/Physics)

Title of Project : Development of sub-cycle time-resolved STM and its applications

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Research Project Number : 17H06088 Researcher Number : 20134489
Research Area : Mathematical and Physical Sciences
Keyword : Scanning tunneling microscopy, CEP control, Spectroscopy with subcycle time resolution

【Purpose and Background of the Research】

We have been carrying out research on a new microscopy technology that enables (1) spectroscopy with femtosecond time resolution (optical pulse width) while (2) confirming the local structure and electronic state of a target with the atomic-level spatial resolution of scanning tunneling microscopy (STM). In this study, we will develop new microscopy technology that enables probing with the spatial resolution of STM with subcycle time resolution. This research is expected to lead to the development of a new scientific field.

【Research Methods】

In this study, we will realize a measurement method for clarifying the dynamics of subcycles with the resolution of STM. This will be achieved by introducing advanced quantum optics technology, such as the carrier envelope phase (CFP) technique, to directly control the phases of the electric field in pulses. The target local structure is selectively excited while monitoring the surrounding environment by STM because the electric field immediately below the STM probe is amplified about 10^6-fold. Therefore, a mechanism that enables the measurement of the dynamics of the local structure with subcycle time resolution while controlling the properties in the excited electric field can be realized through the use of the CFP control technique with monocycle pulses.

【Expected Research Achievements and Scientific Significance】

Figure 1 shows an example of the new microscopy using molecules as a target. In general ultrafast spectroscopy, the relaxation process after excitation is observed. In contrast, with our method, measurement with subcycle time resolution is carried out while controlling the properties of the target. Using the results obtained, molecular functions, which can be the basis for novel function, can be optimally obtained and are expected to lead to a wide range of applications. The targets of measurement include not only molecules but also carriers in semiconductor devices and the dynamics of phase transitions. Thus, the development of a new academic field is expected.

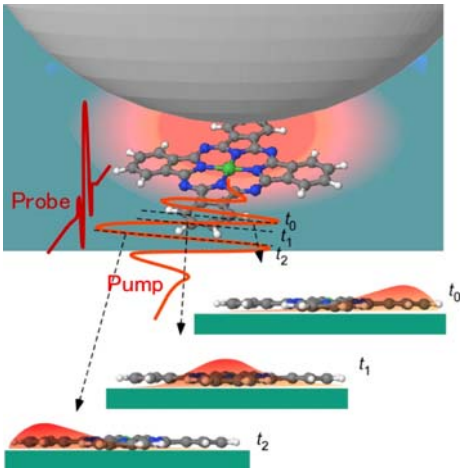

Fig. 1 Charge transfer and transition, as well as the molecular structure, in a single molecule are controlled with a monocycle external field and then measured and visualized by STM with subcycle time resolution.

【Publications Relevant to the Project】

・ S. Yoshida et al., Probing ultrafast spin dynamics with optical pump-probe STM, Nature Nanotech. 9, 588-593 (2014), and refs. therein.
・ K. Yoshioka et al., Real-space coherent manipulation of electrons in a single tunnel junction by single-cycle terahertz electric fields, Nature Photon., 10, 762-765 (2016).

【Term of Project】 FY2017-2021

【Budget Allocation】 453,600 Thousand Yen

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