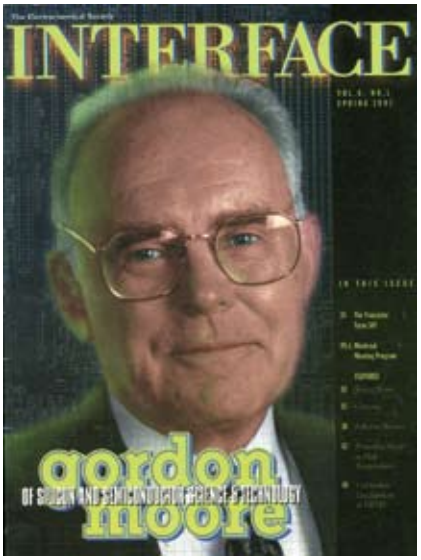
Gordon E. Moore and His Legacy: Four Decades and Counting

by Krishnan Rajeshwar and Fred Roozeboom

Forty years is a long time but amazingly enough, innovations in mainstream silicon microelectronics have largely continued to follow Gordon Moore's prescient predictions. The contributions of this remarkable individual, an ECS member for 48 years and currently an emeritus member, have been well documented in these magazine pages including a cover story for the spring 1997 issue (see image at right). In May 2006, ECS announced the establishment of the Gordon E. Moore Medal for Outstanding Achievement in Solid-State Science and Technology. This was made possible by an endowment from Intel Corporation in honor of its co-founder. "This award honors Moore's tremendous achievements in this field, which have had a strong and lasting influence on ECS, its members, and the work that they perform," said Mark Allendorf, ECS President. "Intel's support enables ECS to continue to recognize the most accomplished individuals in a vital and active part of the Society." Justin R. Rattner, chief technology officer of Intel, said, "It is a privilege for Intel to endow this award of The Electrochemical Society, home to the scientific disciplines at the core of the modern semiconductor industry. … we honor not only our founder, but also the link between fundamental science and innovation, which is at the core of both Intel and ECS." Winners of the predecessor to this prestigious award have included solid-state and semiconductor pioneers such as J. Woodall, B. Deal, A. Cho, and N. Holonyak. The new winner of the medal will be announced in an award ceremony at the plenary session of the ECS spring meeting in Chicago in May 2007 (see page 23 of this issue).

In this brief perspective of the re-named award, we can only offer brief glimpses into the backdrop and links between Gordon Moore, Intel, and ECS that have led to the endowment. Hark back to April 19, 1965, when Gordon Moore mused about the future of integrated electronics in an internal document for Fairchild Semiconductor,



which was subsequently published by *Electronics* magazine in an issue celebrating the 35th anniversary of electronics.[1] This ground-breaking paper was entitled, "Cramming More Components into Integrated Circuits," and a facsimile of it appears as Chapter 4 in a recent book on the historical aspects and implications of Moore's "law".[2] It is worth noting that Moore's observation on the underpinning trends in the Si microelectronics industry was called a "law" only later by another very large scale integration (VLSI) pioneer, Carver Mead, who holds the Gordon and Betty Moore endowed professorship (emeritus) at Caltech. The reader is further referred to an article[3] by Dan Hutcheson in the Spring 2005 issue of *Interface*, "Silicon: Into the Nano Era" for an eloquent discussion of the role that Moore's law has played in driving the technological and economic growth of the Si microelectronics industry. Any discussion of the history of Moore's law also will not be complete without recognition of the key roles played by Douglas Engelbart (a co-inventor of today's personal computer (PC) mechanical mouse), Jean Hoerni (discoverer of the planar process for manufacturing Si transistors), Jack Kilby (who in 1958 demonstrated a linear oscillator based on an integrated circuit (IC) containing a germanium transistor, a resistor, and a capacitor), and Robert Noyce (inventor in 1959 of a planar Si IC based on Hoerni's diffusion process). Indeed, these halcyon days of Si microelectronics saw a bewildering series of very important discoveries emanating mainly from R&D groups in three companies: Shockley Semiconductor, Fairchild Semiconductor, and Intel. Gordon Moore had a pivotal role to play in *all* these companies!

What is Moore's law? What does it exactly predict? We can only very briefly address these questions here by returning to Moore's original paper.[1] When this paper first came out in 1965, Si chips contained about 60 distinct devices. By contrast, Intel's Itanium chip crams 17 billion transistors in a single chip. As recently as a decade ago, chips were built at the 500 nm feature size level; current PC processors are fabricated at the 90 nm level. A 65 nm level chip has been already demonstrated and both Intel and IBM very recently announced a 45 nm chip.[4] Chips at the 30 nm level, and smaller, are not far behind. A logarithmic trend can be immediately discerned and this exponential scaling of chip component density with time is one of the underlying tenets of Moore's law. However, the periodicity or "Moore's clock cycle"[3] has been the subject of debate. Moore's earlier prediction of a doubling every year of chip component density was later updated by him in a 1975 paper,[5] which showed that the integration growth of metal-oxide-semiconductor (MOS) logic was slowing to a doubling every 18 months instead. On the other hand, the average rate for microprocessor units (MPUs) and random access memories (DRAMs) ran at a doubling every *two* years, as illustrated in Fig. 1. (Reference 3 may be consulted for a further elaboration of these trends.) It is quite conceivable that Si transistors will continue to shrink down to about the 4 nm level. This is estimated to occur around 2023 (see Fig. 2).

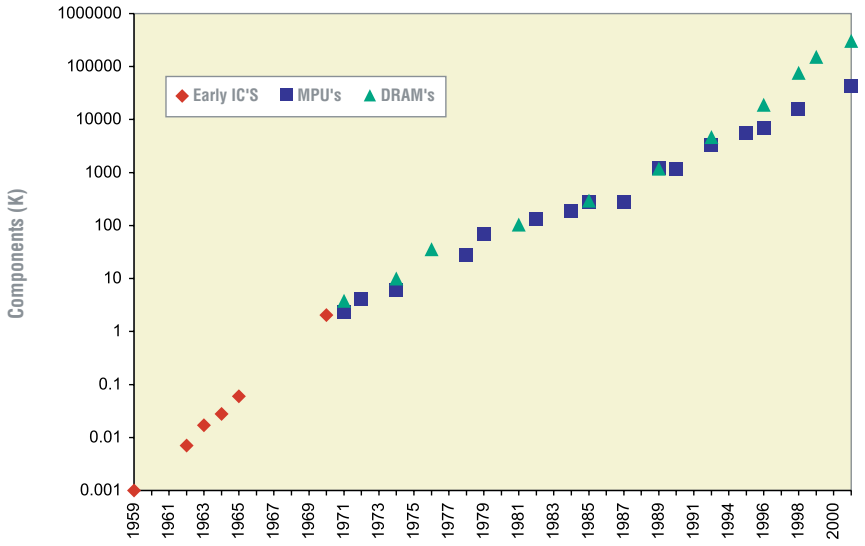


Fig. 1. *The forces behind the law were still strongly in effect when Gordon Moore retired in 2001, leading him to quip that "Moore's law had outlived Moore's career." (Reproduced from Ref. 3.).*

Where will we be four decades from now? At the 4 nm technology node, the Si doomsayers have predicted that we will hit "Moore's wall."[3] At this juncture, the transistor source and the drain, which are separated by the channel beneath the gate and the gate dielectric, will be close enough for the electrons to drift across on their own, leading to device failure. Furthermore, silicon dioxide will no longer be able to function as the gate dielectric. Indeed beyond even the 32 nm and 22 nm technology nodes, disruptive technologies and new device architectures are anticipated. This in turn requires new paradigms in materials (beyond Si), design, and processing since the scaling rules for complementary MOS (CMOS) circuits no longer apply. In Fig. 2, this technology domain is depicted as "Beyond CMOS."[6-10] This domain encompasses technologies based on carbon nanotubes, Si, or other semiconductor nanowire crossbars, molecular electronics, etc.

The cost of manufacturing IC chips ("fab" costs) has steadily crept up over the years. Indeed, as the cost (to the consumer) of computing power falls, the cost for manufacturers for adhering to the Moore's law trajectory will have the opposite trend. This has led to a "flattening of the Si chip manufacturing world"[11] as, increasingly, chip companies have started outsourcing manufacture (and even design) from the U.S., Europe, and Japan to all corners of the globe. Thus as the microelectronics community continues to innovate to keep Moore's law alive, there is an ever-increasing awareness, more R&D effort, and more business drivers to push the strategic research agenda of "More than Moore."[6-10] This third technology domain (Fig. 2) is based on or derived from Si technologies that do not scale with Moore's law such as radio frequency, power/high voltage, and sensor/actuator/microelectromechanical systems (MEMS). At an architectural level, the system complexity can be addressed, at least partly, by the system-on-a-chip (SoC) and system-in-package (SiP) approaches. Because of their programmability, SoCs can be manufactured in large numbers for a range of applications, offering maximum reuse of costly design and testing protocols.[12] Whereas a SoC has the lowest cost per function, NXP Semiconductors[8-10] and others including IBM, Intel, Samsung, Texas Instruments, Toshiba, Georgia Institute of Technology, and Fraunhofer Gesellschaft[11] have shown that a SiP focuses on achieving the highest value for a single-packaged modular platform combining electrical as well as non-electrical platform components. The three technology domains in Fig. 2, namely, More Moore, Beyond CMOS, and More than Moore, can be brought together into total *system* solutions by deploying so-called "heterogeneous integration."[6] Unfortunately, roadmaps (for example, of the ITRS genre) are virtually non-existent in this space and the agendas of materials suppliers, designers, and tool/device makers are not well aligned. Nonetheless, the first consortia have begun to gel here, *e.g.*, the e-CUBES project[13] in Europe and the EMC[3D] consortium.[14]

All this portends a rather unpredictable but very exciting juncture for the future of microelectronics. The mantra "faster, cheaper, smaller" will undoubtedly continue to apply to this industry. The micro(nano?)electronics industry will become more global and will pervade ever deeper into our everyday life with products ranging from computing, video games and entertainment, data storage, automotive and aviation electronics, wireless communication, healthcare, security, education, robotics, and who knows what else. Gordon Moore can justifiably be proud of the role he played in the explosive (exponential) growth of this industry.

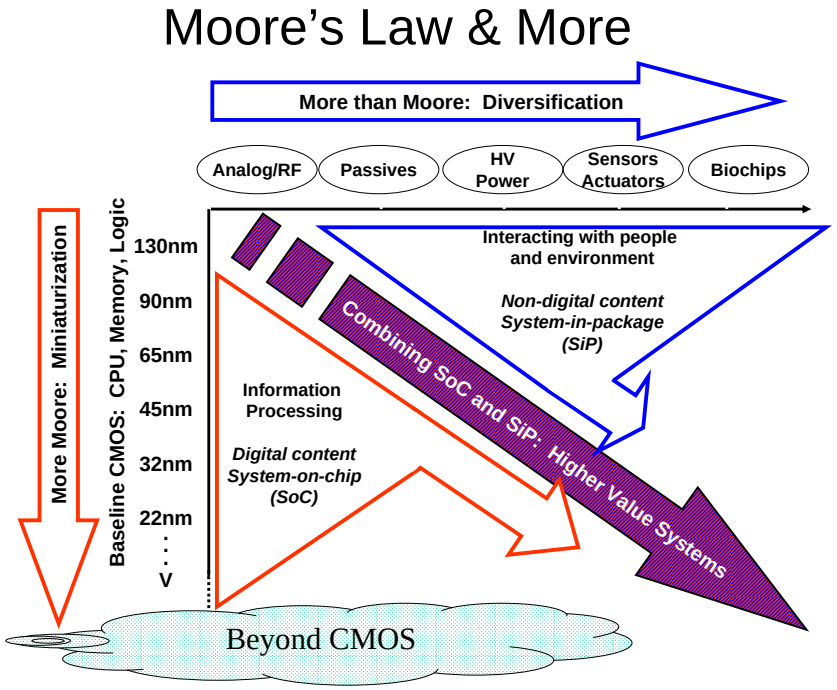


Fig. 2*. Projected scaling of the three technology domains. (Refer to text and Ref. 6).*

His contributions will live and breathe, to a small measure, through the renamed ECS award. Will the "Moore thread" of industry innovation continue unbroken through another four decades or more? Through paradigms like "Beyond CMOS" and "More than Moore" it most certainly will, because the lifestyle and activities of our future generations will demand nothing less. ■

Acknowledgments

We thank Mark Allendorf, President of ECS, for seeding the idea for this article and Mary Yess, Deputy Executive Director and Director of Publications of ECS, for nurturing its growth and fruition. Many colleagues provided encouragement and feedback, particularly, George Celler (Soitec USA), Dennis Hess (Georgia Institute of Technology), and Mart Graef (NXP Semiconductors).

References

1. G. E. Moore, *Electronics*, **38** (8), 19 April 1965, p. 114.
2. D. C. Brock, editor, *Understanding Moore's Law*, Chemical Heritage Press, Philadelphia, PA (2006).
3. G. D. Hutcheson, *Interface*, **14** (1), p. 17 (2005).
4. *The Wall Street Journal*, 27 January 2007.
5. G. E. Moore, *Tech. Dig. Int. Electron Devices Meeting*, 1975.
6. ITRS Roadmap, 2005 edition (http://www.itrs.net/Links/2005ITRS/Home2005.htm); see Introduction, p. 8.
7. ITRS Roadmap, 2005 edition (http://www.itrs.net/Links/2005ITRS/Home2005.htm); see chapter on "Assembly and Packaging."
8. F. Roozeboom, A. L. A. M. Kemmeren, J. F. C. Verhoeven, F. C. van den Heuvel, J. Klootwijk, H. Kretschman, T. Fri , E. C. E. van Grunsven, S. Bardy, C. Bunel, D. Chevrie, F. LeCornec, S. Ledain, F. Murray, and P. Philippe, *20th SB Micro Conference*, Florianopólis, Brazil, Sept 4-7, 2005.
9. G. Q. Zhang, M. Graef, and F. van Roosmalen, *7th Int. Conf. on Thermal, Mechanical, and Multiphysics: Simulation and Experiments in Micro-Electronics and Micro-Systems*, EuroSimE, 2006.
10. F. Roozeboom, A. L. A. M. Kemmeren, J. F. C. Verhoeven, F. C. van den Heuvel, J. Klootwijk, H. Kretschman, T. Fri, E. C. E. van Grunsven, S. Bardy, C. Bunel, D. Chevrie, F. LeCornec, S. Ledain, F. Murray, and P. Philippe, *Thin Solid Films*, **504**, 391 (2006).
11. T. L. Friedman, *The World Is Flat*, Farrar, Straus and Giroux, New York (2005).
12. H. van Houten, *Materials Today*, November 2004, p. 72.
13. www.ecubes.org. Also see: P. Ramm, "European Activities in 3D System Integration - The e-CUBES Project," Proc. Pan Pacific Microelectronics Symposium 2007, Jan. 30-Feb.1, 2007, Maui, Hawaii.
14. www.emc3d.org: EMC-3D Introduction and Overview in Semiconductor International, Feb. 2007 issue.

About the Authors

Krishnan Rajeshwar is the Editor of *Interface*. He is also a Distinguished Professor of Chemistry and Biochemistry and Associate Dean (College of Science) at the University of Texas at Arlington. His research interests span a broad spectrum in energy conversion and environmental pollution remediation. He may be reached at rajeshwar@uta.edu.

Fred Roozeboom is a Senior Principal Scientist at NXP Semiconductors (formerly Philips) Research in Eindhoven, The Netherlands. His research interests are in semiconductor thin film technology, passive integration, and 3D heterogeneous integration. He may be reached at Fred.Roozeboom@nxp.com.

ECS Expands Online Journal Archive in Digital Library

An additional 20 years of content from the *Journal of The Electrochemical Society* (JES) has been added to the ECS online archive. The JES archive now begins with Volume 102 from 1955. This is the latest phase of an ongoing project to make the entire JES content accessible in electronic format, ultimately going all the way back to its first iteration published in 1902. All articles from *Electrochemical and Solid-State Letters* (ESL), the other technical journal published by ECS, are already available online going back to the publication's launch in mid-1998.

This legacy content project has been underway for several years, and has been made possible by contributions to the Centennial fund-raising campaign and ECS operating revenues. ECS gratefully acknowledges the financial support that has helped make the archive possible. Generous gifts have been received by individuals: James Amick, Ralph Brodd, Larry Faulkner, Robert Frankenthal, and Wayne Worrell—all past presidents of the Society; and from the ECS Battery Division. In recognition of their sponsorship, each donor has a JES archive volume as a named collection.

The archive is accessible from the ECS Digital Library (DL) at www.ecsdl.org, which provides a home for all ECS digital content. Articles in the archive are available as full-text PDF files, with HTML-formatted tables of contents, abstract pages, and searchable database records. Complete JES content in the DL includes the current volume, backfile, and archive. The backfile is the content of the five (5) years preceding the current year. The archive consists of all the past volumes that are not part of the backfile. ECS members and subscribers have access to the current volume and the backfile. Through the end of 2007, ECS members will also have free trial access to the JES archive.

ECS journals provide the most authoritative research in solid-state and electrochemical science and technology. Subjects covered include: batteries and energy storage; fuel cells and energy conversion; corrosion, passivation, and anodic films; electrochemical and chemical deposition and etching; electrochemical synthesis and engineering; physical and analytical electrochemistry; dielectric science and materials; semiconductor devices, and materials, and processing; sensors and displays; and nanostructured materials, carbon nanotubes, and fullerenes. Authors interesting in submitting to the journals may visit the ECS website for instructions.

The ECS Digital Library offers high-quality content and the connectivity so essential in the current scientific community. If you are interested in helping ECS advance its mission by making a donation to the digitization project, please contact Mary Yess, Deputy Executive Director, mary.yess@electrochem.org. ■

FNCN Division Smalley Research Award

The ECS Fullerenes, Nanotubes, and Carbon Nanostructures (FNCN) Division has established its first award: the FNCN Smalley Research Award. The award was formalized in 2006 by the FNCN Division to honor the memory of Richard Smalley. Smalley, who died in 2005, was well known for his pioneering research on carbon nanotubes. In 1996, Smalley, along with Sir Harold Kroto, and Robert Curl were awarded the Nobel Prize for the discovery of the for his famous discovery of Buckminsterfullerene (C_{60}).

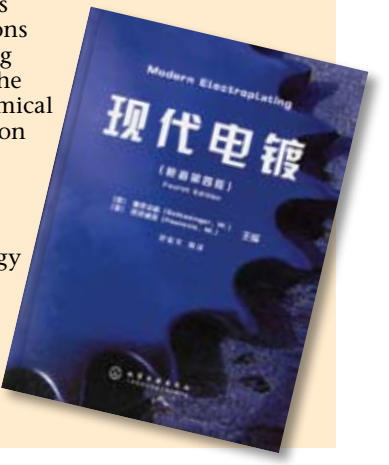
In 2000, Smalley founded Carbon Nanotechnologies, Inc., a company that is now a leading commercial producer of single-walled carbon nanotubes. In his last years, he expanded his horizons beyond the scope of conventional chemistry or physics research to seek solutions to the immense problem of future global energy needs. See the winter 2005 issue for a brief summary of Smalley's life and career (http://www.electrochem.org/dl/interface/wtr/wtr05/wtr05_p18-21.pdf).

Francis D'Souza, chair of the FNCN Division, said, "Naming the award after Rich Smalley was the right thing to do since it recognizes his pioneering research and entrepreneurship on fullerenes and carbon nanotubes. This award is expected to increase the visibility of the FNCN Division within and outside ECS. As such, the FNCN Division is comprised of an international body of scientists including those from the North America, Europe, and Japan. Therefore, the award will have an international flavor to it. We also hope that the newly established award will encourage more researchers to participate in the FNCN Division-sponsored symposia and make ECS the venue to discuss and disseminate their research findings."

The Award is intended to recognize in a broad sense, those persons who have made outstanding contributions to the understanding and applications of the science of fullerenes, nanotubes, and carbon nanostructures. The award consists of a scroll, a $1,000 prize, and the Division may provide travel assistance to the spring meeting in which the recipient is accepting the award. The recipient of the award is also expected to present a lecture on an appropriate subject relating to the FNCN Division and in the appropriate symposium. The first award will be presented at the spring ECS meeting in Phoenix, AZ, May 18-23, 2008. ■

Chinese Translation for ECS Monograph

The Society monograph, *Modern Electroplating*, recently was published in Chinese translation by the Beijing-based Chemical Industry Press. The book was the Society's first monograph, was originally published in 1942, and was edited by R. O. Hull. Now in its fourth edition, the editors are Mordechay Schlesinger and Milan Paunovic. The 800-page book is geared toward experienced deposition practitioners and novices alike, providing thorough, up-to-date explanations of the principles and techniques of electroplating technology. It also highlights the transition in the electronics industry from physical to electrochemical methods, especially with regard to next-generation technologies such as copper interconnects. Dr. Schlesinger is a professor in the Department of Physics at the University of Windsor (Canada); and Dr. Paunovic was until recently a research staff member in the Electrodeposition Technology Department at the IBM T. J. Watson Research Center (U.S.). Information about the English version of the book, sponsored by ECS, and published by John A. Wiley & Sons, may be found at http://www.electrochem.org/dl/monographs/index.htm. ■



New Category of Travel Grants Offered by Battery and HTM Divisions

The **Battery Division** and the **High Temperature Materials Division** (HTM) have introduced a new type of travel grant, specifically to help junior researchers attend and present at ECS meetings.

HTM Division Chair Eric Wachsman said that, "new post-graduate researchers typically have not yet established the financial resources to attend scientific meetings, even though this is essential to their career. Therefore, HTM has created the **Young Investigator Travel Grant** specifically to help those young faculty and scientists participate in HTM symposia, with the hope that they will consider becoming members of ECS and the HTM Division."

KM Abraham, Battery Division Chair, said, "the **Young Faculty Travel Grant** represents an important avenue in the Battery Division's on-going efforts to promote battery science and technology."

Grants of up to $1,000 will be available to post-doctoral associates, junior faculty members, and other young researchers under the age of 35 who are planning to present at an ECS Meeting in a symposium sponsored by either of the aforementioned Divisions. For more information please visit the ECS website (http://www.electrochem.org/sponsorship/travel_grants.htm#fac); or contact Bor Yann Liaw (Battery Division) at bliaw@hawaii.edu; or Jeff Fergus (HTM Division) at jwfergus@eng.auburn.edu. ■

Special Centennial Campaign Draws to Successful Close

In 2002, ECS launched its first capital fund-raising campaign to recognize the celebration of ECS and its 100 years of service to electrochemists and solid-state scientists and engineers around the world. The Centennial Campaign ended five years later on December 31, 2006, and raised over $700,000.

William D. Brown, the chair of the Financial Policy Advisory Committee and an active member throughout the campaign said, "I am really pleased with the continuing growth and influence of the development program on the activities of ECS and the resulting benefits to the membership. It has been vitally important to raise these funds to support special Society programs; and it is gratifying to see the excellent response from members and friends. I'm confident that, as the Society membership becomes more aware of how important the work of the Development Office is to improving, and even increasing, member benefits, we will continue to witness strong and growing support for the development effort."

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>
> **William D. Brown**
> Chair of the Financial Policy Advisory Committee

Goals for the campaign were set based on member needs as well as the needs of the scientific community as a whole. Throughout the five years, the needs changed, members and constituents continued to be consulted, and new budget-saving ideas were encouraged. The program areas included Meetings, Publications, Membership, and Education.

In the area of Education, with a five-year pledge for $125,000 from the Oronzio De Nora Foundation in 2003, the Oronzio De Nora Postdoctoral Fellowship was established to assist a postdoctoral scientist or engineer in the research of the field of industrial electrochemistry. The first recipient of the fellowship was Nicholas Mano, of the University of Texas (see the fall 2005 issue of *Interface*, p. 56).

Another educational program that was created through the campaign was the Student Chapter program. In 2003, the University of Central Florida was recognized as the first Student Chapter. Since then, nine other universities worldwide have been accepted into the program.

The purpose of Student Chapters is to give students an opportunity to understand electrochemical and solid-state sciences, to have a venue for meeting fellow students, and to receive recognition for their organized scholarly activities and community services.

The following schools are recognized as ECS Student Chapters:

- Electrochemical Society of the University of Central Florida,
- ECS Cleveland Section and Ernest B. Yeager Center for Electrochemical Sciences Joint Student Chapter,
- New York Capital Region Student Chapter,
- The Ohio State University Student Chapter,
- University of Florida Student Chapter,
- University of Virginia Student Chapter,
- University of California - Berkeley Student Chapter,
- Technical University Brno Student Chapter,
- University of Rome "Tor Vergata" Student Chapter, and
- University of Texas at Austin Student Chapter.

The Herbert Uhlig Summer Fellowship was another program that has received many donations. The award was established to honor the memory of past ECS president and Honorary Member, Herbert H. Uhlig. Once the goal for the Fellowship is met, it will be the fifth summer fellowship that will be offered to students who are interested in continuing their studies during the summer months.

The campaign has raised money to create a Special Membership Fund. This fund offers financial assistance to members who cannot pay their dues because of temporary financial hardships. Each year, ECS has been able to assist several members from the special fund so they can continue to remain loyal ECS members. The fund helps strengthen the mission of the Society, which is to encourage research and dissemination of knowledge in the fields of electrochemistry and solid-state science.

In 2006, five ECS past presidents, over 60 ECS members, and one Division provided funds to assist ECS with digitizing the archives of the *Journal of The Electrochemical Society*. The Digital Library offers members and subscribers all ECS content in one seamless resource, available all the time. Currently, ECS has digitized the content of the *Journal* back to 1955 and is offered to members and subscribers on a trial basis until the end of 2007. Also included in the Digital Library is the content of *Electrochemical and Solid-State Letters*, *ECS Transactions*, *Interface*, and Meeting Abstracts.

The Development Committee and ECS would like to thank all donors who have made the campaign a success. The Society could not have established these programs without your help. Thank you! ■

FMS National Materials Advancement Award

Leo Christodoulou received the National Materials Advancement Award, presented by the Federation of Materials Societies (FMS) at the National Press Club in Washington DC this past December. The award recognizes individuals who have demonstrated outstanding capabilities in advancing the field of materials science and engineering, and who contribute to the application of the materials profession to national policy in the United States. Previous recipients of the award include ECS member Jerry Woodall, of Purdue University and a National Medal of Technology Laureate; the late Representative George E. Brown, Jr., Chairman of the House Science Committee; Arden Bement, Director, National Science Foundation; Mary Good, former Under Secretary of Commerce; James Roberto, Deputy Director, Oak Ridge National Laboratory; and the late John H. Hopps, Jr., Deputy Under Secretary of Defense.

FMS is an umbrella organization whose member societies, which include ECS, represent the professional societies, universities, and National Research Council organizations that are involved with materials science, engineering, and technology. The purpose of FMS is to aid the mater ials community in obtaining information from, and exchanging information with, the policy community. An important FMS goal is to help the materials community to arrive at consensus in materials policy and to assist it in informing policy makers of materials concerns. ECS has a representative on the FMS Board of Trustees. More information about FMS may be found at www.materialsocieties.org.

Dr. Christodoulou's work at DARPA has profoundly changed the frontiers of materials science by identifying new materials concepts, innovative synthesis, and processing technologies. His research has been associated not just with advancing the technical state-of-the-art but with the beneficial societal and national applications of materials and structures research and development. He also has been highly effective at integrating the nation's universities into these programs and supporting the research training of graduate students, thus contributing to the transformation of the future of materials science and engineering.

Dr. Christodoulou received his degrees in metallurgy from Imperial College of Science, Technology, and Medicine in London, England. He was a postdoctoral research fellow at Carnegie Mellon University, served on the faculty of Imperial College and the Virginia Polytechnic and State University, and served over a decade at Martin Marietta Laboratories. He joined DARPA in 1999. He has received numerous prizes from his peers, authored or co-authored over 60 technical papers, and is a named co-inventor on more than 20 U.S. patents or their foreign equivalents. ■

FMS recently presented its National Materials Advancement Award to ***Leo Christodoulou*** *(right). ECS representatives to FMS attended the ceremony on December 6; they included* ***Roque Calvo*** *(ECS Executive Director, left) and* ***Guy Davis*** *(ECS's FMS Trustee, center).*

Photo by Mattox Photography, Washington, DC

Division Officer Slates Announced

New officers for the 2007-2009 term have been nominated for the following Divisions. The Energy Technology Division is voting by the new online balloting system. All other Divisions listed will hold elections at the upcoming ECS meeting in Chicago, Illinois (May 6-10, 2007). All election results will be reported in the summer 2007 issue of *Interface*.

Electronics and Photonics Division

Chair
Albert Baca, Sandia National Labs
Vice-Chair
Pablo Chang, Northrop Grumman
Jr. Vice-Chair
Yue Kuo, Texas A&M University
Secretary
Andrew Hoff, University of South Florida
Treasurer
Fan Ren, University of Florida
Members-at-Large
Cor Claeys, IMEC
D. Noel Buckley, University of Limerick
Sorin Cristoloveanu, INEP-INPG Minatec
George Celler, Padova University
M. Jamal Deen, McMaster University
Manfred Engelhardt, Qimonda
Ulrich Goesele, Max-Planck Institute
Dennis Hess, Georgia Institute of Technology
Chennupati Jagadish, Australian National University
Carlton Osburn, North Carolina State University
George Rozgonyi, North Carolina State University
Masaharu Watanabe, SEZ Japan Inc.
Laszlo Fabry, Wacker Chemie AG
Howard Huff, Sematech, Emeritus
Bernd Kolbesen, G. W. Goethe University
Gerald Oleszek, University of Colorado
Kenji Shiojima, NTT Photonics Laboratories
Jerzy Ruzyllo, The Pennsylvania State University
Rodney Ridley, Fairchild Semiconductor
Robert Fitch, U.S. Air Force Research Lab
Takeshi Hattori, Sony Corporation
Hiroshi Iwai, Tokyo Institute of Technology
Durgamadhab Misra, New Jersey Institute of Technology
Fred Roozeboom, NXP Research
Edward Stokes, University of North Carolina
Jennifer Wang, Northrop Grumman
Junichi Murota, Tohoku University

Energy Technology Division

Chair
Karim Zaghib, Hydro-Quebec
Vice-Chair
S. R. Narayanan, Jet Propulsion Laboratory
Secretary
Jean St-Pierre, University of North Carolina
Treasurer (one to be elected)
Scott Calabrese Barton, Michigan State University
Jeremy P. Meyers, University of Texas Austin
Jun John Xu, Rutgers University

Organic & Biological Electrochemistry Division

Chair
Isao Taniguchi, Kumamoto University
Vice-Chair
Albert Fry, Wesleyan University
Secretary/Treasurer
James Burgess, Case Western Reserve University

Physical and Analytical Electrochemistry Division

Chair
Hugh DeLong, U.S. Air Force
Vice-Chair
Paul Trulove, U.S. Naval Academy
Secretary/Treasurer
Shelley Minteer, Saint Louis University
Members-at-Large
Ingrid Fritsch, University of Arkansas
Tom Zawodzinski, Case Western Reserve University
Robert Mantz, Army Research Office
Sylvie Morin, York University

Corporate Membership News

The ECS Corporate Membership program has witnessed some excellent growth in the Benefactor level Corporate Memberships during the latter part of 2006, with three new Benefactors bringing us to a total of five. We welcomed one new Corporate Member, **Lam Research**, at this level; and had two existing members upgrade their memberships: **Duracell** (up from the Sponsoring level) and **Industrie de Nora S.p.A.** (up from the Patron level).

Founded in 1980, **Lam Research Corporation** is a major supplier of wafer fabrication equipment and services to the world's semiconductor industry. The company's innovative etch technologies empower customers to build the world's highest-performing integrated circuits. Lam's etch systems shape the microscopic conductive and dielectric layers into circuits that define a chip's final use and function. The company also offers a next-generation wafer cleaning solution, which employs proprietary technology and can be used throughout the semiconductor manufacturing process. Headquartered in Fremont, California, Lam maintains a network of facilities throughout the United States, Asia, and Europe to meet the complex and changing needs of its global customer base.

At the fall ECS meeting, the Board of Directors approved additional benefits for the Corporate Membership packages. Members at the levels of Sponsoring, Patron, and Benefactor, which currently receive online access to ECS's serial publications, will now receive not only the current content in these journals, but also all archived content as well. This includes the archive of the *Journal of The Electrochemical Society,* which has just added another 20 years worth of content, going back to 1955. The Patron level members will now receive online access to ECS's serial publications for two facilities, up from one. All members will be able to send their employees to the newly created Corporate Tutorials, free of charge.

As an ECS Corporate Member, your organization benefits through: password-free online access to current and archived ECS serial publications; recognition throughout ECS's website and publications; subscriptions to two highly rated journals in the field, the *Journal of The Electrochemical Society* and *Electrochemical and Solid-State Letters*; a subscription to *Interface*; complimentary individual membership; and free registration to our biannual meetings (Benefactor level only), which attract upwards of 3,500 scientists each year.

If your organization is interested in supporting ECS and receiving the benefits of Corporate Membership, please contact Amir Zaman, Associate Director of Corporate and Government Relations, at amir.zaman@electrochem.org or 1.609.737.1902, ext. 103. ■

Looking for Student News

ECS takes an active interest in the affairs of its Student Members, and we are always interested in hearing from you about your interests, activities, and accomplishments.

Send all correspondence to:

INTERFACE
65 South Main Street
Pennington, NJ 08534-2839, USA
Tel: 609.737.1902
Fax: 609.737.2743
E-mail: interface@electrochem.org

www.electrochem.org

ECS Co-Sponsored Conferences

In addition to the regular ECS biannual meetings, ECS and its Divisions also co-sponsor meetings and symposia organized by individuals and/or other organizations, of interest to the technical audience ECS serves. The following is a list of the co-sponsored meetings for 2007.

- XVI Simpósio Brasileiro de Eletroquímica e Eletroanalítica, April 15-19, 2007 (Águas de Lindóia, Brazil), www.xvisibee.iqm.unicamp.br
- 25th International Power Sources Symposium, April 23-27, 2007 (Bath, United Kingdom), www.ipss.org.uk
- Hydrogen & Fuel Cells 2007, April 29-May 2, 2007 (Vancouver, Canada), www.hfc2007.com
- 2007 International Society of Electrochemistry Spring Meeting, May 1-4, 2007 (Dublin, Ireland), spring07.ise-online.org
- 2007 International Conference on Advanced Capacitors, May 28-30, 2007 (Kyoto, Japan), capacitor.electrochem.jp/ica2007
- 8th International Conference on Advanced Batteries and Accumulators, June 3-7, 2007 (Brno, Czech Republic), www.aba-brno.cz
- 10th International Symposium on Solid Oxide Fuel Cells, June 3-8, 2007 (Nara, Japan), sofc.electrochem.jp/sofc-x/
- EuroCVD 16, September 16-21, 2007 (Scheveningen, The Netherlands), www.eurocvd16.nl
- NACE Northern Area Eastern Conference 2007, September 24-26, 2007 (Ottawa, Canada), www.nace.org
- 2007 Fuel Cell Seminar, October 15- 19, 2007 (San Antonio, Texas, USA), www.fuelcellseminar.com

To request an ECS co-sponsorship of your technical event, please contact Amir Zaman, Associate Director of Corporate and Government Relations, at amir.zaman@electrochem.org or 609.737.1902, ext. 103.