Present Views and Future Prospects of Thin Film and Surface Physics

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During my third year in university (1964), I investigated the temperature dependency of electrical conductivity in discontinuous metallic thin films as part of student experiments. In this regard, conductance through film grains has a semiconductor-like temperature dependency having an activation energy inversely proportional to grain radius. At that time, Neugebauer and Webb had showed that this could be explained by an activated tunneling mechanism in which the energy of charging film grains by a single electron is the activation energy. The interesting aspects of this phenomenon prompted me to perform these experiments. In addition, Ivar Giaever, who received a Nobel prize for measuring superconducting gaps by measurement of tunnel current between superconducting thin films, had observed a Coulomb blockade in conductance through Sn grains that form a thin oxidized film on a surface. Accordingly, the above phenomenon can also be regarded as a classical phenomenon in what is called a "trivial effect." As you know, however, the measurement of conductance through literally one grain by a scanning tunneling microscope (STM) and its explicit theoretical treatment came as a big surprise. Consequently, after treating tunnels between grains theoretically in a semi-classical manner and performing similar calculations and experiments, I was somewhat disappointed to have been "beaten to the punch" in this way. This so-called Coulomb blockade phenomenon also suggests that a staircase effect in tunnel-current characteristics can be obtained through multiple instances of grain charging by an electron, and that memory with storage retention can be achieved at room temperature for sufficiently small grains.

The invention of the STM was a major breakthrough. With a structure featuring a sharpened probe tip that could pick up information from a local area on a surface, the STM takes on the form of a profile meter. Furthermore, as the tunnel current emitted from one atom on the sharpened probe tip has atomic-order resolution, the STM makes it possible to actually see individual atoms. A person knowledgeable of experimental electronic circuits can easily create an STM-related mechanism. For example, if information from the surface of the probe can be fed back as position data, the result is a scanning probe microscope (SPM). Atoms and molecules can also be observed as well as manipulated by an atomic force microscope (AFM), but determining the makeup of a surface on a large scale requires high-speed scanning and/or parallel operation of many probes that can each view a local section. In short, nano techniques having a two-dimensional span as opposed to "pinpoint nano" are desirable. Without such techniques, we will not be able to take full advantage of the outstanding features of nanotechnology to achieve novel devices for conveying information.

In relation to phenomena involved with material properties, the discovery of materials exhibiting new properties can give birth to new developments. Films of the carbon family such as diamond thin films and fullerene are examples of such materials, while the carbon nanotube is a key example of how the discovery of a completely new material can lead to explosive progress in research. It should be mentioned here that a joint program on such topics was formed among concerned divisions at this autumn's annual meeting of the JSAP. Among researchers that have created diamond thin films, some noticed the existence of whisker-like matter, and the discovery of this structure should be commended. Configuring carbon nanotubes with such a structure would be optimal for STM and AFM probes, and a structure that could enclose various kinds of atoms and molecules within a tube would be similar to a peapod type of atom/molecule syringe. This structure is also expected to act as wiring material between man-made nanodots.

Thin film and surface physics covers a wide area of research. In the field of ferroelectrics, for example, materials development and the development of film-formation techniques are actively being pursued with the aim of achieving ferroelectric memory. Furthermore, the discovery of new material properties is linked with the development of practical devices. While piezoelectric materials have been known for some time, ZnO, which has come to be used as a surface filter, is gaining prominence as a newly evolving material. In the field of transparent conducting films, indium tin oxide (ITO) is a substance that has been researched for some time, but research continues with the aim of improving its properties even further. These technologies include many divisions of applied physics plus crystal engineering, applied electronic properties, and vacuum and surface techniques that act as a basis for creating devices. As such, they are becoming the foundation of modern industry including the development of new technologies for the fabrication of various types of thin films.

The International Conference on Atomically Controlled Surfaces, Interfaces and Nanostructures has been held by the Thin Film and Surface Physics Division every two years in Europe, the United States, or Japan since its first meeting in Tokyo in 1991. The word "Nanostructures," by the way, was added to the name of this conference at the 1999 meeting held in France. The 7th International Conference known as ACSIN-7 will be held in November 2003 at the New Public Hall in Nara, Japan. We are looking forward to strong participation from overseas researchers at this meeting. You can obtain more information at http://www.ele.eng.osaka-u.ac.jp/acsin7/.

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