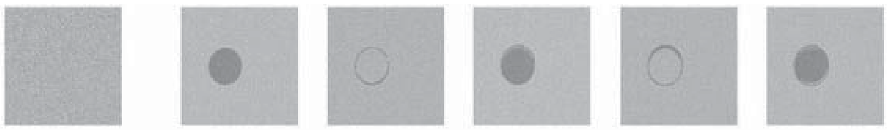
Toward a Healthy Future

Almost four years have passed since we started our project "Nanotechnology Excellence, Nihon University — Nanomaterial-based Photonic, Quantum and Bio Technologies —" in the strategic research scheme of our university, "Nihon University *N*. Research Project."

The purpose of our project is to contribute to finding solutions for three big issues — (1) treatment of cancer, which accounts for a third of deaths in Japan, (2) shortage of fossil fuel and increase in the atmospheric CO_2 concentration, particularly after the Fukushima accident, and (3) dire need for massive and secure information processing — for a healthy future comes true. Despite the apparent diversity of these issues, views from nanoscience and nanotechnologies may allow a common approach from different but relevant fields. Our approach to these issues is on the basis of nanomaterials, particularly from the viewpoints of quantum mechanical interactions of matter with light. This interdisciplinary endeavor is being made through collaboration among practitioners in science, engineering, and medicine from five of the Colleges of Nihon University.

The first year saw some excellent achievements, such as one in the area of super-high speed recording, which was covered as research topics in several journal articles, and another on the analysis of genetic network, which was published in *Nature* (Nagase, Balmain et al., *Nature* 2009, *458*, 505). The most notable in the second year was the research on quantum information by Inoue et al. The three major achievements were that: (1) the highest rate of 2.8 kilobit in the entanglement distribution at the telecommunication wavelength to date, (2) the detection efficiency of 98.4% with their photon-number resolving detector, the highest for an optical photon detector, and (3) the fabrication of the first superconducting nanowire single photon detector using niobium film. One of these works was published in *Nature Photonics* (Inoue et al., *Nat. Photon.* 2010, 4, 655.) and led to the successful awarding of the Strategic Information and Communications R&D Promotion Program (SCOPE) funded by the Ministry of Internal Affairs and Communications. In the third year, the highest rate (24 kbit/s) and the longest distance (100 km) quantum information transfer were achieved using the highest-rate single-photon detector and the most sensitive photon-number resolving detector, which were developed by Inoue and co-workers (Inoue et al., *Phys. Rev. Lett.* 2011, 106 250503). In the area of super fast recording, behaviors of spins in a magnetic material in a femto second regime were revealed for the first time (Tsukamoto, Itoh et al. *Nature* 2011, 472, 205).

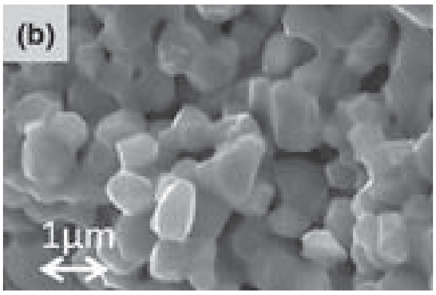
In the fourth year, Tsukamoto et al. have found, surprisingly, that heat is enough to flip over the magnetization in a work published in Nature Communications (Tsukamoto, Itoh et al., *Nat. Commun.* 2012, 3, 666). This is unconventional process given that heat is the antipodal to directionality. The process occurs at room temperature, which bodes well for practical applications.



Ultrafast heating flips over the magnetization! *Nat. Commun.* 2012, *3*, 666.

In the energy area, greener alternatives are being researched that maximizes the use of solar energy as an energy source and hydrogen as an energy storage material. Stored energy as hydrogen may again be converted to electricity with fuel cells. Solid oxide fuel cell consists of three major components: the fuel electrode, the electrolyte, and the air electrode. Hashimoto et al. (*J. Amer. Ceram. Soc.* 2012, *95*,

3802) has developed the optimized material for each of these phases: a material for the fuel electrode, Fabrication and performance tests for prototypical fuel cells using these materials are ongoing.



Optimized material for the electrode in fuel cells. *J. Amer. Ceram. Soc.* **2012**, *95*, 3802.

In the medical area, our research on pyrrole-imidazole polyamides, a class of synthetic compounds that can be tailor-made to selectively recognize the base sequences in DNA, covers a whole range from the synthesis and chemical characterization to in vitro and in vivo studies. Some PI polyamides showed positive results in retarding the growth of osteosarcoma cells, hepatoblastoma cells, and Wilm's tumor cells. Investigation on other PI polyamides has progressed further and now reached the stage of marmosets experiments, which are conducted in collaboration with the Central Institute for Experimental Animals. Preliminary results suggested that the drug is effective in the inhibition of the skin scar. In the area of regenerative medicine, Fukuda et al. are attempting to induce iPS cells by using PI polyamides which target TGF-β1. Kano et al. is developing new pluripotent cells from fat cells on the bases of his finding that fat cells can be dedifferentiated. In the environment of this collaborative project, a new combination of technology and medicine is being formed. Application of plasma for the treatment of skin malignant melanoma is now being examined.

A very basic quantum mechanical riddle was solved this year. The Hund rule, a textbook principle of quantum mechanics, has concealed its origin for a long time until Sako et al. found the mechanism behind the rule (Sako et al., *J. Phys. B* 2012, 45, 235001). The work was chosen as an "IOP Select" paper for the novelty, significance and potential impact on future research. This work will also be highlighted in *Europhysics News*.

Journal of Physics B: Atomic, Molecular and Optical Physics > Volume 45 > Number 23

Tokuei Sako *et al* 2012 *J. Phys. B: At. Mol. Opt. Phys.* **45** 235001 doi:10.1088/0953-4075/45/23/235001

Origin of the first Hund rule and the structure of Fermi holes in two-dimensional He-like atoms and two-electron quantum dots

IOPSELECT

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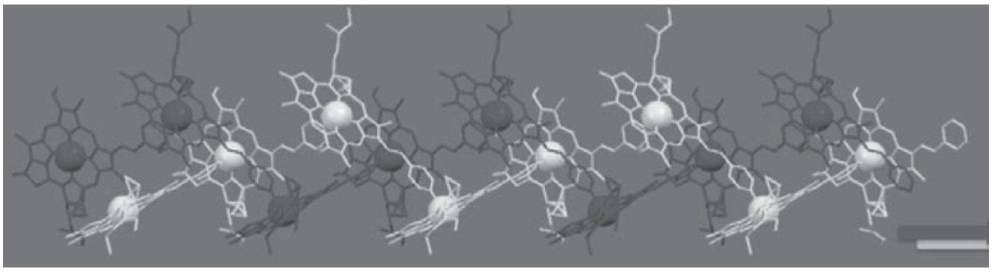
Self-assembly of molecules leads to higher order structures and novel materials. Finding new motifs of molecular assembly is important for the understanding how molecules assemble themselves and for the development of new functional materials. Otsuki et al. found that synthetically modified chlorophyll molecules form double stranded helices reminiscent of the DNA double helices. Work is ongoing for revealing the structural requirements for the formation of such structures as well as photophysical properties of these assemblies.



X-ray crystal structure of a double helix of synthetic chlorophyll molecules.

Training young generation researchers is another important objective of our project. This year 10 research fellows including post-doctoral fellows and 4 research assistants are working with financial support from the Project. Good news is that 6 students who presented their works as part of the Project were awarded excellent presentation prizes in academic meetings.

We are doing our best, through our research, to create a center of excellence in the field of nanoscience and nanotechnology, which will hopefully be recognized as such in the scientific communities academic and industrial, domestic and international, in another year when the Project will have been completed.

Joe Otsuki, Principal Investigator, January 19, 2013.