Electron Tunneling and Photon Emission in Terahertz Field-Driven Scanning Tunneling Microscope

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Scanning tunneling microscope (STM) is one of the important experimental techniques to investigate nanoscale materials with atomic spatial resolution. However, the temporal resolution of STM is limited by the speed of electronic circuits, preventing STM from investigation of nanoscale ultrafast dynamics such as initial energy transfer and dissipation of photoexcited states. Because the ultrafast dynamics at the nanoscale determine the subsequent processes such as modification of material properties and photochemical reactions, it is strongly desired to establish a method to investigate nanoscale dynamics with a high temporal resolution. To this end, we combined STM with terahertz monocycle pulses [1-3], and investigated the terahertz-induced luminescence due to the terahertz-induced electron tunneling [4].

In the experiment, we used the Yb fiber laser with the output energy of 8 μJ, repetition rate of 100 kHz, and the pulse duration of 200 fs. The terahertz pulses are generated by a $LiNbO_3$ prism excited by the pump pulses with the tilted wavefront. The generated monocycle terahertz pulses with the peak electric field of approximately 200 V/cm are directed into ultrahigh-vacuum STM equipped with the terahertz focusing optics. Because the terahertz pulses modulate the tip-sample voltage at the picosecond timescale, both burst of tunneling current and plasmon luminescence due to inelastic electron tunneling are induced when terahertz pulses are shined on the tip. From the dependence of the luminescence intensity on the amount of tunneling current and the tip conditions, the plasmonic pico-cavity around the tip apex plays important roles for the generation of photoluminescence. The results demonstrate that terahertz STM could be a new method for investigating ultrafast dynamics occurring at the nanoscales [5].

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