配备计算机系统的CSTM-9000型扫描隧道显微镜

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扫描隧道显微镜（STM）是近几年发展起来的一种新型表面分析仪器。由于它可在原子尺度上研究物质的表面结构和与表面电子行为有关的物理、化学和生命现象，因此引起了从事表面科学、材料科学、生命科学和微电子科学等领域研究的科学家的高度重视。

STM的工作原理是基于量子隧道效应。将原子线度的极细针尖作为一个电极，待测样品的表面作为另一个电极，当二者间的距离小于1nm时，在外加偏压的条件下，电子会穿过针尖和样品之间的势垒从一个电极流向另一个电极。这即是所谓隧道效应。隧道电流强度对隧道间隙十个敏感。利用隧道电流对隧道间隙的依赖关系，通过电子反馈线路控制针尖在样品表面扫描时隧道电流恒定，也就控制了针尖与样品表面之间距离的恒定。这样，针尖在样品表面扫描时运动的轨迹就直接表征了样品表面形貌。如果在扫描时监测表面各点电流与电压的关系，就可得到表面隧道谱，给出表面电子结构的信息。利用两个电极间距离与隧道电流的依赖关系，还可以测量样品表面的势垒变化。

与其它表面分析仪器相比，STM具有以下优点：（1）具有原子级高分辨率，平行和垂直于样品表面方向的分辨率分别可达0.1nm和0.01nm。（2）可实时得到样品表面实空间的形貌，从而可用来研究一些动态变化。（3）可以得到最表面层的局域结构信息，而不是对整个表面的平均性质。（4）可在真空、大气、常温、低温甚至在水溶液下工作，拓宽了可被研究样品的范围。（5）可得到表面电子结构的有关信息。（6）观察过程对样品无损伤，仪器造价低廉。所有这些优点，使STM在近几年内得到了迅猛的发展，应用范围不断拓宽。迄今已召开了五届STM国际会议，发表有关论文1000余篇。

早期的STM一般由记录仪或示波器显示图象，这样不仅限制了仪器的分辨率，而且不利于数据的存储和图像的快速处理。中科院化学所于1988年初研制成功配备计算机系统的数字化扫描隧道显微镜CSTM-9000。仪器由STM探头和减震系统、电子控制机箱和计算机系统组成。该系统配备A/D、D/A和高分辨图形控制卡，得到的数据可以实时地在高分辨图形终端上以彩色灰度象显示出来，并可随时将数据直接存储在40M的计算机磁盘内。这些数据可随时调出，对图象进行平滑、背底扣除、图象增强、选区放大、原子间距离计算、剖面线分析、非正交性校正和三维图象显示等分析和处理。这种配备计算机系统的STM，不仅大大提高了工作效率，而且能够有效地进行数据分析和处理。这台仪器的横向分辨率为0.1nm，垂直分辨率为0.01nm。经中科院组织的专家鉴定认为，该仪器的主要性能指标已达到国际先进水平，而且造价低廉。国外同类产

品需9万美元，而CSTM-9000全套设备仅为十余万元人民币。CSTM-9000的研制成功，获1990年国家科技进步二等奖，现在已提供给多家大学和科研单位使用。

Computer-Controlled CSTM-9000 Scanning Tunneling Microscope

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Scanning tunneling microscope (S-TM) is a new kind of surface analytical instrument developed in recent years. The appearance of STM makse it possible to observe the arrangement of individual atoms on the surface of a sample and to study the physical and chemical properties related to the behavior of surface electrons. This unique technique has attracted special attention from scientists who work in the field of surface science, material science, life science and microelectronics.

The development of STM is based on the tunneling effect in quantum theory. If a small voltage is applied between an atomically sharp tip and the surface of the sample to be studied, a tunneling current will flow from the tip to the sample when the gap between them is reduced to a very close distance (less han 1 nm usually). The intensity of the tunneling current is very sensitive to the gap between the tip and the surface. An electronic feedback loop is used to keep the tunneling current constant by adjusting the tip-sample separation. The topography of the surface of a sample can be measured by raster scanning the tip in an x-y scan across the surface and measuring the height of the surface from the voltage applied to the piezo controlling the height (z) of the tip.

It is important to point out that since the tunneling current reflects the local density of electronic states at the surface of a sample STM can be used to perform atom-resolved electronic spectroscopy: i.e., scanning tunneling spectroscopy (STS). A local measurement of the electronic structure can be made experimently by stopping the tip over a particular site on the surface, opening the feedback loop so that the position of the tip remains fixed, and then recording a tunneling current versus bias voltage curve. The variances in the barrier height on the surface can also be measured from the dependence of the tunneling current upon the distance between the tip and the sarface of a sample.

Compared with other surface analytical techniques, STM owes the following unique advantages: (1) STM has a resolution as high as atomic level. The lateral and vertical resolutions can reach 0.1nm and 0.01 nm, respectively; (2) The topography of the surface of a sample in real space can de obtained in real time. The capability of real-time observation can be applied to the dynamic studies; (3) The local structure of the top layer, rather than the average property of the bulk can be observed; (4) STM can be operated under different environments, such as vacuum, ambient temperature, low temperature, etc. Samples can even be immersed in water or other solutions. This capability makes STM measurements on a wider variety of samples than virtually any other technique; (5) The information about electronic structure on the surface of a sample can be obtained; (6) In most cases, special techniques for sample preparation are not required, and the detection would not damage samples. Furthermore, the cost of the instrument is relative low. All these advantages mentioned above encourage the rapid development of STM in recent years and widen the range of its applications. Five international conferences on STM/STS have been held and more than 1000 papers regarding aspects and applications of STM have been published in broadly viewed journals so far.

In the original design, the image data were recorded and displayed by x-y plotter or oscillograph. With improved resolution or more complicated surface structures this sample method could no longer satisfy increasing demands on picture quality. Furthermore, the image data "acquired" were not in a computer-like format. Therefore, fast picture handling, such as archiving, retrieving, transferring between computers, etc., was difficult to realize with this system.

A computer-controlled STM has been constructed at Institute of Chemistry, Academia Sinica and commercial ones (CSTM-9000) have become available. The instrument consists of core STM, vibration isolation system, electronics and computer system. The hardware of the computer control system includes the IBM PC/AT computer, high-speed and high-resolution A/D and D/A converter cards, a high-resolution graphics card and a graphics terminal. Z-axis topography or tunneling current data can be displayed during scans in real-time in top-view. Topview images are presented with specimen tilt and offset subtracted. After the sample has been scanned, a series of additional display modes are available to aid in data analysis. Data can be presented as height or slope-shaded-3D surface plots. The operator can select one of seven predefined color tables or design his own using the color editor. Analysis and processing of images include image enhancement, correlation, cross-sectional analysis and image zoom, etc. The lateral and vertical resolutions of this instrument is 0.1 and 0.01 nm, respectively. The commercial STMs have been used in many laboratories of universities and institutes.