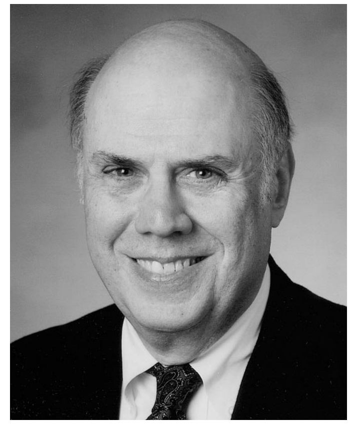
# Introduction: Materials for Electronics

Robert D. Miller received his Ph.D. in Organic Chemistry from Cornell University and spent a postdoctoral year at Union Carbide Research Institute in Tarrytown, NY. He joined IBM at the T. J. Watson Research Laboratories in Yorktown Heights, NY, after his postdoctoral year. He currently manages the Advanced Organic Materials Department at the IBM Almaden Research Center. He is a member of the American Chemical Society and the Materials Research Society and serves on the editorial advisory boards of Chemical Reviews and Advanced Functional Materials. During his career, he has received five IBM awards for outstanding technical achievements, has received 29 invention plateau awards, and is a member of the IBM Academy of Technology. Dr. Miller was elected a Fellow of the Division of Polymeric Materials Science and Engineering in 2006 and the Materials Research Society in 2007 and is a member of the National Academy of Engineering. Dr. Miller is a coinventor on more than 70 patents and patent publications and has published more than 350 articles in refereed technical journals.



Ed Chandross is a native New Yorker and, after his education in the public schools, got his professional degrees at MIT and Harvard. Although intending to enter the academic world, he was unable to resist an offer from the famous Bell Labs to join an expanding chemical research effort where he could have his own program. He began in 1959, the start of the period known to many as the “golden days.” Having been entranced by a chemiluminescence demonstration as a college freshman, he set out to understand how a chemical reaction could generate an excited state. That led to the discovery of peroxalate chemiluminescence, eventually commercialized as the ubiquitous Lightstick. It was followed by pioneering work in electron transfer chemiluminescence. Dealing with excited states led him into the developing world of organic photochemistry where he pursued excimers and exciplexes, ending in reversible photodimerization for optical information storage. Simply following his nose provided an interest in photoresists, where moving to deep-UV exposure required new chemistries and materials. During the 1980s he morphed into a materials chemist, stimulated by interesting opportunities to invent new technologies. They included optical fiber manufacture where ultrapure materials were needed, as well as advances in sol−gel chemistry for casting large silica bodies. After the telecom bubble burst at the turn of the century, he accepted an irresistible retirement offer and started a consulting business. He agreed to stay at Bell Labs part time and still has an office there. In addition to consulting work, he has served on various journal and university advisory boards, organized some conferences, and is currently an editor of ACS’s Chemistry of Materials. He maintains an active interest in squelching the excessive hype in contemporary science and had much success in the area of molecular electronics. A long-standing interest in electronics has included building hi-fi equipment and two CRT color television sets. It is now directed to computers, which are far less hazardous to play with. Along the way, Ed has acquired various honors; the most recent are election to the National Academy of Engineering and ACS Fellow (inaugural class). He intends to stay professionally active as long as possible, considering retirement to be an impolite word.

It is widely recognized that the electronics and photonics industries are major parts of the world economy as well as being responsible for many of the advanced technologies that have added so much to our lives. However, it is not generally known that many of the products they have provided are not simply the province of physics and electrical engineering, as commonly perceived, but are built on complex chemistry and chemical engineering platforms. In fact, this is a major arena where nanotechnology is practiced. This issue of Chemical Reviews covers a number of diverse contributions to Electronic Materials that are based on chemical and materials sciences.

Let us begin with semiconductor technology. The ever-shrinking dimensions of devices have required better performance of patterning materials, and some of the changes are discussed in two articles by Sanders and Kim, Park, and Hinsberg on modern lithography and self-assembly. Thin films of both active and passive materials are critical components and have often been deposited by chemical vapor deposition (CVD) processes. However, thinner films require greater control, and atomic layer deposition, reviewed by George, has assumed more importance. New, ultrathin, uniform dielectric layers, with *k* values as high as possible, and their applications are reviewed by Ponce Ortiz, Facchetti, and Marks, while advances in back-end-of-the-line (BEOL) insulator materials are covered by Volksen, Miller, and Dubois. A desire to implement new nanostructures has led to many new areas of work. The preparation, properties, and applications of colloidal nanocrystals are reviewed by Talapin, Lee, Kovalenko, and Shevchenko, and silicon nanowire science is summarized by Schmidt, Witteman, and Gösele. Semiconductor nanowire applications for energy conversion are discussed by Hochbaum and Yang.

Many of the wet chemical processes cannot be pushed to the nanoscopic dimensions needed because solvent viscosity/surface tension damages features and supercritical fluids (SCFs) provide an advantage. Romang and Watkins cover current issues in this area. Finally, the critical need for planar surfaces in CMOS integration has been answered by chemical−mechanical planarization (CMP) of metals and dielectric surfaces, a mixture of abrasion and chemical transformation, and Krishnan, Nalaskowski, and Cook bring us up to date on progress here.

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On the macro side sits large-area electronics, an area that has generated much interest and a variety of products, including many on flexible substrates. This goes far beyond the traditional printed circuits and includes the applications of organic semiconductors. Arias, MacKenzie, McCulloch, Rivnay, and Salleo describe the state of the art in this emerging technology. A well-known application here is the huge xerographic printing and copying industry, which was revolutionized in the 1970s by the introduction of organic photoconductors. New materials for these applications are still sought, and Weiss and Abkowitz update this area in their review article.

The demand for storage is insatiable. Traditionally this has been cheaply delivered by magnetic disk drives. The magnetic storage business is continually pressed for higher storage densities and faster access times and has been plagued by reliability issues. Electronic memories are currently fashionable and rely on flash memories made by conventional silicon technologies. Here miniaturization, storage capacities, read-write longevity, and long-term data retention are the challenges. Fast, stable, high-density storage class memory technologies are currently in great demand. One of the most promising newer technologies involves phase-change memories, and the article by Raoux, Welnic, and Ielmini brings us up to date on advances in PCM materials and processes.

Photonic technologies encompass much more than the ubiquitious optical fibers that make high-speed Internet traffic possible. The demand for more bandwidth has inspired the search for new modulator materials with lower dielectric constants, as well as higher nonlinearities facilitating lower drive voltages and enabling the higher speeds needed. Dalton, Sullivan, and Bale review the organic polymer modulators that may make such applications achievable. Photonic circuits also need new materials, and Moon and Yang report on some important aspects of photonic crystals.

Stable, reversible color changes provide the cornerstone for many potential applications. One of the best studied techniques is electrochromism. A widespread application of electrochromic materials is in automatic darkening rear view mirrors that are now in many automobiles. Electrochromic processes are also of interest for some display technologies. Beaujuge and Reynolds summarize the chemical aspects of this field.

The newest and perhaps most exciting material with many potential applications contains only graphitic carbon known as graphene. Here there is much fascinating chemistry, and the review by Allen, Tung, and Kaner addresses this young field.

Finally, we do not pretend to cover even most of the many chemical connections with the electronic and photonics industries in this single thematic issue. There are clearly many more that provide topics for futures reviews, thematic issues, chapters, and books. Here we have chosen some topics primarily to highlight the importance of their chemical heritage and hope to inspire more attention to opportunities in the field.

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