Materials for electronic devices beyond CMOS

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Materials development continues to play an ever more crucial role in the success of the semiconductor industry. As CMOS devices are reaching their physical limits, even with new materials and geometries, it has become necessary to drive research on new devices, most of which would be enabled by yet another "generation of new electronic materials". Of course, the most-visible driver of "beyond CMOS" devices and materials has been the desire to maintain improvement in speed to power ratio. However, increasing opportunities are also being identified for reaching higher levels of performance in a broader suite device/circuit parameters (*e.g.*, for analog and RF) and in integrating new functionalities (*e.g.*, new forms of memory and sensors) into systems on-chip and in-package.

It has traditionally taken about a decade to introduce new materials into IC manufacturing and even longer for new devices. The principal obstacle at this time is the identification of the most promising devices. Once this is accomplished, we will have the "fun" of developing how best to fabricate them into practical (including cost-effective!) integrated systems. There have been many factors that have enabled the IC industry to accomplish this so successfully with Si-based systems. One of them is the simplicity and "beauty" of Si crystals and silicon dioxide dielectrics. Future materials, with the exception of graphene, are far more complicated and difficult to control. Some of them are layered materials such as metal sulfides, selenides, and tellurides. There are a plethora of electronic effects found in multi-component materials systems, from bulk effects (*e.g.*, multiferroic materials) to surface effects (*e.g.*, topological insulators). It took the IC industry a few decades to optimize and control defects in bulk Si, as a single element. The industry now faces the challenge of learning to control the defect chemistry of multi-component systems as well as their surfaces and interfaces. In this presentation, we will discuss some of these new materials, their potential benefits, and challenges. In addition, we will discuss the challenges and opportunities associated with conducting early research toward these new technologies in precompetitive partnerships between companies, universities, and government agencies.