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Ultimate Manipulation of Atoms and Molecules A New Project

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In fiscal 1992, a new project under the MITI-sponsored National R&D Program, titled "Ultimate Manipulation of Atoms and Molecules" (or "Atom Technology" in short), has been initiated for a planned period of 10 years with expected total budget of about ¥ 25 billions. The "Atom Technology" Project aims at systematically establishing technology for precisely observing and manipulating individual atoms and molecules on solid surface (2 - dimensional) or in a free space (3 - dimensional), as a generic technology for diversified fields of industry, such as new materials, electronics and biotechnology.

1. INTRODUCTION

In a few years, we shall have the 21st Century. It is a fin-de-siecle just now. In this century, we had a number of major changes in the fields of science and technology. Since the invention of transistors four decades ago, electronics has been intimately involved in our daily life, and now has grown to one of key industries. However, its high growth rate up to now will not necessarily be guaranteed in the coming century.

For instance, in case of LSI memory chips, where the memory capacitance has increased with a rate of 4 times in 3 years, the pace is approaching to physical and technological limits, and the extrapolation of the current technology may suggest the presence of a non-surmountable wall at 0.1 m resolution in the end of this century.

The same applies to the materials science. An artificial superlattice film fabricated by depositing a few atoms-thick layers of different elements one over another is an assembly of interfaces, as it were. Hence, the main arena is the world of non-equilibrium, where no text book is available, and neither phase diagram nor almanac have authoritative power. Some revolutionary concept or approach is urgently needed.

An ultimate technology emerges out of such backgrounds as a great need, namely, static and dynamic observation and manipulation of materials and material formation at atomic and/or molecular levels, or handling of individual atoms and molecules. This radical technology closely adjacent to science may be called atom technology. Not only in electronics, but also in chemical industry and biotechnology, in reference to development of new catalysts, and decoding and manipulation of genes, the manipulation technology of atoms and molecules is urgently needed. This is a typical common basic technology of interindustrial and interdisciplinary nature. The project "Atom Technology" has been organized for meeting those needs.

2. ORGANIZATION, FUNDING AND STAFFING

The present project significantly deviates from the existing development-oriented MITI projects in respect to its nature and way of implementation.

As described above, a main purpose of this project is to establish a basic technology for precisely observing and manipulating individual atoms and molecules on solid surface and in 3-dimensional space, as a generic technology for various fields and industries. Namely, the project is to be categorized as a long-term fundamental research program.

Moreover, in order to stimulate strong interaction between researchers coming from different backgrounds, the project is to be implemented not through the conventional distributed research system, but through the concentrated joint research system, in which selected researchers from indus

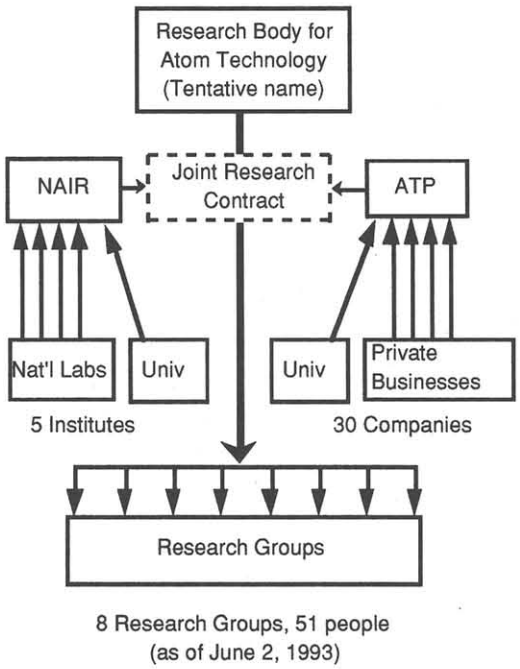

Fig. 1 Organization chart of the "Atom Technology" Project.

tries, academia and government research organizations, both domestic and overseas, are invited to Tsukuba area to pursue intensive joint research.

Around ¥ 25 billions, including labor cost by less than 20%, will be funded by the MITI for the project for a planned period of 10 years. Additional fund is expected to come from private sectors.

Figure 1 shows a chart describing organization of the Atom Technology project. NAIR represents the National Institute for Advanced Interdisciplinary Research which was founded on the 1st of January, 1993, in Tsukuba, as a new AIST institute attached to the MITI, while ATP the Angstrom Technology Partnership founded on the 16th of February, 1993. ATP, consisting of 30 private companies, is a sort of technology research consortium which is commissioned for the task of carrying out the project.

By the joint research contract between NAIR and ATP, the Research Body for Atom Technology (named tentatively, RBAT) was organized in May, under which researchers coming from academia, industries and government research institutes keep their equal partnership although the project is conducted in the buildings of NAIR.

As for the number of research staff members, it was initially discussed that a minimum of 50 is required to run the project effectively. However, RBAT has now 51 people (as of June 2, 1993) ; 17 from AIST institutes and 2 from the University of Tokyo, respectively, via NAIR, and 32 from private businesses via ATP. In addition, several post-doctoral fellows as well as graduate students are also participating.

Eiichi Maruyama (ATP) was appointed as the Project leader, Kiyoyuki Terakura (Univ. of Tokyo) and Kazunobu Tanaka (NAIR) as Project sub-leaders, while Hiroshi Tokumoto (NAIR), Masakazu Ichikawa (ATP), Masashi Ozeki (ATP) , Toshihiko Kanayama (NAIR), Takao Okada (ATP), Yoshinori Tokura (Univ. of Tokyo), Kiyoyuki Terakura (concurrently) and Kazunobu Tanaka (concurrently) as group leaders, respectively.

3. RESEARCH AREAS

The Phase I spanning first 6 years includes the following basic research areas :

(1) To exploit technologies for observing, identifying and manipulating atoms and molecules on solid surface under every conceivable condition and environment, by utilizing mechanical probe and focused beam technology, and for dynamically observing diffusion and chemical reaction of atoms and molecules on solid surface in-situ.

(2) To exploit technology for capturing atoms and molecules in a limited 3-dimensional space by utilizing ion trap and laser cooling to form atom assemblies and cause reaction, association and dissociation under strict control, and for observing the process in-situ. This may hopefully lead to realizing the self-organizing process of the biological system in the mechanism of forming atom assemblies.

(3) To exploit technologies for identifying, modifying electronic state of and manipulating organic molecules and polymers of biological significance, such as DNA, through the combination of mechanical probe and laser technology.

(4) To construct an innovative "theoretical experiment system" by combining a supercomputer and sophisticated software systems, for the purpose of theoretically elucidating atomic-molecular processes through the simulation based on the First Principle calculation.

These research areas are covered by 8 research groups in the Project, headed by 8 group leaders described above.

In actual research activities of 8 groups, nanoscience as well as nanotechnology (in more popular expression of "atom technology") should be emphasized as ambivalence of this project. Obviously, fabrication of novel nanostructures by means of novel techniques will be one main concern. At the same time, finding of new chemical and/or physical phenomena originating from them is another important expectation in this project.

In order to push up those dreams into reality, several key issues should be emphasized;

(1) scanning probe techniques on solid surface,
(2) in-situ dynamic microscopic observation techniques of gas-phase and surface process,
(3) self-organization mechanisms for preparing nanometer-scale structure, including self-limiting and self-assembly, and
(4) first-principle study of atom-molecule processes.

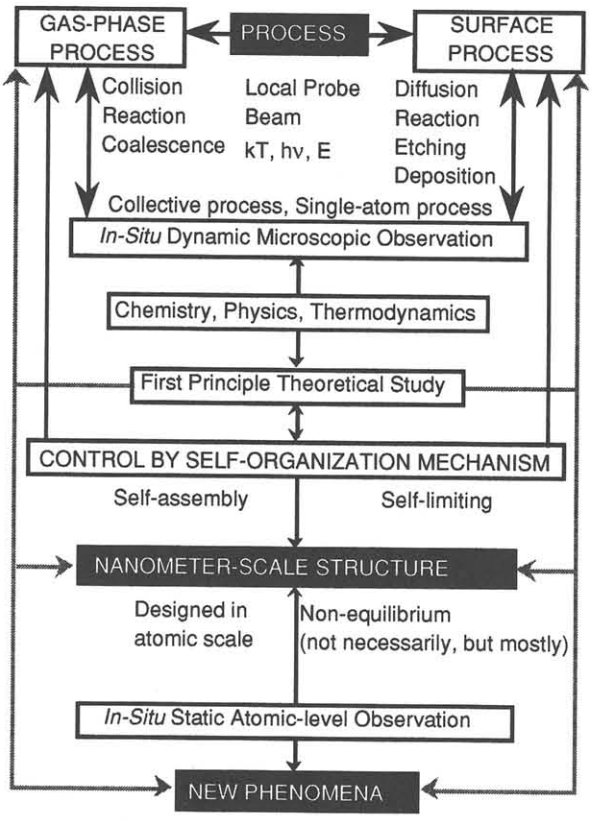

Fig. 2 Block diagram describing key issues of the "Atom Technology" Project.

The reason why the above key issues are needed is shown in Fig. 2.

SUMMARY

A challenge to nano science and nanotechnology is urgently needed, which is common to electronics, materials science, biotechnology and other fields.

The project "Atom Technology" started in 1992 FY for a planned period of 10 years. It is to be implemented through the concentrated joint research system, in which researchers from industries, academia and national labs, both domestic and overseas, are invited to the Research Body for Atom Technology to pursue intensive joint research.

Scanning probe microscopy as well as beam-probe techniques, in-situ dynamic atomic-level observation techniques, self-organization mechanisms, and first-principle theoretical studies, are pointed out to be key factors for opening up nanoscience and nanotechnology.