Presentation of Foundation-Assisted Research Findings 2003
Control and Application of Nano-structure

Chairman Seya

The 11th Presentation of Research Results was held in the U Thant Conference Hall of the United Nations University in Tokyo on July 15. Following Chairman Seya's greeting, Foundation director, Professor Ryoichi Ito, Department of Science and Engineering, Meiji University, delivered the opening speech as the Selection Committee Chair for Natural Sciences Area 2. Kyoto University Professor Emeritus Teruya Shinjyo, a member of the same committee, and Professor Yasuhiro Shiraki of the Graduate School of Engineering, Tokyo University, presided over the presentation of the five research project results summarized below.

Professor Ito, Selection Committee Chair

Professor Shinjyo, Selection Committee member

Professor Shiraki, Selection Committee member

Developments in the Tunnel Magnetoresistance Effect in Spin Electronics
Terunobu Miyazaki, Professor, Department of Applied Physics, Graduate
School of Engineering, Tohoku University

Matter is a collection of atoms and those atoms are comprised of a nucleus and electrons moving about its periphery. These electrons have both electrical charge and spin, and moreover, there are two types of spin, left and right, that depend upon the direction of rotation. Accordingly, the electrons have angular momentum for the orbital rotation and the spin, respectively. However, the spin angular momentum produces a magnetic moment in the atom. Those items with the moment lined up in parallel are called ferromagnets and those pointing in disparate directions are called paramagnets. A sandwich of an electrical insulating material between ferromagnetic materials and the insulating material as thin as 1 nanometer, a tunneling current will flow as a result of the quantum effect and produce a large magnetoresistive effect. Research into magnetism and electrical conductance using tunnel junction thin films based on these principles has grown in abundance and developed a new field called spin electronics. This research is being pursued toward the development and applications of high-performance, lowpower- consuming magnetic memory devices.

Development of Gigantic Magneto—Optical Effects
Tetsuya Hasegawa, Professor, Department of Chemistry, School of Science, University of Tokyo

The direction of the electron spin in paramagnetic materials is disparate and does not indicate the quality of the material as a magnet. However, the spin becomes aligned in certain types of material when light is applied to it and is indicative of the magnetic properties. Conversely, it is also possible to create light with a magnetic field. If you use this mutual interaction of light and magnetism to cause light to react, it becomes possible to develop devices that can control light at will. In this research project, we made use of combinatorial chemistry techniques and laser molecularbeam epitaxy (MBE) to synthesize test samples of oxide thin films made of numerous elements at once. Using a minute probe, we rapidly evaluated the magneto-optical effects. Consequently, among the combination of diverse elements, thin films made of cobalt-doped titanium dioxide or manganite exhibited gigantic magneto-optical effects are found out. We expect this field to hold promise as a component technology for next-generation communications technologies, including optical memory devices.

Optical Microcavities Based on Self-Organized Pyramidal Structures and their Development into Nanophotonics
Ikuo Suemune, Professor, Research Institute for Electronic Science,
Hokkaido University

As a specific example of controlling the mutual interaction between substances and light, a resonator containing photons in a three-dimensional space has the possibility of being an efficient light-emitting element. One photon can be generated at a time using the discrete energy level of a quantum particle. However, the optimal conditions are limited since it is easy for the generated light to have various energy states mixed together in applications of only quantum particles. Therefore, the combination of quantum particles with a three-dimensional photon resonator creates a light source that rapidly emits a single photon each time. As a method of realizing this concept, we selectively grew a semiconductor thin film and imbedded quantum particles from cadmium sulphide (CdS) in a zinc sulphide (ZnS) pyramidal resonator with a single pattern size of approximately 790 nanometers. Sharp natural light emissions was observed at room temperature. This will make it possible to develop next-generation quantum information processing devices by realizing singlephoton emitting diodes for which the frequency of the light can be freely selected.

Characterization of Nanoscale Structures by Scanning Probe Microscopy
Yukio Hasegawa, Associate Professor, Institute for Solid State Physics,
University of Tokyo

Device miniaturization continues to shift from the micron to the nanoscale. In the world of the nanometer, we cannot ignore previously unremarked quantum-scale phenomena. In building devices, we are now being called upon to assess what phenomena are occurring and what we can use. In scanning tunneling microscopy (STM), the patterns of oscillations in the electron density of states is observed at the surface of a material from ripples on the surface of the material. And we can evaluate the pattern change and the material's reaction to items, such as thin films, placed on the surface. Moreover, we devised a self-excited oscillation structure on a needle-shaped atomic force microscopy (AFM) probe and observed the size of the force from the chemical bonding at work between the tip of the probe and the material. Using this probe, we also succeeded in manipulating atoms placed one-by-one by human agency on the substrate surface. We can look forward to applications of these technologies in both device fabrication and analysis.

Optical Observation and Creation of Nanostructures
Satoshi Kawata, Professor, Applied Physics, Graduate School of Engineering, Osaka University

We can expect to find a wide range of industrial applications if we can explore the nanoworld with photons. Since the energy level of photons is low, the damage to living tissues, cells and various organic materials is small and the range of applications become wide area. On the other hand, however, the energy density of visible spectrum and infra-red light is diffracted by light wave characteristics and may spread spatially over a range of several hundred nanometers. As a method of surmounting this obstacle, the first is nearfield Raman scattering in nearfield microscopy that makes use of photon tunneling. Second, is the method of containing photons for extremely brief periods of time in small spaces. In other words, this method piles more photons on top of photons to raise the photon density and uses a photon absorption process based on multi-photon, non-linear dispersion. As an example of a microstructure developed according to Method 2, we three-dimensionally scanned near-infrared laser light using the photopolymerization of a polymeric material and created a 5 x 8 micron cow, realizing the technology for nanolevel fabrication.