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George E. Pake Prize: A Few Challenges in the Evolution of Semiconductor Device/Manufacturing Technology

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In the early 1980s, the semiconductor industry faced the related challenges of "scaling through the one-micron barrier" and converting single-level-metal NMOS integrated circuits to multi-level-metal CMOS. Multiple advances in lithography technology and device materials/process integration led the way toward the deep-sub-micron transistors and interconnects that characterize today's electronic chips. In the 1990s, CMOS scaling advanced at an accelerated pace enabled by rapid advances in many aspects of optical lithography. However, the industry also needed to continue the progress in manufacturing on ever-larger silicon wafers to maintain economy-of-scale trends. Simultaneously, the increasing complexity and absolute-precision requirements of manufacturing compounded the necessity for new processes, tools, and control methodologies. This talk presents a personal perspective on some of the approaches that addressed the aforementioned challenges. In particular, early work on integrating silicides, lightly-doped-drain FETs, shallow recessed isolation, and double-level metal will be discussed. In addition, some pioneering efforts in deep-UV lithography and single-wafer processing will be covered. The latter will be mainly based on results from the MMST Program – a $100M+, 5-year R&D effort, funded by DARPA, the U.S. Air Force, and Texas Instruments, that developed a wide range of new technologies for advanced semiconductor manufacturing. The major highlight of the program was the demonstration of sub-3-day cycle time for manufacturing 350-nm CMOS integrated circuits in 1993. This was principally enabled by the development of: (1) 100% single-wafer processing, including rapid-thermal processing (RTP), and (2) computer-integrated-manufacturing (CIM), including real-time, in-situ process control.