【Grant-in-Aid for Scientific Research (S)】

Broad Section D

Title of Project : Scanning tunneling microscopy for the development of ultimate nano-optics

Yousoo Kim
(RIKEN, Cluster for Pioneering Research, Chief Scientist)

Research Project Number : 18H05257 Researcher Number : 50373296
Keyword : Near-field light, Scanning tunneling microscope, Single molecule, Energy transfer/conversion

【Purpose and Background of the Research】
The interaction between light and matter is the origin of various "functions" such as color, luminescence, photochemical reaction, photoelectric conversion, etc.
When irradiated on a metal nanoscale structure, light can be collected in a tiny region of several nm which far exceeds the diffraction limit (several 100 nm) of light. We have studied spectroscopic measurements and photochemical reactions at the single-molecule level by using extremely small light (near-field light) localized between a metal probe of a scanning tunneling microscope (STM) and a metal substrate. However, the frequency and polarized state of the near-field light used so far have been extremely limited. That is mainly because that only the electric field component has been examined in the limited frequency range such as visible to near infrared in the linear response range.
This study aims at realizing near-field photochemistry and developing single-molecule spectroscopic measurement based on the interaction between the near-filed light at the STM tip and various quantum states of a target molecule.

【Research Methods】
For further development of near-field optical science, it is necessary to understand the near-field light itself more from the basic scientific point of view and to elucidate the interaction with the substance. However, in order to examine the near-field light itself precisely, it is enavitable to use a microscope having a spatial resolution of an atomic scale (~0.1 nm) which is sufficiently smaller than the size of the near-field light of several nm. Therefore, in this research, we precisely control the frequency and polarization state of the near-field light induced just under the STM probe, by changing the irradiating light variously. In addition, we clarify the interaction between near-field light and matter by conducting high-precision measurement and theoretical analysis using the quantum state of a single molecule as a probe in a system defined at the atomic level.

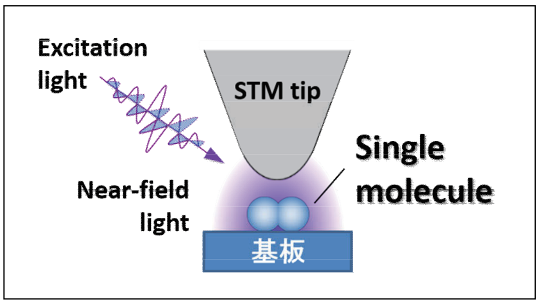

Figure 1 A schematic of creation of near-field light and its interaction with a single molecule

【Expected Research Achievements and Scientific Significance】
The detailed studies of the interaction between the near-field light and the matters will provide the establishment of the principle which governs the elementary process in the near-field optical microscope, near-field photochemical reaction, enhanced Raman scattering spectroscopy, etc.

【Publications Relevant to the Project】
・E. Kazuma, J. Jung, H. Ueba, M. Trenary, Y. Kim, “Real-space and real-time observation of a plasmon-induced chemical reaction of a single molecule” Science 360 (2018) 521.
・ H. Imada, K. Miwa, M. Imai-Imada, S. Kawahara, K. Kimura and Y. Kim, “Single molecule investigation of energy dynamics in a coupled plasmon-exciton system” Phys. Rev. Lett. 119 (2017) 013901.
・ H. Imada, K. Miwa, M. Imai-Imada, S. Kawahara, K. Kimura and Y. Kim, “Real-space investigation of energy transfer in heterogeneous molecular dimer” Nature 538 (2016) 364.

【Term of Project】 FY2018-2022

【Budget Allocation】 150,600 Thousand Yen

【Homepage Address and Other Contact Information】
http:// www.riken.go.jp/Kimlab/index.html
ykim@riken.jp