Award Achievements
The 4th Heinrich Rohrer Medal –Grand Medal–
Prof. Wilson Ho

"For the development of scanning tunneling microscopy-based inelastic electron tunneling spectroscopy (STM-IETS), enabling the detection of various chemical and physical properties of single atoms and molecules, thereby opening up quantitative science by STM."

Ever since the invention of the scanning tunneling microscope (STM) in 1981 by Gerd Binig and Heinrich Rohrer, a persistent goal, pursued by numerous researchers, was to achieve chemical sensitivity with atomic-scale resolution. This goal was first reached 17 years later by the Ho Group with inelastic electron tunneling spectroscopy (IETS) and microscopy of the vibrational excitation of a single acetylene molecule adsorbed on the surface and subsequently in numerous molecules, including a single hydrogen atom. STM-IETS measured energy transfer from tunneling electrons to a molecule with sub-Ångström resolution. The realization of atomic-scale inelastic electron tunneling gave rise to a new window into nanoscience with spatially resolved excitation spectra. The inelastic intensity revealed the coupling strength of electrons to the nuclear and spin motions, including the novel spin-vibration entangled states. This coupling drove a broad range of chemical and physical phenomena involving charge, spin, and nuclear displacement, such as those in chemical reactions, molecular electronics, superconductivity, and magnetism.

In a series of papers, the Ho Group showed quantitative visualization of single-molecule dynamics induced by spatially resolved IET: rotational motion, vibrational-rotational energy transfer, conformation structural change, breaking and making of a chemical bond, and hydrogen atom diffusion by tunneling. By transferring a carbon monoxide molecule to the STM tip, a new structural probe was advanced by detecting changes in the vibrational intensity of the CO to reveal skeletal structures of individual molecules and intermolecular interactions. Extension of IETS to spin excitations led to the discovery of spin splitting of vibronic progression modes in molecules without unpaired electrons, entangled spin and vibration states, and exchange interactions between two magnetic molecules. Most recently, the Ho Group discovered that THz radiation field induced an ac voltage modulation, and the nonlinearity in the gap led to IETS based on rectification current from light coupled to the STM. Furthermore, THz photons can be absorbed by a single molecule that led to the invention of the quantum superposition microscope combining pump-probe femtosecond THz pulses with the STM to create superposition of two-level hydrogen for sensing surface electric field at the atomic scale. These experiments by STM-IETS were advanced with homemade instruments, including the scanner, electronics, and software of the STM, and the development of new experimental methodology.