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Invited

Scope of Atom Technology Project —Toward "Self Organization"—

Eiichi Maruyama

Joint Research Center for Atom Technology (JRCAT)
1-1-4 Higashi, Tsukuba, Ibaraki 305, Japan

Atom Technology Project is a MITI's new 10-year project which started in the fiscal year of 1992. It is being carried out in the Joint Research Center for Atom Technology as an intensive and cooperative research work of national laboratories, universities and industrial laboratories, both domestic and overseas. It aims at new breakthroughs in material science and technology.

1. Introduction

The invention of the scanning tunneling microscope (STM) by Binning and Rohler opened a new possibility of the observation and manipulation of individual atoms and molecules one by one.

Since then, many variations of the scanning probe method have been developed and our understanding of solid state surface has made a remarkable progress.

"Atom Technology" refers to technology for precisely observing and manipulating individual atoms and molecules on a surface or in free space, and to its supporting technology. It is expected to allow the development of innovative structures and materials which have been hitherto unknown.

Atom technology is regarded as being a technology fundamental to the future of various industrial and technological fields such as material science, biotechnology, electronics, chemistry and so forth.

2. Atom Technology Project

The Ministry of International Trade and Industry (MITI) has embarked on a project entitled "Research and Development of Ultimate Manipulation of Atoms and Molecules (Atom Technology)" under the Industrial Science and Technology Frontier Program (formerly called the National Research and Development Program) from fiscal year 1992. The total budget of the project is expected to be 25 billion yen.

As a governmental drive mechanism for this project, the National Institute for Advanced Interdisciplinary Research (NAIR) was instituted on January 1, 1993, under the auspices of the Agency of Industrial Science and Technology (AIST) of MITI. In response to the government's R&D program, Japanese industries have decided to amass expertise and resources, both domestic and overseas, to pursue this project. And they have founded a technological research association, the Angstrom Technology Partnership (ATP).

3. Organization

The Atom Technology Project is being intensively carried out in the "Joint Research Center for Atom Technology (JRCAT)". This center, instituted under the equal partnership of the NAIR and the ATP, employs elite research scientists invited from government research laboratories, private enterprises, universities, and overseas research organizations (Fig. 1).

4. Research Groups and Themes

By the beginning of April 1994, 83 research scientists were resistered as the members of JRCAT. They are carrying out their research work in ten research groups. Their themes are as follows :

a) Scanning probe techniques for observation / manipulation of atom / molecules on solid surfaces (Tokumoto Group)

This group try to develop the scanning probe techniques for observation and manipulation of

atoms and molecules on solid surfaces and then to explore the new nanoscale structures showing the new physical phenomena.

b) Observation and formation of atomic-scale structures using beam technology (Ichikawa Group)

In situ characterizations of structure and composition of surfaces and interfaces are performed at atomic / nano-scale by combining scanning interference electron microscopy (SIEM, a kind of electron holography) and scanning tunneling microscopy (STM).

c) Measurement and control of the surface reactions in nano-structure fabrication (Ozeki Group)

The main purpose of this group is to establish a technological base of nano-structure fabrication on solid surface. To this end, they use chemical reactions between molecules and solid surface without any mechanical probes such as STM or AFM.

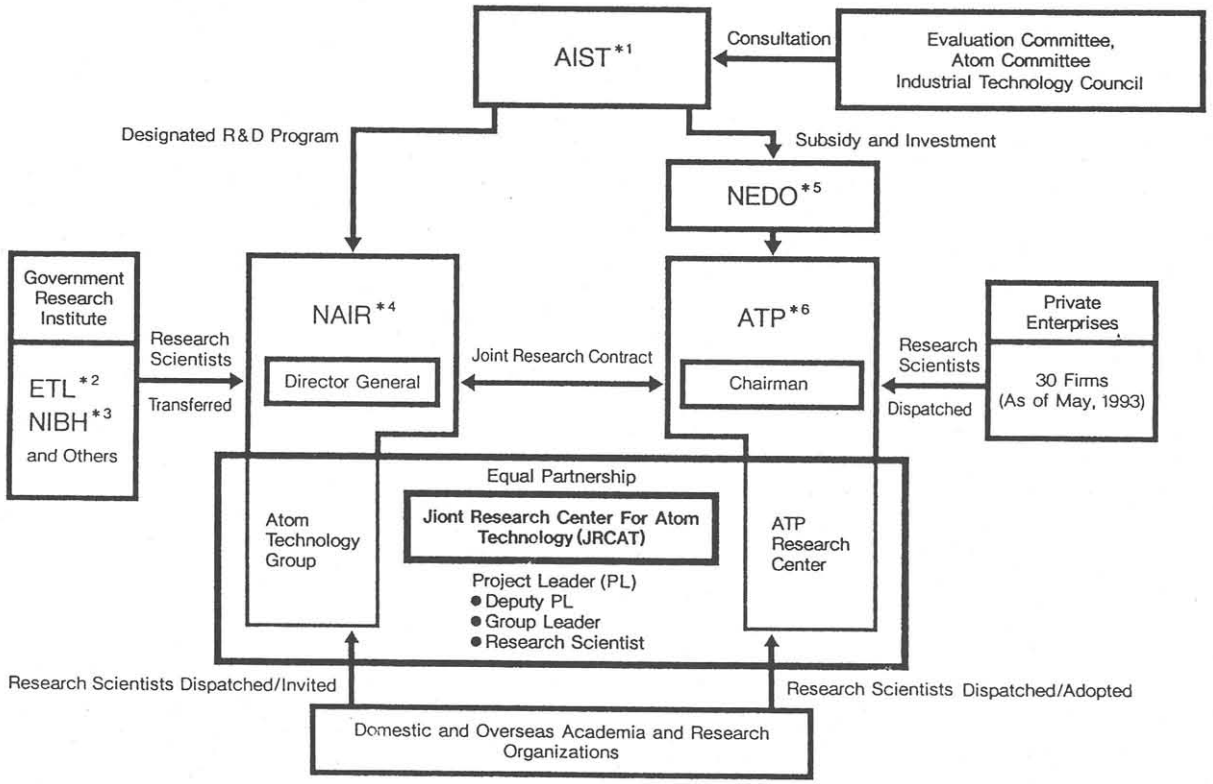
d) Formation and manipulation of nanoparticles for controlled self-assembly of nanostructures (Kanayama Group)

It is a significant challenge to develop formation technology of nanostructures with atomic precision. This group is seeking to construct desired nanostructures by exploiting self-assembly of nanometric building blocks.

e) Observation and manipulation of organic molecular structures (Okada Group)

The scanning probe microscopy (SPM) has already become a useful tool in surface in its ability to characterize surfaces of hard materials (metals, semiconductors, etc). Moreover, this group is assuming that laser-induced fluorescence spectroscopy (LIFS) can be keys to determine the nucleotide sequence of DNA.

f) Exploration of new electronic materials and related physics for development of atom technology (Tokura Group)



*1 Agency of Industrial Science and Technology
*2 Electrotechnical Laboratory
*3 National Institute for Bioscience and Human Technology
*4 National Institute for Advanced Interdisciplinary Research
*5 New Energy & Industrial Technology Development Organization
*6 Angstrom Technology Partnership

Fig. 1 Research Organization Chart for JRCAT

This group aims at exploring new electronic materials and related physics for development of atom technology. The exploratory materials they focus on are (1) 3d transition metal oxides with controlled band filling as strongly correlated electron systems, and (2) organic molecular systems with specialized functions.

g) Theoretical techniques for atomic and molecular processes (Terakura-Uda-Hamada Group)

The mission of the group is to carry out theoretical and computational researches in cluster, surface, and solid state physics on the microscopic basis in order to provide prescriptions for manipulating materials at the atomic level and to design novel materials with desired properties solely by computational method.

h) Exploratory studies in burgeoning technological fields (Tanaka Group)

This group is dedicated to the exploration in sprouting technological fields. In six years of Phase I, the group will strive for studying the dynamic process of structure formation and physical properties at the level of atoms and molecules, and ultimately leading to the creation of new material structure and function, with three different systems : (1) silicon hydride thin film, (2) magnetic thin film and (3) electrical double layer at the solid-liquid interface.

5. Toward " Self Organization"

The Atom Technology Project aims at precise manipulation and control of atoms and molecules. It will produce novel orientation of atoms and structure of novel materials and devices in atomic scale. In order to utilize physical or chemical properties of these materials for industry, however, some multiplication process of the same atomic configuration might be indispensable. This process may be called "Self Organization". Crystal growth might be a most primitive example of the Self Organization. Formation of biological substance might be a most sophisticated one. The ultimate aim of our Project, therefore, will be the understanding and control of self organization of new materials. Even if this target is too far for 10-year project, it is certainly worth challenging and every new step toward Self Organization will result in a new progress of material science and technology.