The Fourth Awarding of The Heinrich Rohrer Medals
(Grand medal and Rising Medal)

February 3, 2024
The Japan Society of Vacuum and Surface Science (JVSS)

It is our great pleasure to announce the winners of the fourth awarding of The Heinrich Rohrer Medals. The Medal was established after the name of Late Dr. Heinrich Rohrer, one of the Laureates of Nobel Prize in Physics in 1986, for recognizing researchers who have made the world-top level achievements in the fields of nanoscience and nanotechnology.

The 4th Heinrich Rohrer Medal -Grand Medal-

- Franz J. Giessibl

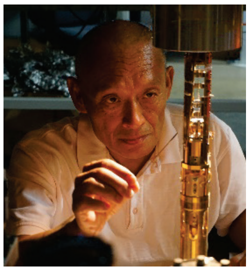
Universität Regensburg, Germany

"For the invention of the qPlus force sensor, which proved that sub-atomic spatial resolution is achievable in atomic force microscopy (AFM) and scanning probe microscopy (SPM), revolutionizing their range of applications for both AFM and SPM."

- Wilson Ho

University of California, Irvine, USA

"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."



The 4th Heinrich Rohrer Medal -Rising Medal-

- **Yi Chen** (born in 1992)

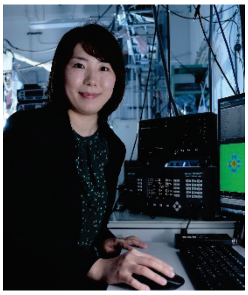
  Peking University, China

  "For the pioneering contributions that have pushed the boundaries of scanning tunneling microscopy along two directions which are the creation of the first atomic scale multi-qubit platform and the innovative visualization of exotic excitations in a quantum spin liquid."

- **Miyabi Imai-Imada** (born in 1988)

  RIKEN, Japan

  "For the significant achievement of the first atomic-scale visualization of photocurrent channels within a single molecule by the development of resonant fluorescence utilizing tunable laser techniques for single-molecule spectroscopy."



Award Ceremony

The award ceremony will be held at the 10th International Symposium on Surface Science, ISSS-10 (https://www.jvss.jp/conference/isss10/), on October 20-24, 2024, at Kita-kyushu, Japan, which is organized by The Japan Society of Vacuum and Surface Science (JVSS). The awarding will be in collaboration with Swiss Embassy in Japan. The laureates will deliver the award lectures on their research achievements during ISSS-10.

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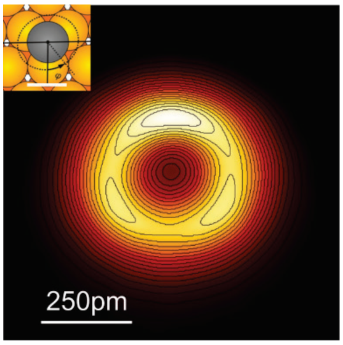
Award Achievements
The 4th Heinrich Rohrer Medal –Grand Medal–
Prof. Franz J. Giessibl

"For the invention of the qPlus force sensor, which proved that sub-atomic spatial resolution is achievable in atomic force microscopy (AFM) and scanning probe microscopy (SPM), revolutionizing their range of applications for both AFM and SPM."

Prof. Giessibl has improved atomic force microscopy (AFM) to achieve true atomic resolution. He obtained a PhD with Gerd Binnig, Heinrich Rohrer's colleague, friend and co-recipient of the Nobel Prize in Physics 1986 for the invention of the scanning tunneling microscope (STM). In his thesis, Giessibl demonstrated for the first time true atomic resolution by AFM using a home built low-temperature AFM to image atomic defects on KBr. He then joined a Stanford spin-off company to develop an ultra-high vacuum AFM. He achieved the first atomically resolved image of the Si 7x7 reconstruction by AFM with this device, important as the first 7x7 image by STM convinced the world about the prowess of STM. The 7x7 result by AFM launched the field of atomically resolved Noncontact-(NC) AFM, the NCAFM conference is still conducted annually since 1998. After resolving 7x7 by AFM, Giessibl did not immediately see another big goal for AFM and left physics for new lands, joining management consultancy McKinsey. The new experiences with benchmarking in the consulting practice triggered his idea to build an AFM that utilizes a key innovation of the watch industry. Parallel to his work as a consultant, he set up a home laboratory and invented a novel sensor for the AFM that is based on the time keeping element of a quartz watch, he called it the qPlus sensor. To see if this could give a fresh boost to AFM, he joined the University of Augsburg. Only a few years later, he established the qPlus sensor as a new core of the AFM that even achieves subatomic resolution, i.e. it resolves single electron clouds in an atom. The result even sparked the interest of Gerhard Richter, one of the most influential painters of our time, and led to an ongoing exchange resulting in Giessibl's contributions to three works of Richter: *First View* (2000), *Graphite* (2005) and *Two grey double mirrors for a pendulum* (2018) and inspirations to *Silikat* (2004) and *Strontium* (2006). At Richter's 90^{th} birthday, a book appeared that reports about the fruitful exchanges between artist and scientist. The qPlus sensor not only increases spatial resolution with respect to the previously used silicon cantilever, it is also self sensing via the piezoelectric effect so it is easy to use in challenging environments such as low temperatures and ultrahigh vacuum. The high stiffness of the quartz sensor and the relatively large size allows to use metal tips that oscillate at sub-Angstrom amplitudes, thus reuniting STM and AFM for simultaneous current and force experiments.

To open new applications, Giessibl reached out to Gerhard Meyer and Leo Gross at IBM Rüschlikon and to Andreas Heinrich at IBM Almaden. The Rüschlikon group used the qPlus sensor to image the charge state of single atoms and to atomically resolve organic molecules by terminating the qPlus tip with a CO molecule, opening a new field in its own. The Almaden team measured the force needed to move an atom by replacing the metal tip of an STM designed by Don Eigler with a qPlus sensor. This also opened a new avenue to grasp the physics behind atomic manipulation. Giessibl spent a sabbatical with Joseph Stroscio at NIST and helped to build a millikelvin STM/AFM for high magnetic fields. Together with his Regensburg team, Giessibl used the qPlus to standardize subatomic resolution, gain more knowledge on atomic manipulation, perform spin-resolved AFM, combine inelastic electron tunneling spectroscopy with AFM, explore the possibilities of atomically resolved lateral force microscopy, resolve metal clusters atomically and measure their site-dependent reactivity, study the bonding properties of electrons in a quantum corral, obtain atomic resolution in ambient and electrochemical environments etc.. Giessibl also supported commercial manufacturers of low temperature STMs to outfit their products with the qPlus sensor and thereby expanded their utility dramatically. Today, approximately 500 low temperature qPlus STM/AFMs are in operation globally.

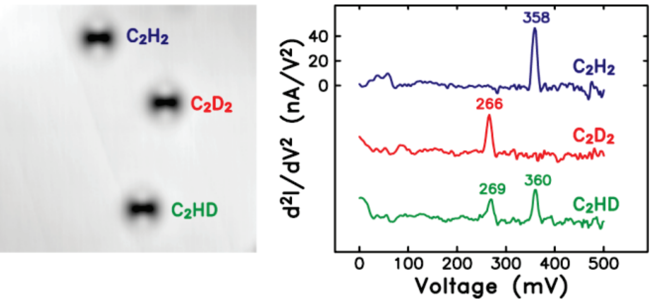


Award Achievements
The 4th Heinrich Rohrer Medal –Grand Medal–
Prof. Wilson Ho

"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.



Award Achievements

The 4th Heinrich Rohrer Medal –Rising Medal–

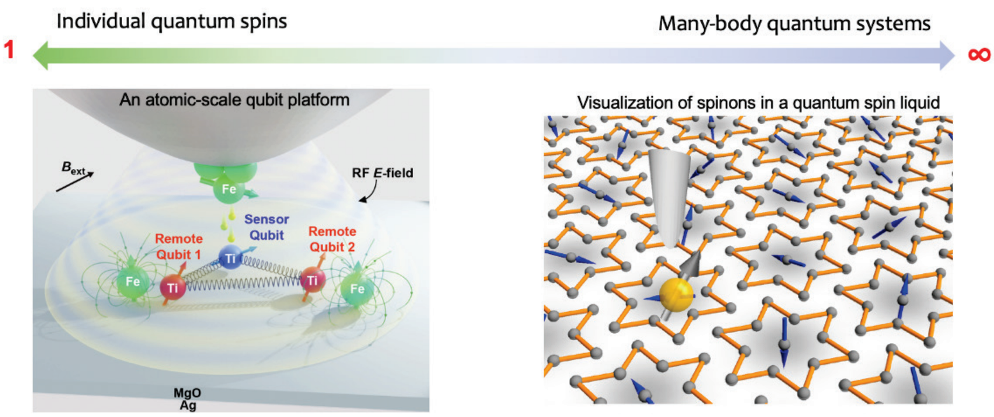
Prof. Yi Chen

"For the pioneering contributions that have pushed the boundaries of scanning tunneling microscopy along two directions which are the creation of the first atomic scale multi-qubit platform and the innovative visualization of exotic excitations in a quantum spin liquid."

Prof. Yi Chen has extended the capability of scanning tunneling microscopy (STM) to two unexpected yet important domains, i.e., studies of spin qubits and spin liquids.

Recent technological developments have made the following question no longer a fantasy: can one construct a qubit platform, one atom at a time, with an STM? Together with colleagues, Chen has used and developed an arsenal of cutting-edge surface-science techniques to make this happen. Using STM-based atom manipulation, spin qubits can be constructed with Å precision. The biggest remaining question, however, is how to detect and control the spin qubits lying outside the tunnel junction, a task that seemingly violates the basic principle of STM. Chen and colleagues have realized that this is possible in the coherent regime —the spin under the tip can act as a sensor qubit that detects state populations of other spin qubits around it. With additional microwave control methods, fast gate operations such as CNOT and CCNOT are thereby demonstrated. This first atomic-scale multi-qubit platform promises a variety of simulation and sensing schemes with sub-nm precision.

Chen's second contribution concerns the use of STM to hunt for elusive quasiparticles called spinons. Long predicted in exotic states of matter called spin liquids, spinons carry no charge and are notoriously difficult to identify via conventional probes. In certain cases, however, spinons become itinerant, hence the material can be seen as a "charge-neutral metal". The question then becomes how to detect metallic behavior with an STM, a task that many STM pioneers have beautifully demonstrated. Using surface-science techniques (e.g., spectroscopic imaging and atom deposition), Chen and coworkers have made a series of discoveries, including imaging of spinon Fermi-surface ordering as well as spinon-induced Kondo screening of magnetic impurities. This methodology has carved out a new area of research for STM, where other types of exotic fractionalized quasiparticles such as Majorana fermions may now be visualized.

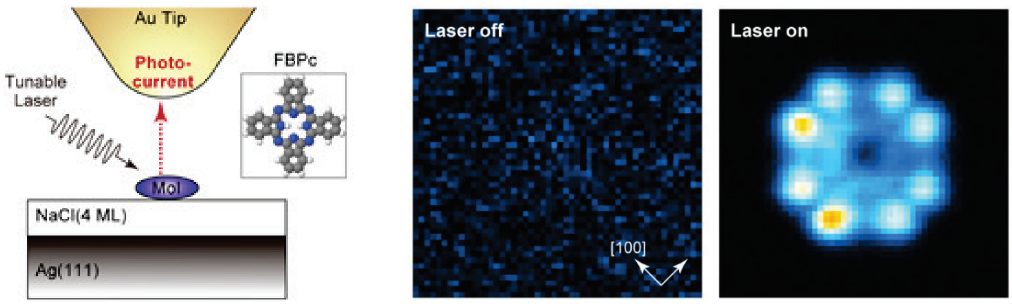


Award Achievements
The 4th Heinrich Rohrer Medal –Rising Medal–
Dr. Miyabi Imai-Imada

"For the significant achievement of the first atomic-scale visualization of photocurrent channels within a single molecule by the development of resonant fluorescence utilizing tunable laser techniques for single-molecule spectroscopy."

Dr. Miyabi Imai-Imada succeeded the first atomic-scale visualization of photocurrent channels in a single molecule, and a description of the mechanism with an ultimate precision based on the frontier molecular orbitals. Photoinduced electron transfer (PET) plays an essential role in light energy conversion processes, such as photocurrent generation, photocatalysis, and photosynthesis. The quest for an atomic-scale comprehension of PET has been a longstanding pursuit. However, the spatial resolution of conventional microscopic techniques for photocurrent measurement has previously been insufficient to resolve individual molecules, leaving the detailed mechanism obscured at the atomic scale. Dr. Imada-Imai, however, has recently achieved an advancement by enhancing the spatial resolution in photocurrent measurement by an order of magnitude higher than previous efforts. Her innovative approach combined a tunable laser with a scanning tunneling microscope (STM) to achieve the long-standing goal of visualizing photocurrent channels in a single molecule with atomic resolution. As the first author, she conceived and executed the project, with invaluable assistance from Dr. Hiroshi Imada, Prof. Yousoo Kim and her dedicated collaborators.

Dr. Imai-Imada's findings not only provide a novel strategy for enhancing the efficiency of light energy conversion in organic devices but also lay the technical foundation for unprecedented atomic-scale visualization of excited states. This breakthrough has the potential to revolutionize our fundamental understanding of functional energy conversion processes in the excited states.



(Left) A schematic illustration of the experiment and the structure of free-base phthalocyanine (FBPc). (Middle, Right) The current images of an FBPc molecule measured under the laser-off (middle) and laser-on (right) conditions.