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"Basic and Applied Research in the Field of
Electronics and Communications"
November 1, 1988 - October 31, 1991
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Submitted by
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July, 1992
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10. **ABSTRACT**
    - (Maximum 200 words)
    - Results of the research done under this contract are described in the articles or presented at the meetings enumerated in the attached List of Publications.
    - Key Words: Atomic physics, Communications, Electromagnetics, Electronics, Lasers, Microwaves, Molecular physics, Quantum electronics.
The MIT Research Laboratory of Electronics Joint Services Program is comprised of nineteen work units spanning a broad array of topics in high-speed optics, surfaces and phase transitions, submicron structures, electronic conduction, properties of electronic interconnects, and atomic and molecular physics.

A major emphasis of the work in high-speed optics has been the development of femtosecond optical pulses by means of nonlinear, self-limiting optical processes. These ultrashort pulses have been used as probes of electronic processes, and also in a variety of novel techniques for optical signal processing. Optical transmission in fiberoptic systems has also been studied, including techniques for the introduction of solitons with a resulting high signal-to-noise ratio.

In the area of surfaces and phase transitions, a balanced program includes both theorists and experimentalists. Theoretical studies have allowed the accurate prediction at atomic-level dimensions of realistic semiconductor surfaces at room temperature, subject to deposition of electronic materials such as aluminum. These theories also account for surface reconstruction among the top monolayers of a substrate lattice. Accurate studies have also characterized phase transitions in chemisorbed systems, and high-resolution x-ray diffuse scattering has been used to experimentally confirm theoretical predictions of surface restructuring, as well as to reveal new phenomena in model systems. Unique phases in colloidal crystals have also been revealed experimentally, and a new apparatus has been built to study chemical reaction dynamics on semiconductor surfaces, thus providing for the first time an accurate characterization of chemical reactions at semiconductor surfaces as a result of common processing procedures such as reactive ion etching.

The JSEP program at MIT has built up a strong submicron structures laboratory which utilizes x-ray lithography to build a large array of structures and electronic devices. One example of the exploitation of this capability is the construction of very narrow field-effect transistors, which show quantum confinement effects, and which have led to a new understanding of electronic conduction in submicron silicon field-effect transistors. Many other extremely small structures and devices which exhibit novel quantum effects at low temperatures are also being fabricated. By means of the control of kinetic growth processes, the microstructural evolution of thin-film electronic materials (including both semiconductors and metals) has been extensively studied and characterized with a view toward providing high-quality semiconductor materials, as well as metals with large grain size which are resistant to electromigration. Following the theme of studying the properties of interconnect structures, basic electromagnetic studies of multilayer media have been made in the time domain so that transmission characteristics in complex computer interconnect structures can be precisely understood.

A major thrust of the MIT Research Laboratory of Electronics JSEP program has been fundamental studies of high-precision metrology using the techniques of atomic and molecular physics. Recently, with the advent of laser techniques to provide for atom isolation at millikelvin temperatures, new experiments are leading to techniques for the precision measurement of mass and time using trapped atomic particles. In fact, the entire MIT RLE JSEP program is increasingly characterized by techniques for the manipulation and representation of individual atoms and charge carriers. This new understanding is expected to lead to an entirely new class
of electronic devices based on new effects brought about by a variety of quantum confinement phenomena that are exhibited at very small sizes and very low temperatures.
Principal Investigators Supported by
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Degrees Awarded Under Joint Services Support  
November 1, 1988 - October 31, 1991  
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Quantum Well Heterostructures for Guided Wave Optics  
No degrees reported.

High-Frequency InAlAs/InGaAs Metal-Insulator-Doped Semiconductor Field-Effect Transistors (MIDFETs) for Telecommunications  
No degrees reported.

Substitutional Doping of ZnSe Grown by Chemical Beam Epitaxy  
No degrees reported.

Stability and Reliability of Thin Films and Thin Film Lines  
No degrees reported.

Electromagnetic Waves in Multilayer Media  
Chang, Jr., I.Y., S.B./S.M., 1989  
Lam, C-W., S.M., 1989  
Lee, C.F., Ph.D., 1990  
Nghiem, S.V., S.M., 1988  
Tsuk, M.J., Ph.D., 1990  
Yang, Y-C.E., Ph.D., 1989

Sub-100nm Structures: Technology and Electronics  
Early, K.R., Ph.D., 1991  
Ismail, K., Ph.D., 1989  
Meyer, P.G., S.M., 1989  
Shahidi, G.G., Ph.D., 1989

Ultralow-Temperature Measurements of Nanometer-Scale Semiconductor Devices  
No degrees reported.

Quantum Transport in Low-Dimensional Disordered Systems  
No degrees reported.

The Consequences of Low-Dimensionality in Oxide Superconductors  
No degrees reported.

Ultrafast Optical Devices  
Amparan, A.B., S.B., 1990  
Kesler, M.P., Ph.D., 1988  
Khatri, F.I., S.B., 1990
Femtosecond Optical and Electronic Processes
   LaGasse, M.J., Ph.D., 1989
   Schoenlein, R.W., Ph.D., 1989

Microwave Quantum Optics and Precision Measurements
   Gentile, T.R., Ph.D., 1989

Precise Physical Measurements
   Magill, P.D., Ph.D., 1988
   Martin, P.J., Ph.D., 1988

Measurement of Electron-Phonon Interactions Through Large-Amplitude Phonon Excitation
   No degrees reported.

Resonance Raman Studies and Applications
   No degrees reported.

Excitations, Groundstate Properties, and Phase Transitions of Surfaces
   No degrees reported.

High-Resolution of X-Ray Diffuse Scattering
   Evans-Lutterodt, K.W., Ph.D., 1989

Statistical Mechanics of Surface Systems and Quantum-Correlated Systems
   Hilliard, Jr., J.E., S.B., 1989
   Hoston, Jr., W.C., S.M., 1991
   Hui, K.C-L., Ph.D., 1989
   Marko, J.F.D., Ph.D., 1989
   Netz, R.R., S.M., 1991
   Pickett, G.T., S.B., 1989

Step Structures on Semiconductor Surfaces: Thermodynamics, Kinetics, and Influence on Heteroepitaxy
   No degrees reported.

Electronic Processes in the Etching of Deposition on Semiconductor Surfaces
   McGonigal, M., Ph.D., 1989
1.1.1 Published Journal Articles


1.1.2 Journal Articles Accepted for Publication


1.1.3 Journal Articles Submitted for Publication


1.1.4 Books/Chapters in Books


1.1.5 Theses


McGonigal, M *Reactive Chemisorption of Molecular Fluorine on Si(100).* Ph.D. diss., Dept. of Chem., MIT, 1989.


### 1.1.6 Meeting Papers Presented

**American Physical Society Meeting, St. Louis, Missouri, March 20-24, 1989.**

Antoniadis, D.A. "Surface Superlattice and Quasi-One-Dimensional Devices in GaAs."


Smith, H.I. "X-Ray Lithography and Nanostructure Fabrication."

**American Physical Society Meeting, Anaheim, California, March 12-16, 1990.**

Marko, J.F. "Density Functional Theory of Phase Transitions in Fluids of Anisotropic Particles."

**American Physical Society, General Meeting, Cincinnati, Ohio, March 18-22, 1991.**

Berker, A.N. "Quenched Fluctuation Induced Second-Order Phase Transitions."
Hoston, W., and A.N. Berker. “New Multicritical Phase Diagrams from the Blume-Emery-Griffiths Model with Repulsive Biquadratic Interactions.”


American Vacuum Society, Boston, Massachusetts, October, 1989.

Schulberg, M.T., M. McGonigal, D.J. Gladstone, K.B. Laughlin, and S.T. Ceyer. “The Etching of Si(100) with a Molecular Beam of F₂.”


Berker, A.N. “Absence of Temperature-Driven First-Order Phase Transitions In Systems with Random Bonds.”


Laughlin, K.B., D.J. Gladstone, M. McGonigal, and S.T. Ceyer. “Dynamics of the Reaction of F₂ with Si(100).”


Haus, H.A. “Femtosecond Lasers with Fiber Optics.”


International Conference of Atomic Physics, Ann Arbor, Michigan, July 1990.

Pritchard, D.E. “Atom Optics.”


Pritchard, D.E. “Experimental Studies of Atom Diffraction and the Mechanical Forces of Light on Atoms.”


Haus, H.A. “Femtosecond Lasers with Fiber Optics.”

International Symposium on Nanostructure Physics and Fabrication, Texas A&M University, College Station, Texas, March 8-10, 1989.


Bennett, B.R., and J.A. del Alamo. “Index of Refraction Anisotropy in Mismatched InGaAs/InP Heterostructures Measured by Ellipsometry.”

McGonigal, M., M.T. Schulberg, D.J. Gladstone, K.B. Laughlin, and S.T. Ceyer. “Reactions of F₂ with Si(100).”


Hoston, W., and A.N. Berker. "Bicritical and Tetracritical Phase Diagrams of the BEG Model: Dimensionality Effects."


Topical Meeting on Ultrafast Phenomena, Monterey, California, May 14-17, 1990.


1.1.7 Published Meeting Papers


1.1.8 Meeting Papers Accepted For Publication
