4-2　WTEC調査報告：分子研におけるナノ粒子・ナノ技術

WTEC (World Technology Evaluation Center)のナノ粒子・技術研究チームが下に掲げた日程で来日, 来所し, 所内研究者とのインタビューを行い, 分子科学研究所における「ナノ粒子・ナノ技術」に関する研究を調査した。

訪問者：Dr. Lynn Jelinski　Cornell大学教授　WTECナノ粒子・技術研究チームメンバー

訪問日：平成9年7月23日

所内対応者：

伊藤光男所長, 薬師久彌教授, 渡辺芳人教授, 塩谷光彦教授, 加藤立久助教授, 藤田誠助教授

以下に, (1)WTEC概要, (2)WTECナノ粒子・技術研究概要, (3)分子研におけるナノ粒子・ナノ技術の調査報告を掲載する。

4-2-1　WTEC program

The World Technology Evaluation Center (WTEC) at Loyola College (previously known as the Japanese Technology Evaluation Center, JTEC) provides assessments of foreign research and development in selected technologies under a cooperative agreement with the National Science Foundation (NSF). Loyola's International Technology Research Institute (ITRI), R.D. Shelton, Director, is the umbrella organization for WTEC. Paul Herer, Senior Advisor for Planning and Technology Evaluation at NSF's Engineering Directorate, is NSF Program Director for WTEC. Several other U.S. government agencies provide support for the program through NSF.

WTEC's mission is to inform U.S. policymakers, strategic planners, and managers of the state of selected technologies in foreign countries in comparison to the United States. WTEC assessments cover basic research, advanced development, and applications. Panels of typically six technical experts conduct WTEC assessments. Panelists are leading authorities in their field, technically active, and knowledgeable about U.S. and foreign research programs. As part of the assessment process, panels visit and carry out extensive discussions with foreign scientists and engineers in their labs.

4-2-2　WTEC Worldwide Nanoparticles/Nanostructures Study: Technical Issues

The purpose of this study is to provide a worldwide assessment of the status and trends in nanoparticle and nanostructure technology and applications research and development. We seek to provide the scientific/engineering community with a critical view of the field, to help identify the most promising areas for future research and industrial development, to stimulate the development of an interdisciplinary and international community of nanoarticles/nanostructures researchers and to identify opportunities for international collaboration in the field.

To meet the goals of the study, we would like to hold discussions that will illuminate both the fundamental scientific and technological issues in nanostructure research and development. This study will consider the full range of issues concerned with nanoparticle/nanostructure synthesis, processing and utilization for creating novel nanostructures. Application of nanostructured materials will cover a broad range of areas, including (1) dispersions and coatings, (2) high surface area materials (such as catalysts and sensors), (3) nanostructured modification of bulk properties (such as quantum dot lasers and GMR devices). In addition, the utilization and incorporation of organic synthesis techniques will be considered, such as those used in the formation of biological materials, and carbon-based nanostructures (for example, C_{60} and carbon nanotubes). Within the wide range of areas and scientific disciplines to be addressed, we wish to focus on the following scientific issues pertinent to all of these areas:

1) What are the scientific drivers (i.e. new phenomena, theory, stimulation methods, instruments) and application advantages to

be gained from control at the nanostructure level? What scientific and technological breakthroughs may be possible as a result?

2) In order to synthesize materials and manufacture devices incorporating these advantages, what are the critical parameters to control in the synthesis of the material and device manufacturing: what is the current status and what is the likelihood of progress?

3) What is the likelihood, and the time scale, for brining such synthesis techniques, and ultimately applications, to fruition? What are the critical issues for manufacturability (e.g. scale up, reproducibility, reliability)?

4) what are the R&D philosophy, directions, and basic concepts underlying the development of nanotechnology in your country in government, academia, and industry? Are any new educational initiatives related to nanotechnology being developed?

5) What is the expected financial dimension of this effort over the next 5-10 years in the government, academia, and industry? Does your country have national projects for the development of nanotechnology and, if so, what are the specific technical emphases in these projects?

6) In what areas of nanostructure technology would there likely be fruitful opportunities for new international collaboration among?

4-2-3 WTEC Nano Panel, Japan Site Reports

Reported by Prof. Lynn Jelinski
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Technology Research Institute
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Dr. Kyuya Yakushi, Professor
Dr. Yoshihito Watanabe, Professor
Dr. Mitsuhiko Shionoya, Professor
Dr. Tatsuhisa Kato, Associate Professor
Dr. Makoto Fujita, Associate Professor

INTRODUCTION

The Institute for Molecular Science (IMS) is one of three institutes under the umbrella of the Okazaki National Research Institutes. The other two are the National Institute for Basic Biology and the National Institute for Physiological Sciences. Together, they employ over two hundred professionals and about 180 technical and support staff. Each of the three Institutes is headed by a Director General, who reports to the President. The Institutes are funded by the Ministry of Education, Science, Sports and Culture (Monbusho).

RESEARCH AND DEVELOPMENT

Research at IMS is directed toward understanding the properties of molecules and molecular assemblies, and to the design and synthesis of new materials, especially those with novel properties. IMS is strongly oriented toward basic research. The faculty members have few teaching duties and can devote themselves, full-time, to research.

IMS has an unusual, almost Harvard-like method for ensuring that research remains fresh and of high quality. This is done by imposing the rule that none of the Assistant and Associate Professors can remain at IMS as full Professors. Instead, they must go to another institution for promotion, as IMS always hires their full Professors from outside. The faculty with whom I spoke, including junior professors, thought that this policy worked quite well.

Research at IMS that falls within the scope of this report is in the general category of synthesis of novel materials, some with inspiration from biology and some with biomolecules as the building blocks. Most of the work that involves nanoparticles involves some form of organometallic chemistry. The hallmarks of the research are two-fold: creativity and the soundness by which thenew materials are characterized and evaluated. Much of the research the WTEC team saw on this visit has been published in high-quality journals such as Nature and the Journal of the American Chemical Society, attesting to the international reputation of IMS and the high quality of the research. Several of the faculty have good collaborations with other scientists in Japan. One has an on-going and productive NSF-funded collaboration with the University of Rochester, and another introduced the visiting WTEC team members to a visiting researcher, on leave from Emory University, who was spending six months in his lab.

Japan seems to be in a leadership role in the production of metallofullerenes. IMS has a large-scale facility for producing fullerenes, and Prof. Kato has been successful in producing C_{82} that contains Sc, Y, and La inside the cage structure. Kato is now using the metal inside the fullerene as a way to "tune" the reactivity of the outside. For example, he has shown how La@C82 can be reacted with disilanes and diazo compounds to form adducts. A combination of ESR and theory is being used to explain the reactivity of the precursor and the products obtained. One could imagine how this ground-up assembly of nanomaterials could be polymerized to produce larger molecules with novel properties.

Another area of research involves the characterization of magnetic transport and optical properties in phthallocyanines (Pc). Of special interest is $PtPc(AsF_6)_{0.5}$, whose transport properties are being studied under high pressure.

Prof. Shionoya, a very young full Professor who recently came to IMS from Hiroshima University, is using novel combinations of DNA, metal ligands, DNA templating, and proteins to produce molecular wires, molecular hoops through which DNA could be threaded, and double-stranded peptides whose helix pitch could be controlled by an entrained copper, that could be induced to go from Cu(I)tetrahedral to Cu(II)square planar, perhaps by electrons delivered by an STM tip.

In a very creative and careful series of single point mutations, Prof. Watanabe has uncovered evidence for, and verified the existence of, a "push-pull" mechanism for cytochrome C peroxidase. This was done by drawing an analogy between peroxidase and cytochrome P-450, and using insights gleaned from similarities in the active site.

Finally, Prof. Fujita's work involves the approach of using self-assembly by transition metals to form organized large structures. He has been able to make various nanocages, which have potential applications for controlled drug release. He has also used three-dimensional organometallic cage compounds to achieve a "ship-in-a-bottle" synthesis of organic molecules, and is currently producing nano-structured molecules with larger cavities than have ever been made before.