AIR FORCE RESEARCH LABORATORY [AFRL]
Manager of the Basic Research Investment for the Air Force Research Laboratory

Research HIGHLIGHTS

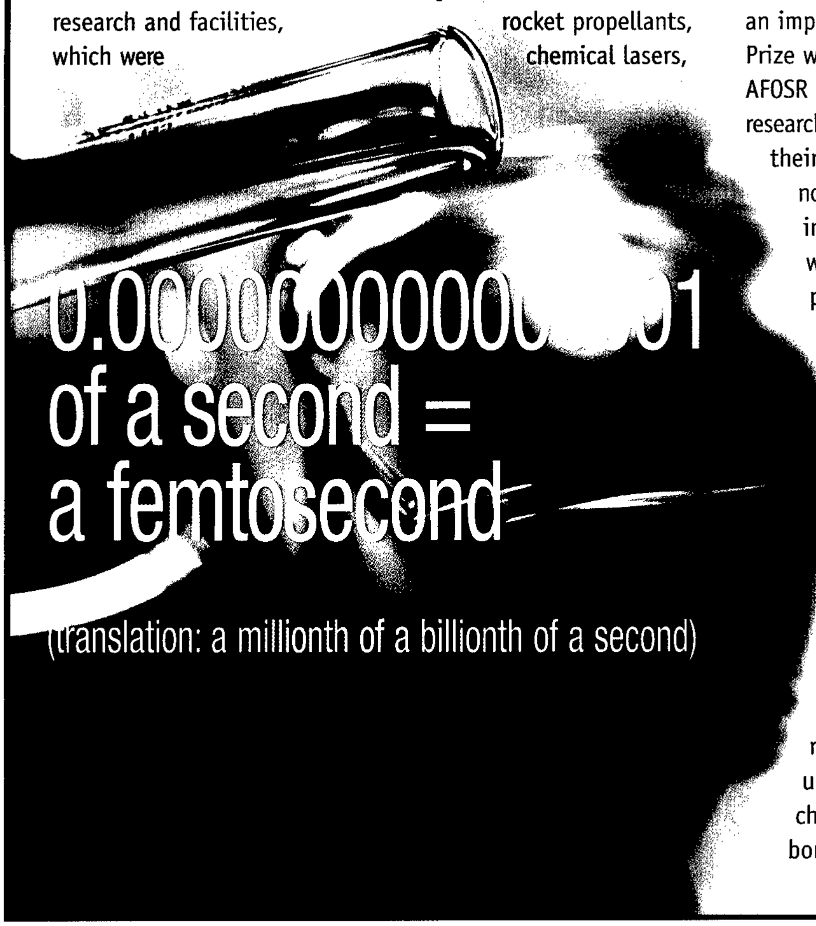
NOV/DEC 99

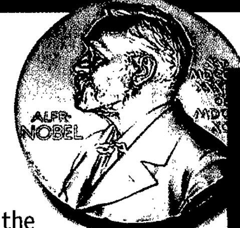
Dr. Ahmed Zewail — 1999 Nobel Prize for Chemistry

AFOSR Plays a Role in Nobel Prize Winner's Work

A researcher at the California Institute of Technology, supported by the Air Force Office of Scientific Research won the 1999 Nobel Prize in chemistry. In 1986, AFOSR support established the initial femtosecond research and facilities, which were used to perform the Nobel Prize winning work. AFOSR support for this pioneering research continues today.

Air Force applications focus on understanding and controlling the release of energy in chemical reactions in systems such as novel rocket propellants, chemical lasers, and the interactions of aerospace vehicles with their environments.






Dr. Ahmed Zewail

Dr. Ahmed Zewail, the Linus Pauling Professor of Chemical Physics and professor of physics at the California Institute of Technology, joins an impressive list of Nobel Prize winners who received AFOSR support for their research long before receiving their Prize. The list, which now contains 36 names, includes Nobel Prize winners in chemistry, physics and medicine.

The announcement was made Oct. 12, 1999 by the Royal Swedish Academy of Sciences.

Dr. Zewail was recognized for his pioneering efforts using ultra-short laser flashes to monitor chemical reactions. These ultrafast lasers image chemical reactions as bonds form and break in real time or at a scale of femtoseconds — 0.000000000000001 of a second (a millionth of a billionth of a second). Because of the ultrafast time scales involved in these studies, this field has been dubbed "femtochemistry." Femtochemistry enables scientists to understand how and why certain chemical reactions take place by probing chemical reactions at their most fundamental level.

"The Air Force played a critical role in some of the first experiments done in the field," said Dr. Zewail. "My experience with the Air Force has been an extremely positive one."

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Resonant Tunneling Diode (RTD) Research

RTD may replace the mighty transistor as the workhorse of integrated circuits

Faster Electroni

Warfighters will benefit from AFOSR supported research that shows promise to make C3I equipment more reliable and powerful while being lighter and using less power.

AFOSR pioneered research into resonant tunneling diodes by supporting efforts at the University of Texas at Dallas, the University of Delaware and with a Texas Instruments division (now Raytheon) in 1994. The success of the research led to greater funding through the Defense Advanced Research Projects Agency (DARPA).

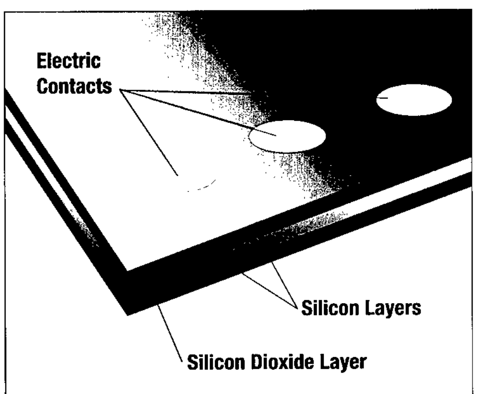
The new device, called a resonant tunneling diode (RTD), may replace the mighty transistor as the workhorse of integrated circuits when it becomes impossible to make transistors any smaller

Combined with transistors on integrated circuits, tunnel diode semiconductor devices will enable faster electronic circuits that use less power. As a result of the research, mass production of tunneling diodes on silicon wafers is now possible. Among the potential payoffs are:

- Improved battlespace awareness, battlespace management, and decision making with advanced communications networks capable of handling high-data transfer rates.

Circuits that Use Less Power

- More effective radar receivers and missile seekers by adding greater computational capabilities and reducing power consumption and system weight. For missile seekers, more complex target recognition algorithms can be employed. The lighter weight will increase the range, allowing for greater stand-off distances.
- Reduced logistical support or "logistical tail" needed to conduct operations since products incorporating the technology will offer high-data transfer rates at double the current rates, while reducing the number of components ten-fold. Additionally, power consumption could drop anywhere from 10-2,000 times.



The RTD consists of three ultra-thin layers. A layer of silicon is sandwiched between two layers of silicon dioxide with electric contacts on top and bottom to provide a variety of "on" and "off" states.

HOW THEY WORK:

In today's logic circuits, the smallest features of the transistors and wires which connect them are about 50 times narrower than a human hair, or about 0.35 microns (a micron is a millionth of a meter). A state-of-the-art logic chip contains about 4 million transistors per square centimeter, an area about the size of a small fingernail. The semiconductor industry plans to continue doubling the number of transistors on a chip every three years. According to that plan, state-of-the-art transistors will be almost 10 times smaller in 15 years.

Transistors work much like a light switch in that they can be turned on and off. When they are turned on, electrons flow to other parts of the circuit. Likewise, when they are turned off, it blocks those electrons from flowing; resulting in a barrier.

Problems in turning the transistor on and off arise when the barrier is as small as the wavelength of an electron. Even when the switch is turned off, some electrons can actually disappear on one side of the barrier and reappear on the other side. The phenomenon, known as "tunneling," makes the transistor act like a leaky faucet because it can no longer positively control the passage of electrons.

The RTD, developed by researchers, consists of a set of three ultra-thin layers. Those layers— a layer of silicon sandwiched between two layers of silicon dioxide with electrical contacts on the top and bottom— can be on and off in several distinct ways — some with as many as 19 different "on" and "off" states. These varying on and off states correspond to different levels of applied voltage. Since a normal transistor has only an on/off state, the RTD can often do the work of several conventional traditional transistors.

Instead of functioning as a simple switch, a tunnel diode controls the flow of electrical current in an unusual way that causes an up-and-down pattern of current flow in response to an applied voltage. This allows for more complex logic with fewer electronic parts. Thus, systems are smaller, need less power, and are easier to harden to the harsh environments of space and modern warfare.

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Dr. Gerald Witt

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AFOSR Support Helps Aid Nobel Prize Winner's Work

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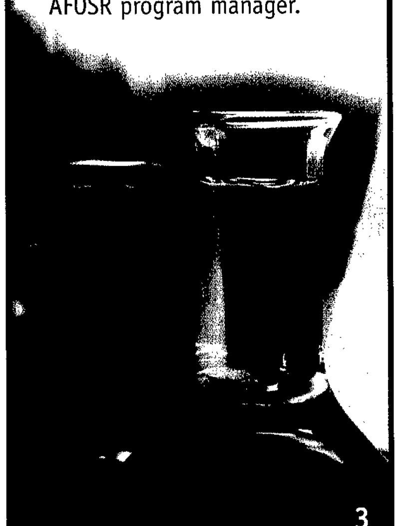
His insights have helped scientists understand how certain molecules are synthesized, how energy is released in reactions and how the outcome of chemical reactions might be controlled. Dr. Zewail's research will have far-reaching applications. Scientists throughout the world are using his research to probe nature at a fundamental level. Among the applications are determining how molecular electronic components must be designed, understanding the most delicate mechanisms in life processes and guiding how the medicines of the future should be produced.

"We will also be able to understand and control signatures from aircraft and rockets, processes that affect chemical erosion in space, and the drag on satellites from their environments," said Dr. Michael Berman, AFOSR program manager.



ESEP ProFiles

The DoD Engineer and Scientists Exchange Program, or ESEP, supports science and technology through international cooperation in military research, development, and acquisition through the exchange of defense scientists and engineers. ESEP provides on-site assignments for U.S. military and civilian scientists and engineers in foreign government organizations and reciprocal assignments of foreign scientists and engineers in U.S. government organizations. ESEP supports current USAF science and technology requirements by seeking specific foreign technologies. It provides insight into the technology and project management techniques of foreign laboratories and centers and opens areas of possible technical cooperation.

Capt. Paul Blue

Air Force Research Laboratory
Aerospace Vehicles Directorate

Capt. Paul Blue

Education:
MS in Mechanical Engineering, University of Minnesota
BS in Mechanical Engineering, University of Nebraska

Current Assignment:
Institute of Robotics and System Dynamics at DLR-Oberpfaffenhofen in Germany.

Description of Work:
Developed a new analysis procedure that reduces the time required to analyze the performance of flight control systems for aircraft that operate over large flight envelopes by up to 90 percent versus traditional point-wise (i.e. flight condition by flight condition) analysis techniques. The procedure enables the predicted flying quality performance of a controlled aircraft to be mapped directly onto its flight envelope. Thus, control engineers can see by inspection at which flight conditions the control system satisfies the flying quality specifications.

Research Highlights

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