Research Is The Key

The Semiconductor Research Corporation

Annual Report 1995

Vision

The Semiconductor Research Corporation (SRC) will be the world's premier research management consortium for providing university-based research results in semiconductor science and technology to its members.

Mission

As the research arm of the semiconductor Industry Association (SIA), the SRC is a not-for-profit, tax-exempt research management consortium which helps solve the North American semiconductor Industry's technical challenges, focusing on long-range university research.

Charter

The SRC manages a low-overhead, industry-driven, pre-competitive research program that addresses the research needs of the SIA's National Technology Roadmap for Semiconductors. Funding for this research is derived primarily from member fees. The SRC is not a government contractor; however, it does encourage government participation and funding support of key research programs.

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The Annual Report of the Semiconductor Research Corporation is published each year to summarize the directions and results of the SRC Research Program, present the formal financial report, and provide information on activities and events of the SRC industry/government/university community for the previous calendar year.

This report is available to any interested person by requesting SRC Publication Number S96011.

Cover: Wafer image in word "RESEARCH" courtesy of Motorola Inc.

What is the SRC?

"For the U.S. semiconductor industry, a flow of new products is the key to staying alive; and new products come from research . . . ."

Robert M. Burger
SRC Vice President & Chief Scientist

The Semiconductor Research Corporation is a consortium of more than 65 companies and government agencies that plays a crucial role in planning, directing and funding the semiconductor industry's pre-competitive, long-term research. This integrated program of applied research is conducted by faculty and graduate students at dozens of leading universities and research institutions in the United States and Canada. Through the SRC, participating companies, government agencies, national laboratories and universities work together to advance semiconductor capabilities.

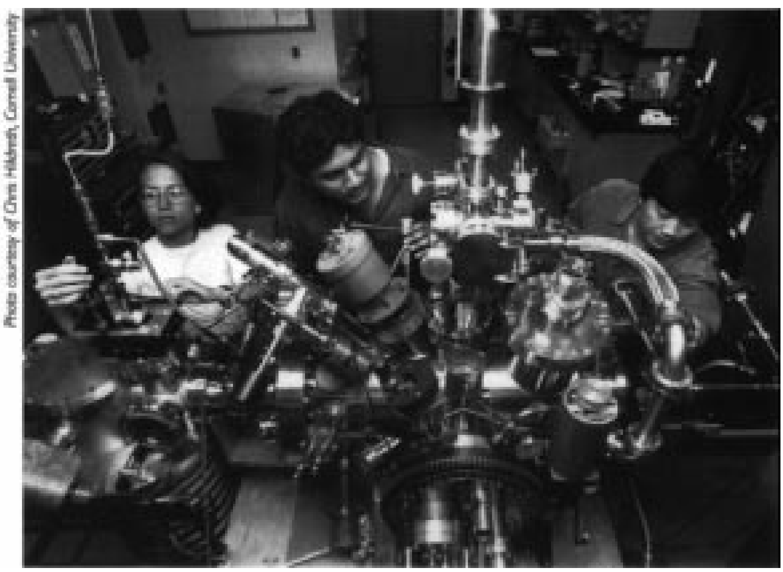
The SRC has invested and managed more than $340 million in semiconductor industry funds for research since its formation by the Semiconductor Industry Association in 1982. SRC research dollars have sponsored hundreds of faculty members and more than 1,000 graduate students hired by the semiconductor industry. Building upon its commitment to transfer research results to its participants, the SRC has sponsored more than 1,000 conferences and workshops, and researchers supported by the SRC have published more than 8,000 research reports. Since 1988, the SRC has assisted its university partners in obtaining more than 120 U.S. patents on research resulting from SRC sponsorship, with another 50 applications pending.

As part of its broad program of industry-relevant research, the SRC supports the education of graduate students, many of whom enter and strengthen the semiconductor industry's workforce. Through their research and their exposure to corporate engineers and scientists in the SRC Industrial Mentor Program, the more than 150 graduates who enter the workforce each year have very strong backgrounds in microelectronics and are capable of contributing to their companies' products almost immediately. The SRC accounts for about 10 percent of all electrical and computer engineering Ph.D.s granted in the United States each year. Overall, the SRC supported more than 800 students at 51 universities in 1995.

The semiconductor industry's participation in the SRC research program has resulted in:

- High-quality university research on mainstream semiconductor technology;
- Unified research goals addressing industry needs, incorporated into the SIA Technology Roadmap;
- Timely and effective transfer of research results to SRC participants for commercialization; and
- Graduate students - industry's future leaders - educated to meet industry needs.

Photo courtesy of Chris Hildreth, Cornell University



The SRC plays a key role in planning, directing and funding the semiconductor industry's pre-competitive, long-term research.

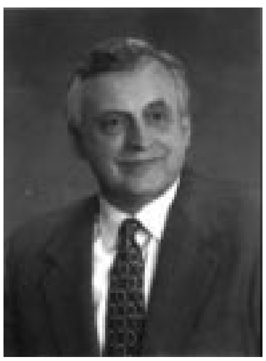
Message from the President and the Chairman

On February 14, 1946, scientists at the University of Pennsylvania introduced a curious machine with an impressive name: the Electronic Numerical Integrator and Computer, or ENIAC. Powered by more than 17,000 vacuum tubes and tilling a 30' x 50' room, ENIAC was designed to compute ballistic trajectories for artillery shells. Its impact changed the face of science and technology forever.

Compared with the mechanical computers of its day, which could complete two calculations per second, ENIAC - the world's first large-scale, general-purpose electronic computer - could process more than 100,000 calculations per second.

Now, 50 years later, echoes of this research breakthrough still resound. ENIAC's descendants, the integrated circuits of today's personal computers, contain more than 3 million transistors on a piece of silicon the size of a fingernail. These semiconductor workhorses can calculate 100 million instructions per second.

The electronics industry, unleashed by ENIAC and other key breakthroughs, has achieved explosive growth worldwide. Today, semiconductors are an integral part of everything from digital pagers, automobiles and high-performance jet aircraft to cellular telephones, CAT scans and the networked computers of the Internet.



Larry W. Sumney

Owen P. Williams

Research is the Key

The key to success for ENIAC a half-century ago and for today's semiconductor industry is research. Research fuels growth. Research provides the knowledge that leads to new tools, new products and new services. Research is a critical investment in the industry's future.

As we rapidly approach the new millennium, the SRC is poised to continue meeting the semiconductor industry's changing needs through world-class research. The SRC research program covers all aspects of semiconductor technology, from device and material physics to integrated circuit fabrication and manufacture.

Redoubling Our Efforts On Behalf of Industry

Through the SRC, more than 65 semiconductor industry companies and organizations share the risks and the rewards of a comprehensive long-term research program. The rewards for SRC participants include early access to both a steady flow of innovative semiconductor technologies for commercialization and a cadre of students that enters the workforce trained in technology areas key to the industry's future.

Like the semiconductor industry with which it is associated, the SRC made great progress in 1995. The SRC refocused and redoubled its efforts on behalf of the North American semiconductor industry by funding and managing approximately $28 million in research contracts at 51 major North American universities and research institutions. This research addressed a broad spectrum of technologies involved in understanding, developing and applying integrated circuits. These included system-level design, materials characterization, silicon device fabrication, critical dimension metrology, advanced lithography tools, integrated circuit interconnection and packaging, and factory automation and control.

A major milestone in technology transfer for 1995 was the introduction of the most useful overview of SRC products ever distributed: the new SRC Research Catalog. This electronic catalog, distributed for use on company networks or stand-alone computers, provides concise, specific information on the SRC research portfolio and products. It enables SRC participants, from working engineers to corporate executives, to easily and precisely locate, track and assess current technical results associated with SRC research activities. The catalog ensures prompt transfer of research results to participants for rapid commercialization.

Working closely with the Semiconductor Industry Association (SIA) and SEMATECH, the SRC continued to align and focus industry research efforts on the goals laid out in the National Technology Roadmap for Semiconductors. By defining the semiconductor industry's needs for the next 15 years, the Roadmap enables better investment decisions and an integrated national technology effort.

The SRC restructured its research program into eight science areas in 1995: Design; Environment, Safety & Health; Factory; Interconnect: Lithography: Materials and Bulk Processes; Packaging; and Process Integration and Device Sciences. These correspond to the Technology Working Groups of the Roadmap.

In an effort to expand the SRC's member base, the SRC board of directors established a new type of membership in 1995. A science area membership is available to large companies that either manufacture or supply equipment, materials or software to the industry, or that purchase integrated circuits. Through science area memberships, these companies can join SRC technology areas related to their business interests. By the end of 1995, the SRC had already enrolled several new science area members [see page 7 for a complete list of participants].

SRC participants have a continuing need for new employees educated in areas relevant to the semiconductor industry. To better meet this need, the SRC created the SRC Student Services program in 1995 to improve management of student-related activities. This program provides a direct link to the more than 800 student scientists and engineers who participated in SRC research in 1995. Member recruitment and hiring of these graduate students is the most effective means of technology transfer.

Closing the Research Gap

The SRC is the leading organization for addressing long-term applied research needs for the North American semiconductor industry. In the past, strong industry laboratories performed this function. Today, universities are the primary source of leading-edge semiconductor research in North America.

In today's era of shrinking corporate and government research budgets and increased global competitiveness, long-range semiconductor research - which provides the knowledge base for future generations of products - faces formidable challenges. Ironically, funding reductions have coincided with the rapid growth of the industry.

Long-term semiconductor research, aimed at developing products more than one or two technology generations in the future, currently receives an annual investment of approximately $140 million from industry and $130 million from the federal government, for a total of about $270 million.

However, the Roadmap identifies significant needs which will not be addressed by the above combined funding. Through its extensive program of university research, the SRC works to leverage industry's R&D investment and help close this gap.

Looking Ahead

Historically, the health of U.S. industry has depended on generating a constant stream of new products. Like the ENIAC researchers before them, SRC-supported university researchers are establishing the technological framework for future generations of products. Many of the advanced semiconductor products that SRC researchers are working on today will reach the marketplace in the next century.

Our thanks go out to the many scientists, engineers, managers and officers from SRC-member companies, participating organizations and universities who made 1995 such a successful year for the SRC. We pledge to build upon their efforts in 1996 and beyond. We will continue to effectively leverage the investment of SRC participants in order to advance North American semiconductor capabilities, close the research gap, and ensure the industry's competitiveness in the global economy of the 21st century.

Whether computed at ENIAC's 100,000 calculations per second, a modern integrated circuit's 100 million instructions per second, or the phenomenal speed of future technologies now in development at university laboratories across North America, the answer to the challenges facing the semiconductor industry is clear: research is and will remain the key to the long-term growth and competitiveness of the North American high-technology industry. Through its comprehensive research program, the SRC will remain a critical component of the industry's continued success.

Sincerely,

Larry W. Sumney	Owen P. Williams
President & CEO	Chairman

1995 SRC Accomplisments

Refocusing SRC Research - Aligning With the Roadmap and Leveraging Industry's Investment

The SIA's National Technology Roadmap for Semiconductors is a technology needs document that serves all industry participants by providing a guide to long-term strategic investment decisions. The SRC worked closely with the SIA, SEMATECH and other industry groups to identify and outline industry research needs and long-term technology requirements for the Roadmap.

Realignment of Research Program

In 1995, to better meet industry's needs as outlined in the Roadmap, the SRC restructured its research program into eight science areas: Design; Environment, Safety & Health; Factory; Interconnect; Lithography; Materials and Bulk Processes; Packaging; and Process Integration and Device Sciences. These science areas correspond to the eight technology areas of the Roadmap.

Science Area Membership

The SRC also revised its categories of membership in 1995. Through new science area memberships, companies that do not manufacture semiconductors can participate in SRC research areas relevant to their business. Science area members may be involved in manufacturing or supplying equipment, materials or software to the semiconductor industry, or purchasing integrated circuits. The new membership category broadens the SRC member base and is the strongest driver yet for communications among industry manufacturers, suppliers and customers.

New Fee Structure

In an effort to strengthen and broaden university-based semiconductor research, and in response to the phase-out of SEMATECH funding for university research (SEMATECH provided almost one-third of the SRC's financial resources during the last seven years), the SRC continued its search for alternative funding sources.

In 1995, the SRC established a new fee structure that, for the next three years, will increase SRC revenues to replace SEMATECH funding. Under the new fee structure, member companies have the opportunity to offset a limited amount of their member fees by assigning employees to the SRC corporate staff. Assignees enhance the depth and scope of SRC program management and heighten their companies' awareness of desirable research products.

Promoting Links With Government

Another effort to find alternative funding sources focused on promoting broader links between the U.S. Department of Energy National Laboratories and the semiconductor industry. After several years of discussion and negotiation, the SRC implemented a new Cooperative Research and Development Agreement (CRADA) with three National Laboratories. CRADAs are contractual agreements between private companies or organizations and federal government agencies in which both parties agree to collaborate on mutual research goals.

The new CRADA established a Center for Semiconductor Modeling and Simulation, with research conducted at Los Alamos, Sandia and Lawrence Livermore National Laboratories. Modeling and simulation are research areas of rapidly increasing importance to industry and government as they design, develop and manufacture increasingly complex integrated circuits.

The SRC also continued its negotiations with the National Science Foundation (NSF) to establish a jointly funded Engineering Research Center (ERC) focused on fundamental, long-term semiconductor research. It is planned that the SRC/NSF joint ERC will be in place in early 1996. Like CRADAs, SRC/NSF partnerships are another step toward increased collaboration between industry and government in support of generic research related to industry's needs.

1995 SRC Accomplishments

Reinforcing Student Services - Meeting Industry's Demand for Qualified Graduates

With its rapid expansion in recent years, the semiconductor industry needs an increasing number of relevantly educated scientists and engineers. To meet this need and improve the quality and accessibility of information about graduate students participating in SRC-sponsored research, the SRC created SRC Student Services in 1995.

Photo courtesy of University of Albany-SUNY

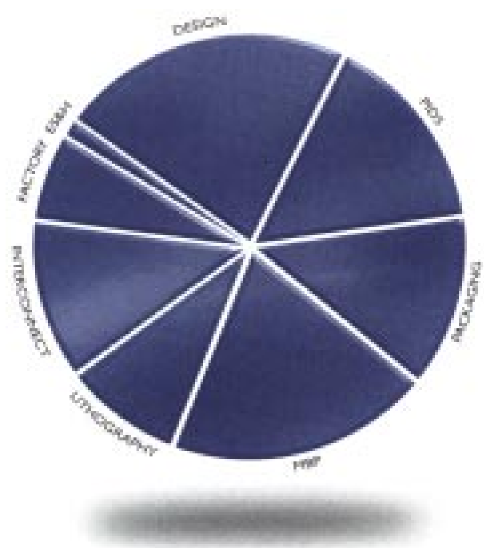
Through SRC research, graduate students are educated to meet industry's needs.

SRC-Supported Students

SRC-supported student researchers - there were more than 800 in 1995 - who graduate and take jobs with SRC members are one of the most direct channels of technology transfer. Nearly 60 percent of the more than 150 SRC-supported graduate students who earned degrees in 1995 took jobs at SRC member companies, or at U.S. universities or government agencies.

1995 Graduate Students Supported by the SRC (by SRC Science Area)

Total: 818 students*



Science Area	# of Students	% of Total
Design	182	22.3%
ES&H	10	1.2%
Factory	54	6.6%
Interconnect	101	12.3%
Lithography	73	8.9%
MBP	164	20.0%
Packaging	108	13.2%
PIDS	126	15.5%

*estimated

Electronic Distribution of Resumes

One new method initiated in 1995 to facilitate the placement of these highly qualified graduate students with SRC members was the electronic distribution of student resumes. The resumes are provided on diskette by Student Services to student information gatekeepers at member companies. The gatekeepers serve as internal champions within their organizations for SRC student researchers, distributing the resumes and helping secure internships and full-time positions.

Company-Named Fellowships

Another 1995 milestone for Student Services was the creation of the first graduate fellowship named for an SRC member company: the AMDISRC Fellowship. Co-funded by Advanced Micro Devices Inc. and the SRC, this fellowship is designed to recognize outstanding academic and research achievement and increase the number of SRC Graduate Fellows in areas of special interest to AMD. Overall, the SRC supported 34 Fellows in 1995, including 10 new SRC Graduate Fellowships. Criteria for the very competitive selection of SRC Graduate Fellows included academic excellence, demonstrated and potential research capability, and relevance of proposed research to SRC goals.

1995 SRC Accomplishments

Redefining Technology Transfer - The New SRC Research Catalog

In 1995, the SRC unveiled the SRC Research Catalog, a project championed by SRC Board Chairman Owen Williams. The catalog, distributed on CD-ROM and diskette for use on networks or stand-alone computers, provides concise, specific information on all research tasks supported by the SRC. The catalog summarizes the major elements of each task, including research background; outlines the planned approach; and documents accomplishments to date and anticipated milestones and deliverables. It also identifies a technology transfer package that provides detailed information needed to transfer research results for each completed task.

A Snapshot of SRC Research

The catalog's electronic format allows it to be updated frequently from the SRC research management database so that information is current. The catalog contains multiple search capabilities, including full-text word searches and targeted searches on specific fields such as task title, task leader and milestones. This feature gives users immediate access to research of interest. By browsing the catalog, engineers, scientists and senior management at SRC participants can access snapshots of the full range of current SRC research activities, capabilities and results.

A Tool for Technology Transfer

The SRC has always worked to ensure that the results of its research are transferred quickly and effectively from university laboratories to industry. By forecasting deliverables and milestones, the catalog helps industry track and assess how the SRC's research contributes to technology advancements needed to meet industry goals. By providing updated, comprehensive information on this research, the catalog has become the premier technology transfer tool for industry today.

Photo courtesy of University of Albany-SUNY

The SRC Research Catalog helps industry track and assess SRC-sponsored university research, such as this work in advanced thin film technology at the University of Albany-SUNY. Here, Albany's Cindy Goldberg loads an 8" wafer for CVD thin film deposition.

SRC Members and Participants

Investing in the Industry's Future

The SRC's strength is its ability to bring industry relevance to university research and to transfer research results quickly from universities and research organizations to industry for commercialization.

The SRC's participating companies, organizations and government agencies make technological advances possible. More than 65 companies and government agencies fund the SRC's work, leveraging their research and development dollars to achieve a substantial return on their investment.

Members

Advanced Micro Devices Inc.
AT&T
Digital Equipment Corporation
Eastman Kodak Company
E-Systems Inc.
Harris Corporation
Hewlett-Packard Company
IBM Corporation
Intel Corporation
LSI Logic Corporation
Motorola Inc.
National Semiconductor Corporation
NORTEL
Texas Instruments Inc.
Westinghouse Electric Corporation

Science Area Members

Alcoa
Cadence Design Systems
DuPont Company
Eaton Corporation
ETEC Systems Inc.
Ford Motor Company
Novellus Systems Inc.
Shipley Company Inc.

Associate Members

Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
MCC
Oak Ridge National Laboratory
Sandia National Laboratories
SEMATECH
The MITRE Corporation

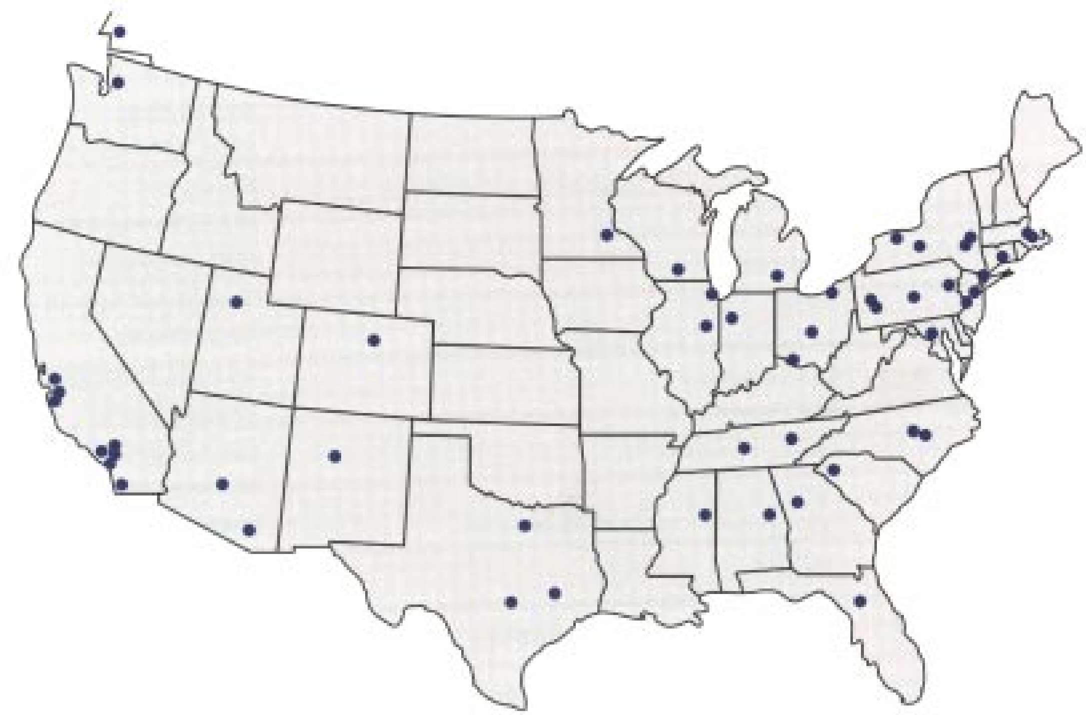
Affiliate Members

AG Associates
ANACAD Electrical Engineering Software Inc.
Analogy Inc.
BTA Technology Inc.
CVC Holdings Inc.
Dawn Technologies Inc.
DesignAid Inc.
Emergent Technologies Corporation
Famtech/Speedfam Corporation
Hestia Technologies Inc.
Ibis Technology Corporation
Integrated Electronic Innovations
Integrated Silicon Systems Inc.
IntelliSense Corporation
LV Software Inc.
Meta-Software Inc.
MicroUnity Systems Engineering Inc.
Mission Research Corporation
OEA International Inc.
Omniview Inc.
PDF Solutions
Process Technology Ltd.
Q-metrics Inc.
SILVACO Data Systems
Solid State Measurements Inc.
Solid State Systems Inc.
Technology Modeling Associates Inc.
Techware Systems Corporation
Tyecin Systems Inc.
Verity Instruments Inc.

U.S. Government Participants

Army Research Office
National Institute of Standards and Technology
National Science Foundation
National Security Agency
Office of Naval Research
Wright Laboratory

SRC-Participating Universities and Research Institutions



Universities and Research Institutions

University of Albany-SUNY
University of Arizona
Arizona State University
Auburn University
Boston University
University of British Columbia
University of California, Berkeley
University of California, Irvine
University of California, Los Angeles
University of California, San Diego
University of California, Santa Cruz
University of Southern California
California Institute of Technology
Carnegie Mellon University
Case Western Reserve University
University of Cincinnati
Clemson University
University of Colorado at Boulder
Cornell University
Duke University
Duquesne University
University of Florida
Georgia Institute of Technology
University of Illinois at Urbana-Champaign
Lehigh University
University of Maryland
Massachusetts Institute of Technology
University of Michigan
University of Minnesota
Mississippi State University
University of New Mexico
North Carolina State University
Northwestern University
University of North Texas
The Ohio State University
Pennsylvania State University
Polytechnic University
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rochester Institute of Technology
Rutgers University
Stanford University
University of Tennessee
Texas A&M University
University of Texas at Austin
University of Utah
Vanderbilt University
University of Washington
University of Wisconsin
Yale University

The SRC Research Program

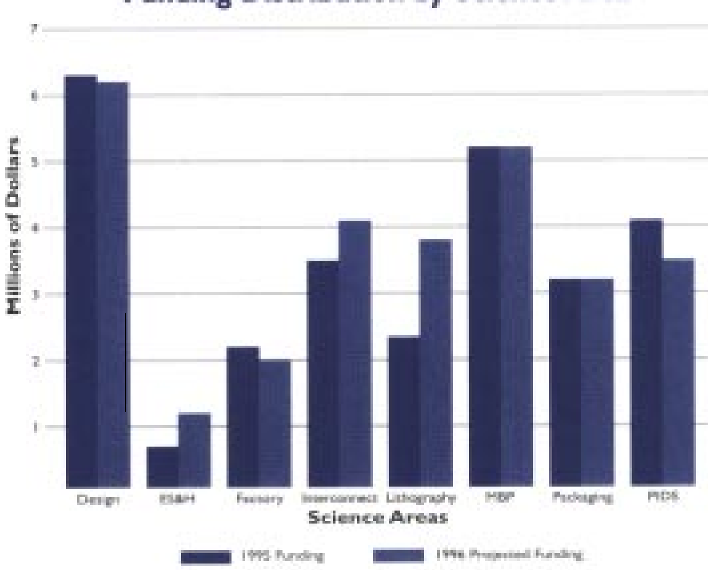
Overview

At the heart of SRC efforts on behalf of its members is the SRC Research Program. This comprehensive, long-term research program covers all aspects of semiconductor design and manufacture, from new device designs and process controls to advanced materials and integrated circuit innovations.

The SRC is not interested in research for research's sake. The potential for application in marketable products and for technology transfer is essential. Through initiatives such as the Student Services program, the Industrial Mentor program and the Research Catalog, research results - now performed at 51 universities across the United States and in Canada - are rapidly transferred to SRC participants for further development and/or commercialization.

Through participation in the SRC and its research program, more than 65 leading semiconductor companies and organizations ensure that a steady stream of innovation flows from university research labs to industry and, from there, into future generations of semiconductor products.

Funding Distribution by Science Area



Organization

The SRC Research Program is organized around science areas that correspond to the Roadmap and provide a structure for relating to industry and universities. Each science area is managed by an SRC research director and has a Technical Advisory Board (TAB). The TABs consist of industry and government scientists and engineers who work with the director to plan research strategy, conduct annual reviews and foster technology transfer at university sites, evaluate research proposals, and provide technical guidance to university researchers.

Each science area also benefits from Industrial Mentors who are assigned by member companies to give individual assistance to university research tasks. Through both the TABs and the mentor program, SRC participants help address research priorities, increase the relevance and productivity of the research, and maximize technology transfer.

New Science Areas

The SRC's research program is updated constantly through TAB interactions to meet the industry's emerging and changing needs and to adapt to changing technologies. In 1995, as part of the continuing effort to keep pace with rapid technological developments, and to align with the goals of the Roadmap, the SRC reorganized its research into eight science areas, corresponding to the technology areas of the Roadmap. The focus and priorities of each are described briefly in the following pages.

1995 Investment

In 1995, the SRC awarded 149 research contracts and grants to 5 1 North American universities. The SRC invested approximately $28 million in these contracts and grants, distributed among the eight science areas.

The SRC also supported more than 800 graduate students in 1995. Of these, more than 150 received their degrees, with the majority taking jobs at SRC members.

Design Sciences

Peter W.J. Verhofstadt, Director
Industry Asignee: Justin E. Harlow III, National Semiconductor Corp.

1995 SRC Technical Advisory Board, Design Sciences

W. Terry Coston
Cadence Design Systems
Chairman

Ray Abrishami
LSI Logic Corp.
Vice Chairman

David Agnew
Bell Northern Research Inc.

O. Ersed Akcasu
OEA International Inc.

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National Security Agency

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George Eaton
National Semiconductor Corp.

Ian Getreu
Analogy Inc.

Robert B. Grafton
National Science Foundation

Kim Hailey
Mema-Software Inc.

John W. Hines
Wright Laboratory

Peter Hopper
SILVACO Data Systems

William H. Joyner, Jr.
IBM Corp.

Bernd Koenemann
LV software Inc.

Greg Ledenbach
SEMATECH

Dave Mavir
Mission Research Corp.

Charles S. Meyer
Motorola Inc.

Kimon W. Michaels
PDF Solutions

Edward T. Nelson
Eastman Kodak Co.

Serban Porumbescu
Solid State Systems Inc.

Victor W. Ramsey
Ford Microelectronics Inc.

Shishpal Rawat
Intel Corp.

Steven E. Schulz
Texas Instruments Inc.

Waqar Shah
Advanced Micro Devices Inc.

Kenneth Sienski
E-Systems Inc.

Kenneth H. Slater
Digital Equipment Corp.

James A. St. Pierre
NIST

Vincent Zagardo
Westinghouse Electric Corp.

Design Sciences addresses the need to rapidly design complex integrated circuits that achieve specified levels of function and performance, while ensuring that the resulting products are manufacturable with high yield, testable to high levels of confidence, and operable with high reliability.

In order for the North American semiconductor industry to maintain leadership in design and computer-aided design, and to handle exponentially increasing complexity, design sciences research must advance rapidly. These advances must enable the move from single component to system level (e.g., multi-chip modules) designs, must cover analog and mixed signal circuits in addition to classical digital designs, and must include both software (especially embedded) and hardware.

To address these challenges, the SRC Design Sciences research program funds research in areas that support the rapid, economic and testable design of very large-scale integration (VLSI) and ultra large-scale integration (ULSI) semiconductor products. Sponsored research also must support the overall SRC goals of productivity, high performance, quality, reliability and manufacturability.

The Design Sciences research program funded 30 research contracts at 21 North American universities in 1995, with a total value of $6.3 million. These contracts supported the research of more than 200 faculty and graduate students.

1995 Research Highlights

• University of California, Berkeley and University of Colorado at Boulder - Researchers led by Prof. Robert Brayton at Berkeley and Prof. Gary Hachtel at Boulder have made significant progress in the development of the Verification Interacting with Synthesis (VIS) tool, and have released VIS-1.0. VIS integrates the verification, simulation and synthesis of finite-state hardware systems. It maximizes performance by using state-of-the-art algorithms, and provides new capabilities and a better programming environment than existing tools.

• Rutgers University - Prof. Michael Bushnell and his team have produced important theoretical advances in modeling and detection of delay faults, leading to a unique built-in self-test methodology for at-speed testing of random logic circuits. Proto type software tools detect untestable circuit paths during the design phase, automatically generate guaranteed test patterns for delay faults, and insert self-testing structures into the circuit. The U.S. Air Force is evaluating the software for use in defense systems.

1995 Technology Transfer Highlights

• University of British Columbia - Prof. Carl Seger and his team have developed the VOSS design verification system and released it to SRC member companies. VOSS exploits mathematical proofs of circuit properties to assure that a design will meet its specifications under all conditions. VOSS combines the powerful techniques of mechanical theorem proving and symbolic trajectory evaluation, in an environment compatible with existing simulation methods. Companies exploring the VOSS research include Intel, Texas Instruments, Motorola and National Semiconductor.

• University of Washington - SRC-sponsored research at the University of Washington, headed by Prof. Carl Sechen, led to the release of TimberWolf 7.0, the most recent in a series of placement and routing tools. This series has been so successful that a startup company, TimberWolf Systems Inc., has been formed to commercialize the software and provide maintenance and support.

Environment, Safety & Health Sciences

Daniel J.C. Herr, Director

The SRC Environment, Safety & Health (ES&H) Sciences research program focuses on research to enable the design and manufacture of new generations of integrated circuits with high-performance processes that minimize environmental impact by: 1) using fewer chemicals, less water and less energy; 2) generating less waste; and 3) employing "environmentally-friendly" materials and technologies.

SRC ES&H Sciences research areas include: Design for the Environment; Utilization of Energy, Water and Materials; Emissions Reduction: and Alternatives to Hazardous/Toxic Chemicals.

Beginning in 1994 and continuing in 1995, the SRC audited all tasks in its manufacturing research program to take stock of research related to ES&H and to raise the visibility of ES&H research issues. The audit found approximately $1 million in manufacturing process research with an ES&H component.

The ES&H Sciences research program funded nine research contracts at five North American universities in 1995. These contracts had a total value of $0.67 million and supported the research of approximately 18 faculty and graduate students.

1995 Research Highlights

• Massachusetts Institute of Technology - Perfluorocompounds (PFCs) are used by the industry for two major applications: wafer patterning and PECVD chamber cleaning. MIT research headed by Prof. Rafael Reif has evaluated alternative chemistries that are more environmentally benign for these applications. After an industry survey, MIT researchers selected candidate chemistries for etch-viability experiments. The goal is to work with semiconductor companies and equipment manufacturers to accelerate development and implementation of PFC replacements.

• North Carolina State University - NCSU researchers, led by Prof. Gary Rubloff, have developed new methods for real-time chemical sensing by mass spectrometry; and for physically-based dynamic simulation of equipment, process, sensor and control-system behavior. Together, these methods continuously capture time-dependent behavior of process variables throughout a semiconductor process cycle. This sensor-supported simulation approach provides information that enables more effective evaluation of the tradeoffs between materials use and performance in deposition and etching processes.

Stanford student Simon Fang (2nd from left) explains the operation of a spectroscopic ellipsometer to John DeGenova of Intel (left) and Prof. Bob Helms (center) and Dr. Weidong Chen of Stanford.

1995 Technology Transfer Highlights

• University of Arizona - Prof. Farhang Shadman and Arizona researchers have developed a new reactive membrane for purifying gases. After consulting with the SRC and SEMATECH, Arizona selected Pall Corporation as a licensee. Two years of joint work with Pall have resulted in a successful plan for product design, optimization and commercialization. Exhibited at Semicon West and Semicon Japan, a novel integrated filter purifier named Pall PPT is the first in a new line of products.

• Stanford University - Prof. Robert Helms, Dr. Weidong Chen (now at National Semiconductor) and other Stanford researchers, working with SEMATECH and Hewlett-Packard (H-P), are developing new wafer-rinsing processes to significantly reduce point-of-use water consumption while achieving high yields and higher throughput. Using the research results, H-P has achieved application-specific solutions that reduce water use by a factor of four. Other companies working with Stanford to transfer this technology include Intel, National Semiconductor, AMD and Texas Instruments.

Factory Sciences

William Atkins, Director

Factory Sciences (FS) research supports the continued evolution of advanced integrated circuit manufacturing, with a paramount goal of maximum competitive advantage through reduced manufacturing costs and cycle times. To support SRC members' manufacturing advancements, FS funds research in four thrust areas: 1) cost reduction; 2) equipment and process control: 3) factory automation and management; and 4) logistics and modeling/simulation.

Cost and cycle time reductions are realized by research results which provide insight into: 1) better approaches to factory programmability and flexibility; 2) more rapid yield learning; 3) improved capital productivity; 4) advanced unit process control; 5) improved factory architecture and information processing; 6) optimized work-in-progress scheduling; 7) enhanced factory reconfigurability; and 8) more rigorous dynamical factory modeling.

The FS research program funded nine research contracts at five North American universities in 1995, with a total value of $2.2 million. These contracts supported the research of approximately 60 faculty and graduate students.

1995 Research Highlights

- University of Michigan - Prof. Jessy Grizzle and Michigan colleagues have conducted research in control theory, incorporating real-time physical and empirical models, The research has been applied to plasma reactive ion etching (RIE) on the AME 8300 platform, and will soon be applied on a PlasmaTherm wide-area etcher and a Lam 9400 polysilicon etch station. The models, in concert with advanced process sensors, have been used to perform real-time plasma process control for RIE. The aim is to reduce the deleterious effects of machine- and plasma-process disturbances on wafer-etch characteristics.

- University of Michigan - Prof. Ken Wise and his team have performed research on integrated microelectromechanical microsensors and produced several different types of devices, including microvalves for ultra-low flow gas flows and a variety of sensors integrated monolithically with CMOS circuitry. Included is a new class of solid-state gas detectors and an uncooled infrared imager for wafer temperature measurements. These devices will be applied in the distributed control loops of VLSI manufacturing tools to improve contamination-free manufacturing, materials purity and process uniformity.

1995 Technology Transfer Highlights

- University of Michigan - Texas Instruments (TI) has incorporated the long-term process-control methodology and techniques developed by University of Michigan researchers, led by Prof. Jessy Grizzle, to make unit process-control improvements at TI. The Michigan research is based on the incorporation of physical models into the control-loop algorithms. It has led to effective commercialization by TechWare Systems of software that incorporates real-time control models.

Interconnect Sciences

William Atkins, Director
Industry Asignee: Vivek Bissessur, Intel Corp.

To meet technology needs outlined in the Roadmap, Interconnect Sciences (IS) supports research addressing: 1) the Roadmap-required parasitic reductions via integrated copper/low dielectric insulators/chemical-mechanical polishing science; 2) new types of dry plasma etching sources and advanced plasma diagnostic methods; 3) improvements in interconnect reliability; 4) surface and interface materials science; and 5) advanced modeling and process simulation.

Additionally, to support Roadmap technology nodes beyond 0.1 µm, IS actively drives research investigations into new interconnect architectures and methods. IS operates within five thrusts: 1) materials; 2) equipment; 3) processes; 4) reliability and quality; and 5) TCAD.

The IS research program funded 15 research contracts at eight North American universities in 1995, with a total value of $3.5 million. The research of more than 100 faculty and graduate students was supported by the IS research program.

1995 Research Highlights

• University of New Mexico - Prof. Joseph Cecchi and his team have developed plasma diagnostics based on infrared laser diode spectroscopy (ILDS). The ILDS sensors have been used to characterize process chemistry, particularly to establish the link between plasma processing wafer-level parameters and the various etching species. Potential industry benefits center on process improvements for chip and plasma-tool makers.

• Stanford University - Dr. Jim McVittie and his team modeled wafer charging during plasma etching, leading to development of a prototype plasma charge probe (PCP). The PCP helps correlate wafer-localized charging effects with device transistor damage and has been used to study process optimization on tools such as Lam ECR, Lam 9600 and AMAT 5000. Potential industry benefits could be significant for the more advanced technology nodes of the Roadmap, since plasma damage is a major concern due to the thinner gate oxides used at those nodes.

Shawming Ma of Stanford University changes the prototype plasma charge probe.

1995 Technology Transfer Highlights

• Massachusetts Institute of Technology - Prof. Herb Sawin and former student Bill Conners, who founded Low Entropy Systems (LES), have applied full-wafer interferometry (FWI) in manufacturing processes such as plasma etch. This research allows *in situ* detection of non-uniformities in etch processing and can detect when a deposition process has reached its target film thickness. SEMATECH is using the FWI-based technology, developed by LES, to produce the same thickness of tetraethoxysilane (TEOS) deposition wafer-after-wafer, thus reducing manufacturing process variation significantly.

• University of Albany-SUNY - Dr. Alain Kaloyeros and his Albany team have researched selective and blanket chemical vapor deposition (CVD) of copper and its alloys. Work has focused on synthesis of environmentally safer precursors, improved understanding of the mechanisms of gas-phase and surface reactions during transport and deposition, and low-temperature integrated CVD processes for copper and its liners for ULSI applications. SRC members involved in developing this research include AMD, CVC Products, IBM, Intel, Motorola, National Semiconductor, Novellus Systems and Texas Instruments.

Lithography Sciences

Daniel J.C. Herr, Director

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SRC Lithography Sciences conducts research that will enable the production of robust lithographic materials, processes, control methodologies and process tools that have the capability and flexibility to produce integrated circuit patterns through the early part of the next century.

The primary goal of lithography is to transfer patterned features reproducibly. Orders-of-magnitude improvements in metrology capability are required to provide nondestructive, *in situ,* real-time measurements at the dimensions specified in the Roadmap. The 1995 investment priorities in the SRC's Lithography portfolio were: 1) resist, alignment and overlay; 2) masks and material; 3) critical dimension metrology; 4) modeling and pattern transfer: 5) contamination; 6) and systems.

The Lithography Sciences research program funded 20 research contracts at 11 North American universities in 1995. These contracts had a total value of $2.3 million and supported the research of more than 80 faculty and graduate students.

1995 Research Highlights

• Cornell University - The change of exposure tools to 193 nm makes it necessary to also change the resists used in lithographic processes. Using novel block-copolymer resist designs, Cornell researchers led by Prof. Christopher Ober and doctoral student Allen Gabor are producing imaging materials with high etch-resistance and transparency at 193 nm. These materials also are compatible with more environmentally benign processes. The feasibility of imaging these materials with deep ultraviolet (DUV) radiation was demonstrated at the SRC-supported MIT Lincoln Labs Resist User Facility. The facility is the first center of its kind, bringing researchers and suppliers together to share ideas, integrate resist research and provide access to state-of-the-art lithographic tools.

• University of Texas at Austin and Cornell University - An SRC research project funded jointly at UT-Austin (led by Prof. Grant Willson) and Cornell (led by Prof. Jean Fréchet) aims to eliminate the organic solvents currently used in photoresists. The UT-Austin/Cornell team has demonstrated a DUV resist formulation that has near-micron resolution, and is water castable and water developable.

1995 Technology Transfer Highlights

• University of California, Berkeley - Prof. William Oldham and his team continued research into optics damage produced by pulsed ArF (193 nm) laser radiation. This project provides the tools for assessing an upper limit on the lifetime of fused silica glass used in 193 nm lithographic applications. The research emphasizes real-time birefringence measurements, with the goal of understanding and characterizing radiation-induced compaction and color center formation. Working with SEMATECH to acquire glass samples from several manufacturers, the Berkeley researchers are evaluating the effects of glass-processing improvements and building a database for optical-property damage-rate predictions. Tool suppliers including SVGL have expressed strong interest in these results.

• Cornell University - Researchers led by Prof. Christopher Ober and Allen Gabor collaborated with the IBM Almaden Research Center and Phasex Inc. to explore commercialization of imageable block copolymers. The Cornell team has demonstrated the feasibility of developing DUV-imageable materials with supercritical CO_2. Through the use of supercritical CO_2, this technology promises significant reductions in the lithographic waste stream.

Ph.D. student S. Chieh fabricates 0.1 μm MOS transistors in the Cornell University Nanofabrication Facility.

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Materials and Bulk Processes Sciences

William T. Lynch, Director
Industry Assignee: Vivek Bissessur, Intel Corp.
University Assignee: Dahua Zhang Kolbas, North Carolina State University

Materials and Bulk Processes Sciences (MBPS) includes the front-end-of-the-line fabrication operations and starting materials for mainstream integrated-circuit fabrication. The tools and processes include those used to fabricate the structure up to the active silicon surface, and the thermal processes and depositions of active films above the interface, such as gate electrodes, elevated source/drain materials and silicidation.

Research in MBPS includes: 1) materials characterization and analysis; 2) gate dielectrics and field oxides; 3) bulk processes; 4) gate stack cluster tools: 5) and modeling and simulation.

The MBPS research program funded 28 research contracts at 18 North American universities in 1995, with a total value of $5.2 million. These contracts supported the research of more than 180 faculty and graduate students.

1995 Research Highlights

• University of Florida - Grid generation for IC process simulation is a time-consuming and difficult task. At the University of Florida, researchers led by Prof. Mark Law have been working on software for automating the grid-generation process. The software estimates the numerical error in the solution from the grid and uses this estimate to refine the grid and better represent the doping and structure, adapting the grid as the structure changes.

• Yale University - Prof. Tso-Ping Ma and his research team have demonstrated very high quality ultra-thin silicon nitride films that look promising as an advanced gate dielectric to succeed thermal SiO_2. The films were formed directly on silicon substrates by a novel jet-vapor deposition (JVD) technique. They exhibit remarkable electrical properties, including low densities of interface and bulk traps, low leakage current, high breakdown field strengths and high resistance to hot-carrier damage. Experimental data indicate that for a given equivalent oxide thickness, gate-leakage current is orders of magnitude lower in the JVD nitride.

1995 Technology Transfer Highlights

Stanford University - Researchers led by Prof. Robert Helms have examined the effects of surface cleaning preparations on the micro-roughness of silicon surfaces. The Stanford team has examined hydrogen fluoride-last cleaning sequences and is developing atomic level models for silicon surface reactions, etching and roughening. These simulation models will analyze and interpret the results from metrology tools such as atomic force microscopes. The ability to prepare ultra-clean, ultra-smooth wafer surfaces and MOS interfaces is a key enabler in the development of deep-submicron technologies. Texas Instruments and Intel have collaborated with the Stanford team on this research. Other SRC participants, including AMD, Hewlett-Packard, SEMATECH and NIST, are also applying the Stanford results.

Prof. Tso-Ping Ma and his Yale University team have demonstrated advanced gate dielectrics with remarkable electrical properties.

• Stanford University - Dr. James Plummer and his colleagues, in collaboration with AT&T and the National Laboratories, have achieved significant breakthroughs in their study of the Transient Enhanced Diffusion (TED) problem in silicon. Chief among these was the direct observation of (311) defect ribbons by AT&T and the correlation of the interstitials stored in the (311) defects with the time dependence of TED. The National Labs clarified the dynamics of the implant collision cascade, based on molecular dynamics simulations of ions implanted into silicon. Commercial suppliers of TCAD tools have been very aggressive in incorporating the Stanford TED models in their codes.

Packaging Sciences

Ronald C. Bracken, Director

The increasing speed and density of integrated circuits is putting ever more stringent requirements on the package to remove heat generated by ICs while maintaining operating temperatures consistent with high reliability. The SRC Packaging Sciences research program focuses on providing the information, tools and methodologies for the design and fabrication of packaging structures to satisfy the electrical, thermal/mechanical and reliability requirements of future packages.

The Packaging Sciences research program funded 15 research contracts at 10 North American universities in 1995, with a total value of $3.2 million. These contracts supported 36 faculty members and more than 100 graduate students.

1995 Research Highlights

• Cornell University - The Roadmap projects the need for continued increase in chip I/O that can only be met by area array interconnects. A Cornell research team, led by Dr. Che-Yu Li, has developed the capability for mechanical reliability modeling of solder array interconnects. This damage-integral based model can evaluate interconnect lifetime statistics as affected by distributions in design, materials, processing and service parameters.

• Lehigh University - A new mode of failure has been observed in plastic packages: delamination involving organic die attach adhesives/lead frame interfaces. Dr. Ray Pearson's research is developing fundamental tools that characterize surfaces and quantify adhesion of these interfaces. These characteristics are critical to predicting reliability and screening candidate materials for desired die attach performance. In 1995, the Lehigh team developed the "bondability diagram" concept, which maps adhesive strength as a function of time/temperature processing variables.

1995 Technology Transfer Highlights

• University of Arizona - The increasing demand for high-speed/high-frequency computing and communication modules in lightweight, compact electronic systems has established system electromagnetic compatibility as a key system-design constraint. Numerical modeling of radiated noise from packaged electronic components is currently in its infancy. Prof. Andreas Cangellaris and his team have designed UACREST, an electromagnetic simulator streamlined for radiated emissions prediction and radiated susceptibility evaluation of packaged electronic systems. Acknowledging the impact of reliable CAD tools on achieving first-pass success, the SRC and SEMATECH are engaged in a cooperative effort to transfer UACREST to the commercial supplier base.

Cornell student Martin Van Derhiede operates a controlled atmosphere reflow unit to prepare a solder joint specimen for fatigue testing.

• Purdue University - The accelerated use of CAE tools is increasing the need for high-quality data on the thermal, mechanical, electrical and physical properties of packaging materials. To meet this need, Prof. Cho-Yen Ho and Purdue researchers continued their work on the SRC/CINDAS Microelectronics Packaging Materials Database. This database - developed by Purdue's Center for Information and Numerical Data Analysis and Synthesis (CINDAS) with support from the SRC - is one of the most requested technical products offered by the SRC. In 1995, evaluated data were generated for new packaging materials including flex laminates, dielectric ceramics, lead-free solders and encapsulants.

Process Integration and Device Sciences

William T. Lynch, Director
University Asignee: Dahua Zhang Kolbas, North Carolina State University

Process Integration and Device Sciences (PIDS) is concerned with the semiconductor device itself and with the physics and chemistry of novel processes. The strategic direction of PIDS is to: 1) shift the focus of device technology from a lithography-dependent, standard-shrink approach by introducing creative structures and process architectures; 2) provide improved predictive modeling; 3) conceive circuit elements that are yield-tolerant of manufacturing defects and parameter variations; and 4) recognize opportunities for paradigm shifts that redirect engineering efforts to circumvent current technology limitations.

The PIDS research program funded 23 research contracts at 12 North American universities in 1995, with a total value of $4.1 million. These contracts supported more than 30 faculty and 125 graduate students in 1995.

1995 Research Highlights

• Duke University - Prof. Teh Y. Tan and Duke researchers worked with G.E. McGuire of MCNC to study the growth of epitaxial $CoSi_2$ films on Si using intermetallic diffusion, and the associated substrate doping properties for both bulk and silicon-on-insulator (SOI) Si. In SOI cases, by pre-doping the Si substrate through shallow ion implantation or by implanting dopant ions into pre-grown epi-$CoSi_2$ films and then performing drive-in anneals, Duke researchers grew void-free epi-$CoSi_2$ films on patterned SOI substrates using very low RTA temperatures. Voids or vacancies often occur in the Si substrate because of Si outdiffusion.

• University of California, Los Angeles - Prof. Kang Wang and his students have addressed integration and scaling limitation issues of low power electronics. The UCLA team has invented and demonstrated a bistable tunneling static random access memory (SRAM), which will increase the benchmark density to close to that of dynamic random access memory (DRAM) with the same feature size. The research is timely for the Roadmap's landmark goal in the year 2005 of achieving a 100 nm feature size. In fact, 100 nm SRAM structures already have been demonstrated in the UCLA laboratory, as have the same structures on a sub-100 nm scale.

• Stanford University - A Stanford team led by Prof. Robert Dutton has developed and implemented a comprehensive surface mobility model for MOS devices - calibrated down to 0.25 pm gate length - for its PISCES modeling program. This model is important since it physically accounts for and consistently calibrates the effects of channel doping and the parasitic resistances from contacts and spacers. Stanford researchers have worked with AT&T to test the model on AT&T's most advanced 0.25 pm MOS technology. Several SRC partner companies are now providing device structures for further evaluation and modeling based on this new approach.

1995 Technology Transfer Highlights

• University of California, Berkeley - Prof. Chenming Hu has led the continued development and commercialization of the Berkeley Short-Channel IGFET Model (BSIM). The latest version of this MOSFET modeling software, BSIM3v3, provides a convenient link between Electrical Computer Aided Design (ECAD) and technology/manufacturing. More than 40 people from 20 SRC member companies attended an SRC technology transfer course on BSIM3v3 in August 1995. Because it can be easily moved between different circuit simulators, BSIM3v3 was selected by an international compact model council to be the first industry standard compact MOSFET model for circuit simulation.

• Massachusetts Institute of Technology - Prof. Jacob White and his team have developed fast methods for on-chip signal integrity analysis. Their FASTCAP and FASTHENRY programs help designers eliminate hard-to-find signal integrity problems by rapidly and accurately computing all coupling capacitances and inductances for extremely complicated structures. Harris Semiconductor, Texas Instruments, IBM and Motorola have modified versions of the programs for applications as diverse as RF signal degradation, electromagnetic compatibility and microsensor characterization.

SRC Technical Excellence Awards

Recognizing Outstanding Research

The SRC Technical Excellence Awards were established in 1991 to recognize research of exceptional value to SRC members. The awards are presented annually for research that significantly enhances the productivity and competitiveness of the North American semiconductor industry. Awards are based on creativity and innovation, utility or impact on industry, relevance to the technical objectives of the SRC and the semiconductor industry, as reflected in the National Technology Roadmap for Semiconductors, and technology transfer success.

In 1995, two research teams were selected as winners of the 1994 Technical Excellence Awards. These were presented at an awards luncheon coinciding with the SRC's June 1995 Board of Directors meeting and research operations review in Research Triangle Park, NC. The 1994 Technical Excellence Award winners were:

- **Prof. Carl Sechen** and his former student **Dr. William Swartz** received the Technical Excellence Award for their layout optimization research, conducted at the **University of Washington** and **Yale University.** The technical contribution of this work is reflected in a series of evolutionary versions of the physical design toolset known as TimberWolf. The various versions of this software package represent the state of the art in integrated circuit design with respect to partitioning, placement and routing. Different versions of TimberWolf, based on the simulated annealing algorithm, have been created for different types of design styles. TimberWolf tools are widely used in industry and have resulted in significant reductions in die size compared to competing approaches.

- **Prof. Mark Kushner,** former students **Drs. Peter Ventzek** and **Seung Choi,** and current student **Robert Hoekstra** received the Technical Excellence Award for research at the **University of Illinois at Urbana-Champaign** (UIUC) on computer modeling of plasma reactors. The technical contributions of their work are powerful and robust simulation tools for plasma sources, tool configurations and chemistries for both deposition and etching that result in realistic geometries, relevant profiles and rates for plasma and chemical processes. The UIUC research products enable end users and vendors to optimize both tool design and process by simulating direct and remote plasma-enhanced chemical vapor deposition, SiO_2 and Si_3N_4 deposition, polysilicon and metal etching, surface kinetics, high plasma density tools, and dust particle generation and transport.

Prof. Mark Kushner (right) and University of Illinois at Urbana-Champaign student Robert Hoekstra were honored with an SRC Technical Excellence Award for their work on computer modeling of plasma reactors.

SRC Industrial Mentor Program

Industry Relevance and Technology Transfer

The SRC Industrial Mentor Program enhances the value of SRC research to industry and provides SRC participants with early access to key technologies. Industry scientists, engineers and managers who participated in the Mentor Program are associated with specific, SRC-funded university research tasks. These experts provide perspective and insight into industry needs, helping focus the research on these needs, as well as accelerating the research and transferring results to their companies. University researchers receive the benefit of direct interaction with industry engineers and access to corporate resources.

In 1995, the Mentor Program included 453 individual mentors from 28 SRC member companies and organizations. Ninety percent of all SRC research tasks had the benefit of an industry mentor during 1995.

To recognize and honor the significant contributions made by individual mentors in the Mentor Program, the SRC presents its annual Outstanding Industrial Mentor Awards. Six mentors were chosen to receive this award in 1995:

- **Noel Strader** of **Motorola Inc.** (Austin, Tex.), has been a mentor to Prof. Richard Newton at the University of California, Berkeley for the past several years. As a mentor on this Design Sciences research contract, Strader has provided Berkeley researchers with real-life industry examples and information about ongoing related work at Motorola. He also has arranged summer internships for doctoral candidates working on synthesis for low-power research.

- **Kathy Early** of **Advanced Micro Devices Inc.** (Sunnyvale, Calif.), has been a mentor to Prof. Franco Cerrina and his team of Lithography Sciences researchers at the University of Wisconsin since 1993. Early has played a key role in the successful development of the lithography modeling software CXrL Toolset by providing researchers with critical industrial data and hardware and software support.

- **Tracy Boswell** of **SEMATECH** (Austin, Tex.), has mentored Prof. Farhang Shadman's Materials and Bulk Processes Sciences research team at the University of Arizona since 1992. Of particular note is her involvement in the development, testing and technology transfer of Arizona's UV/ozone technology. Boswell performed a series of tests to validate the researchers' findings in an industrial plant and organized the transfer of a mobile test skid that demonstrated the advantages of the technology to various industrial fabs.

- **Hsing-Huang Tseng** of **Motorola Inc.** (Austin, Tex.), has been a mentor for Prof. Tso-Ping Ma's Materials and Bulk Processes Sciences contract at Yale University for the past five years. Tseng has provided Yale researchers with numerous test devices? including many not available elsewhere. Most recently, he enthusiastically supported the development of jet-vapor deposited silicon nitride films by providing joint wafer processing services, analyses and financial support.

- **E. Hal Bogardus** of **SEMATECH** (Austin, Tex.), has worked with Prof. Costas Spanos' Factory Sciences research at the University of California, Berkeley for more than seven years. During that period, Bogardus has arranged for direct collaboration with such companies as IBM, Texas Instruments and Lam Research. He has visited the university on many occasions and arranged several visits by researchers to industry sites.

- **Steven Groothuis** of **Texas Instruments Inc.** (Dallas, Tex.), has been a Packaging Sciences mentor to Profs. Carl Popelar and Vernal Kenner at The Ohio State University since 1993. Groothuis has provided insight into the problem of reliability of microelectronic packages and has guided graduate students in their dissertation work. In a broad effort to help OSU researchers work with the entire SRC community, he was the primary organizer of a molding compounds workshop that attracted more than 20 industrial participants.

SRC Intellectual Property

Patented Technologies Add Value for SRC Participants

The SRC's value to the industry's technology base includes appropriate protection of intellectual property assets that result from SRC research.

The SRC has a world-wide, unrestricted, royalty-free, non-exclusive license right to these patents, as well as the ability to sub-license the patents to SRC participants.

In 1995, the SRC added to its intellectual property portfolio, with 22 new U.S. patents issued and 15 new patent applications filed. The newly issued patents cover a number of important technology areas. Some of these include:

Gate Dielectrics

High-quality ultra-thin gate oxides, which incorporate nitrogen atoms, have been developed and patented by Prof. Dim-Lee Kwong at the University of Texas at Austin, The devices, which exhibit a nitrogen profile peak at the silicon oxide (SiO)-silicon (Si) interface, are formed by oxidizing the surface of a monocrystalline Si body in an atmosphere of nitrous oxide (NO) at a temperature above 900°C. The Si body and oxidized surface are then heated in an atmosphere of anhydrous ammonia to introduce additional nitrogen atoms into the oxide and to increase resistance to boron penetration without degrading the oxide by charge trapping. The resulting oxynitride has less degradation under hot-electron stress and approximately one order of magnitude longer lifetime than that of conventional SiO in Metal-Oxide Semiconductor (MOS) applications.

Lithography

A new microelectronic substrate patterning system and method was developed and patented in 1995 by Prof. Fabian Pease and co-workers at Stanford University. The system uses two or more copies of a mask pattern in the radiation path between the radiation source and the microelectronic substrate. The two or more copies of a mask are axially displaced from one another along the radiation path. Thus, the mask pattern is imaged onto the microelectronic substrate as a result of interaction of the radiation with the multiple copies of the mask pattern in the radiation path. The mask pattern thereby images at an increased depth of focus compared to a single copy of the mask pattern. The two or more copies of the mask pattern may be used to increase the depth of focus of transmissive and reflective microelectronic substrate imaging systems.

Advanced Devices

A capacitorless silicon-on-insulator (SOI) dynamic random access memory (DRAM) device has been developed and patented by Prof. Chenming Hu and H.J. Wan at the University of California, Berkeley. The advantages of this new DRAM device include large read current, good immunity to alpha particle-induced single-even-upset, and simple fabrication. Moreover, the device's size is that of a single transistor, making it attractive for ultra-high density memory applications. The charge is stored in the front surface of the thin silicon film of the SOI substrate. The stored charge modulates the function of the read transistor (e.g., the threshold voltage of a MOSFET). The amount of charge read in the capacitorless DRAM cell can easily exceed the amount of charge read in an ordinary DRAM cell.

Software

As another key component of the SRC intellectual property portfolio, the SRC currently has a listing of more than 190 software programs developed under SRC sponsorship.

When used in certain ASIC simulation applications, the software program RICE (Rapid Integrated Circuit Evaluator) - developed by Prof. Larry Pileggi at the University of Texas at Austin - has reportedly enabled modeling simulation which previously required 72 hours to be performed in as little as 20 minutes. A former recipient of an SRC Technical Excellence Award, Pileggi's RICE technology was described and issued a U.S. patent in 1995.

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