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Research HIGHLIGHTS

Research Spawns New Advances in Optoelectronic Technology

An Air Force Office of Scientific Research three-year research initiative is developing the use of a natural resource for optoelectronics that could significantly impact long distance transmissions and large-capacity memory devices.

The natural resource is marine DNA derived from salmon sperm. Dr. Naoya Ogata of the Chitose Institute of Science and Technology in Hokkaido, uses DNA as a host medium, coupling it with various optically-active molecules (dyes) to produce the world's first-ever DNA-based, flexible, photonic films. His unique concept of versatile and bioconjugate materials was first introduced at the Air Force Research Laboratory under the Window-on-Science program.

The Chitose Institute of Science and Technology is a new technical college in Japan and the first of its type in the world devoted to the photonic sciences. The focus at the Institute is the application of materials, devices, and systems for optical communications and optoelectronics, with an ultimate end being the optical computer.

Ogata, a renowned organic and molecular chemist, takes DNA from the sperm of salmon that swim the Chitose River in Hokkaido, Japan. Salmon eggs, being quite popular in Japanese cuisine, do not overburden the ecosystem, while the sperm are over-abundant to the extent of being an environmental pollutant at an estimated 10,000 tons extra per year.

The Ogata group has devised techniques to then convert the easily extracted DNA from water-soluble to insoluble form. The extracted DNA supramolecules are an interesting molecular material with molecular weights of over 1 billion — something no synthetic polymers can achieve. Though the molecules can be hydrolyzed in a wet state, they are quite stable when dry.

There have been few studies on applications that exploit the electrical and optical properties of organic materials and fewer yet on the unique properties and structure of dye-DNA complex as an intelligent material. DNA is a natural polymer and also an versatile polymer in that it exhibits specific and selective responses toward external stimuli such as light, heat or electricity — as required to maintain life.

Most DNA research has concentrated on gene technology, not on the novel properties — such as semiconductivity, enhancement fluorescence, and self-assembled supramolecular structure — that make DNA complexes suitable for the construction of molecular, optical, photoelectric, and electronic devices.

Some of the results of the research to date have been:

- Excited states of the DNA complexes have led to the emission of florescent light. Photochromic thin films were prepared by using DNA-CTM complex as a matrix. Excited states of photoproducts led to the emission of fluorescent light. This allowed the group to detect the change of fluorescence intensity in the solid media by recording excitation/emission spectra during UV-light irradiation and visible irradiation.

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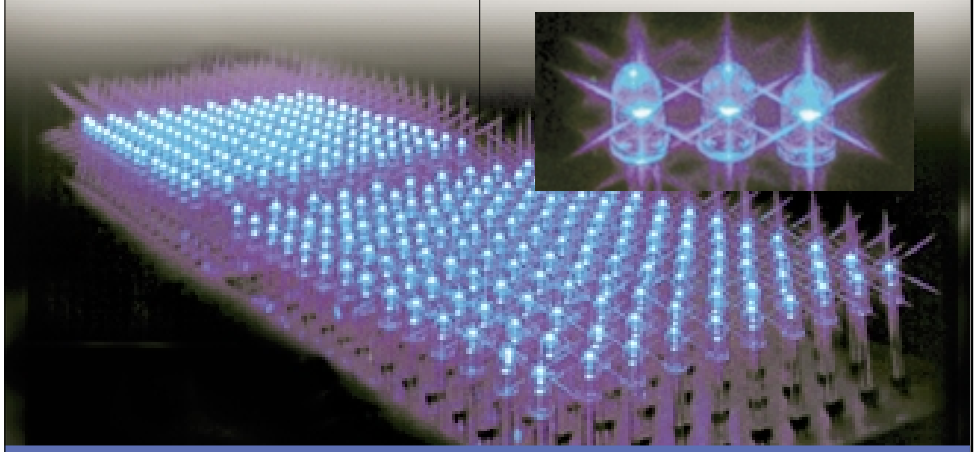

ABOVE: Displays and indicators based on light-emitting diodes (LEDs), laser diodes (LDs) used for optical data storage and sensor and detector surveillance.

Molecule Recombination Research Offers New Approach to Missile Detection

The research of an Air Force Office of Scientific Research-funded physicist may lead to important advances in the Air Force's ability to detect missiles during their boost phase.

Dr. Raymond Flannery, Regent's Professor at the Georgia Institute of Technology, has developed a microscopic theory of three-body recombination processes of electrons and ions in gases. His work has given scientists a better understanding of collisions between atoms and molecules in specific, highly excited states.

Flannery's research also has many potential benefits for the Air Force. By studying the molecular recombination within and around a rocket's exhaust plume, and the detailed signature information it gives off, scientists will be able to improve missile detection capabilities. This research also will enhance the detection of object satellites, warheads, and missiles reentering the atmosphere; it will also improve techniques to counter enemy detection of friendly missiles.

The Air Force Research Lab's propulsion directorate plans to use Dr. Flannery's research to aid in their understanding of the interactions that take place in plasma deposition and etching, the processes most often used in manufacturing large-scale integrated circuits. His work is also helpful in understanding conduction of electricity through plasmas and gases, ignition of flames, and other processes relevant to the development of advanced air and space propulsion systems.

Flannery's work also will help the Air Force continue its efforts in being outstanding stewards of the environment. His research will enable scientists to better understand how pollutants influence atmospheric recombination and to help environmentalists to develop new methods of effectively dealing with the mitigation of these pollutants.

In recognition of his work "to the field of theoretical atomic physics and...for his studies of recombination processes with applications to astrophysics and plasma physics," Dr. Flannery was recently awarded the 2002 Sir David Bates Prize by the Division of Atomic, Molecular, Optical and Plasma Physics of the United Kingdom's Institute of Physics. He was also the winner of the 1998 Allis Prize awarded by the American Physical Society (APS) for his work on ionized gases.

His current research includes development of theories of Rydberg plasmas and of the formation of anti-hydrogen by three-body recombination. In particular, he has recently solved, with his graduate student, a forty-year old problem explaining the mixing of angular momentum sub-states of a Rydberg atom by the time-dependent electric field generated by collision with a charged ion — a process known as collision Stark mixing. The process is of basic significance to Rydberg plasmas — whether at high temperature or ultracold energy regimes.

Flannery is supported by the Physics and Electronics directorate of the Air Force Office of Scientific Research.

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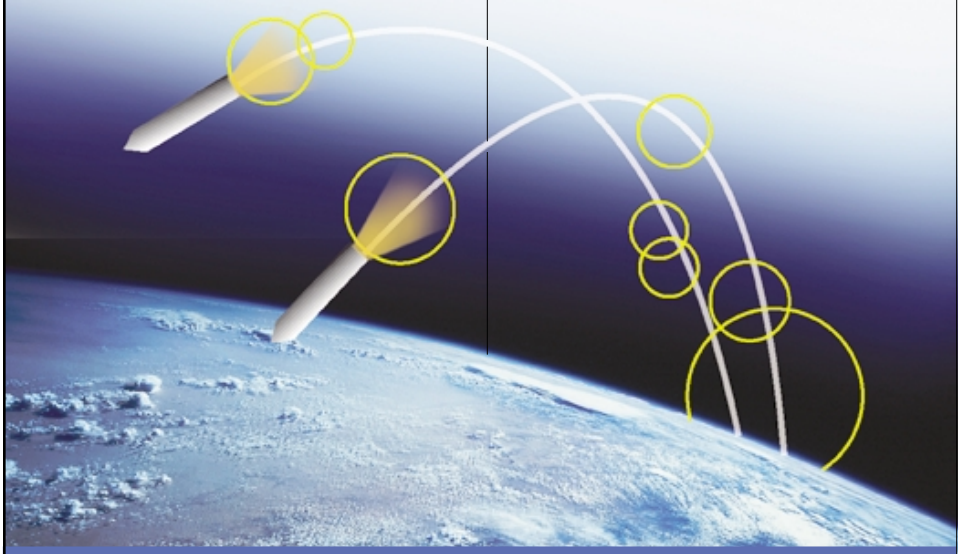

ABOVE: Dr. Raymond Flannery's molecule recombination research funded by AFOSR may lead to advances in the Air Force's ability to detect friendly or hostile missiles during their boost phase.

Research Spawns New Advances in Optoelectronic Technology

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- The fluorescence intensity of the doped-DNA films increased more than 1,000 times when the DNA is intercalated — locked into another — by rare earth metals such as Europium chelates.
- It's been found that the films possess a high threshold to laser light damage relative to other optically-active materials, a usable phenomenon in laser technology.

The complex films are very promising not only as optical and optoelectronic materials, but also for mimicking some properties of cellular membranes. This aspect may make them useful as biocompatible material in drug-delivery and drug-controlling release.

As with many of the AFOSR's initiatives, the research efforts are supporting other projects within AFOSR and the AFRL technical directorates. The marine DNA project directly supports research on biochromophores and nonlinear optical polymers within AFRL, particularly the Green Flourescent Protein Project — related to marine jellyfish — at AFRL's Materials and Manufacturing Directorate.

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Purdue University Calumet Awarded AFOSR Grant to Study Bioelectrics

The Air Force Office of Scientific Research presented Purdue University Calumet's Charles Tseng a $2.3 million, five-year Multidisciplinary Research Initiative (MURI) grant in a ceremony on Sept. 28. The grant will fund his work in bioelectrics, which holds the possibility of a cure for cancer.

Tseng, a professor of biology at the university, will serve as the grant's principal investigator with Purdue University Calumet as the lead institution of a three-university consortium.

Working with Northwestern University's Dr. Chung Lee, he will be exploring the proteins produced by cells that are stimulated by radio frequency fields. With the MURI grant, he will expand his research to explore the effect of electromagnetic fields on proteins and gases. This research will help scientists to determine the parameters that promote cell growth and/or prevent the degeneration of diseased or injured cells, tissues and organs. Tseng's research also should help the military understand how the use of radiation affects military personnel.

The MURI program supports basic science and engineering research of critical importance to national defense. The program is focused on multidisciplinary research efforts that intersect more than one traditional science and engineering discipline. By supporting multidisciplinary teams, the program is complementary to other DoD programs that support university research through single-investigator awards.

"This represents the largest grant ever awarded to Purdue University Calumet" stated Dr. Michael Gealt, the dean of Purdue University Calumet's engineering department.

Dr. Tseng is funded by AFOSR's Physics and Electronics directorate.

ABOVE: The Purdue University Calument Grant Bioelectric front team

AWARDS:

Dr. Karl Christe

An Air Force Research Laboratory (AFRL) senior staff advisor has been named the recipient of the American Chemical Society's (ACS) 2003 Inorganic Chemistry Award for his lifetime achievements in chemistry.

Dr. Karl Christe, an inorganic research chemist at the AFRL's Edwards Research Site who is funded by the Air Force Office of Scientific Research (AFOSR), has been on the cutting edge of efforts to develop HEDM or High Energy Density Matter chemistry. Christe also is active as a research professor at the Loker Hydrocarbon Research Institute of the University of Southern California, partly funded by AFOSR.

Christe and his co-workers are best known for their discovery of the N_5 cation in 1999. It was the first demonstration of a stable and energetic nitrogen species in 110 years. The N_3 anion discovered at that time is the only other known stable polynitrogen species. Its energy is currently used in automotive airbag gas cartridges.

The use of theoretical chemistry, high-speed computer systems, and the experimental skills of Christe's co-workers supported the successful demonstration of the N_5 cation.

Christe came to national prominence in 1986 for developing a process for the preparation of elemental fluorine by chemical means, thought to be impossible at the time. This chemical process had been attempted unsuccessfully by researchers ever since Moisson discovered the element, fluorine, 160 years ago.

"AWARDS" story continued on back page...

ABOVE: Dr. Karl Criste, winner of the 2003 Inorganic Chemistry Award from the American Chemical Society

AWARDS: Dr. John Buckmaster

Dr. John Buckmaster

Dr. John Buckmaster's outstanding contributions in the area of chemically reacting systems has prompted the prestigious American Institute of Aeronautics and Astronautics (AIAA) to award him their "Propellant and Combustion Award."

Dr. Buckmaster, a professor of aeronautical and astronautical engineering at the University of Illinois in Champaign, has been funded by the Air Force Office of Scientific Research for more than 15 years. The AIAA honored him for his "outstanding theoretical contributions to the physical understanding of fluid mechanics in combustion processes ranging from detonation physics to propellants."

Buckmaster also has been linked to an important breakthrough in the modeling of solid rocket propellant. It allows scientists for the first time to numerically replicate the propellant, including any distribution of various-sized spheroids of aluminum perchlorate that are part of such solid propellant cylinders.

With more than 31,000 members swelling its ranks, the AIAA is the world's largest professional society devoted to the progress of engineering and science on aviation, space and defense. In existence for more than 65 years, the AIAA strives to "advance the arts, sciences, and technology of aeronautics and astronautics, and to promote the professionalism of those engaged in these pursuits." Since 1963, AIAA members have achieved virtually every milestone in modern American flight. Buckmaster is funded by AFOSR's Mathematics and Space Sciences directorate.

AWARDS: Dr. Karl Christe

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He most recently won the 2000 Prix Moissan, an international prize in fluorine chemistry. He also has won the 1986 ACS Award for Creative Work in Fluorine Chemistry. He has published more than 290 peer-reviewed papers and holds more than 60 patents.

Considered a trailblazer, Dr. Christe is frequently cited in inorganic chemistry textbooks. His efforts continue to advance the world of chemistry. The understanding and application of those advances will also provide rocket propulsion and energetic materials for the future.

The ACS 2003 National Award has been sponsored by the Aldrich Chemical Company Inc. since 1998. Christe will be presented the award in a ceremony at the 225th ACS National Meeting in New Orleans, March 25, 2003.

Christie is funded by AFOSR's Chemistry and Life Sciences directorate.

Research Highlights

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Research Highlights is published every two months by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission. *Research Highlights* is available on-line at:

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