Reviving an ultra-high vacuum scanning tunneling microscopy for research and education

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Amount requested: $80k

Project Description

In this project, we aim to revive an existing ultra-high vacuum (UHV) scanning tunneling microscopy (STM) system for enhancing research capabilities and for educational demonstrations to our graduate and undergraduate students. When Prof. Bruce Parkinson, a former Chemistry professor, retired, his old UHV-STM system is handed over to PI Chien and Co-PI Zhou. It is a UHV-STM system together with X-ray photoemission spectroscopy (XPS) and several surface science equipment, such as low energy electron diffraction (LEED). However, this whole system has not been functioning for years before moving to Chien's lab and with inspections, the STM controlling system is outdated while the hardware is still functioning. The company does not provide technical support for the outdated controlling system but can support a new controller module. This project is going to work with the company to wire up the existing UHV-STM hardware with the new controlling module to revive this high-end research equipment. This STM is a variable temperature STM (VT-STM) system from Scienta-Omicron (the manufacturer). The price for such STM system is around half million while the whole UHV system (including XPS, LEED, and STM etc) is around $750k. The success of this reviving will provide one extra STM system as well as the whole UHV system to the UW campus for high-end research activities as well as high quality educational hands-on activities for our graduate and undergraduate students.

World-Class Research and Graduate Education Enhancement

Working principle and the capability: STM is a cutting-edge experimental tool that provides real space image of surfaces of materials and molecules with atomic resolutions. It utilizes a metallic tip brought near the sample surface less than 1 nm and applying a bias across the tip-sample junction. The electrons in the sample or in the tip will "tunnel" through the vacuum barrier via a "quantum tunneling effect". Since the tunneling current through the quantum tunneling effect is very sensitive to the tip-sample distance, it can provide superior spatial resolution down to the atomic scale. In addition, since the signal relies on electron tunneling, it can probe the electron local density of states (LDOS) information at the tunneling locations. Combining the two unique capabilities, the STM can provide electronic properties at atomic scale. This makes STM an ideal tool to study novel materials, such as energy materials (solar cells), topological materials (to study the topological surface states), superconducting materials (to directly measure the superconducting gap), catalytic materials (to visualize the catalytic sites), and high entropy materials (to study elemental arrangement and surface oxidation process down to atomic scale). Furthermore, if a magnetic tip (such as Cr tip) is used, magnetic ordering at atomic scale can be revealed. This is important for studying magnetic skyrmion, a magnetic spin texture with non-trivial topology, and chirality induced spin selection (CISS) effect for chiral materials/molecules. All of these are world-class research topics.

Graduate Education Enhancement: There are two existing STM systems on campus. One in PI-Chien's lab and the other in Co-PI Zhou's lab. Both STM systems are very busy instruments. For example, in Chien's lab, three Ph. D students share one UHV-STM system. Zhou also has

three students in her group. This busy instrument makes the use for education not feasible. With the revived STM from this project, hand-on activities by using STM can be designed into graduate level courses. Chien and Zhou have been offering Surface Physics class in physics department and Surface Science class in chemistry department, respectively, that are popular for students in areas of science and engineering discipline. Students in these classes then can learn the state-of-the-art instruments and the data analysis of their own data.

Excellence in Undergraduate Education

There are some undergraduate courses that aim to train students on hand-on experiences in experimental and lab skills. In the physics department, Advanced Lab in Modern Physics and Electronics trains students on lab activities. The instructor, Rudi Michalak, has asked Chien a few times regarding providing educational opportunities for the undergraduate students enrolled in this class on STM and UHV technologies. As mentioned above, due to limited machine time beyond the research activities, there are not much we can do to provide such educational opportunities for undergraduate students. With this project, the revived STM system can provide such an advanced experimental experience for students in the class. In the chemistry department, educational STM systems are available for undergraduate students. STM is part of a bigger experimental equipment family – scanning probe microscopy (SPM), including atomic force microscopy (AFM), and magnetic force microscopy (MFM) etc. The educational STM systems are ideal for teaching students on the basics of the SPM systems. However, the vacuum technique is largely missing. Vacuum technology is extremely important in the semiconductor industry where devices and materials need to be handled under vacuum to reduce contaminations and defects. With the revived UHV-STM system, vacuum technology education can be included in the undergraduate education in the chemistry department.

Justification of Applying this Grant for this Proposal

Why not other sources

The amount (~$80k) of the electronic controlling system is too large for smaller internal funding that typically ranged near $25k and is too small for external instrumentation (like NSF MRI with a minimum budget of $100k). The project is to revive an existing STM system by updating the electronic controlling system, which is not justified in regular external research grants. This opportunity is the ideal source to achieve this.

The critical needs

The STM system did not function for years before the retirement of Prof. Bruce Parkinson. Without the electronic controller system, this system will stay like that for another decade. The cutting-edge hardware will be wasted for the great opportunity to enhance our research and education program.

Existing equipment

As mentioned above, two STM systems (one in Chien's and one in Zhou's labs) exist in the college. Chien's STM is a low temperature (4 K) UHV-STM, an instrument another level better than the system in this proposal, while Zhou's STM is a similar VT-STM system. As discussed above, with the current systems, they are limited in machine time to provide enough research and educational support. Having the STM in this proposal revived, it will greatly enhance our research and educational infrastructure toward tier 1 level.

Budget Justification

While we are finalizing the quotation from Scienta-Omicron, the manufacturer, the cost of the controller system is estimated to be $80k (verbally confirmed by the salesman). This includes shipping and testing.