Improved Materials Dominate Chip Evolution

November 3 2005

Material innovation has replaced scaling as the primary source of performance and feature improvements in leading-edge CMOS semiconductors, IBM technologist Paul Farrar, Jr. told attendees at the ISMI Symposium on Manufacturing Effectiveness recently.

Farrar, vice president for semiconductor process development at IBM, said "scheduled innovation" is responsible for more than 60 percent of CMOS performance gain at the 65 nm technology generation, and nearly that much for the 90 nm generation.

"Innovation is the key to the industry," Farrar noted. "There is no new technology—there is not the 'next CMOS'—so [progress] has to be innovation off of CMOS," Farrar said. In the future, he added, "the majority of advancements will be dictated by how well we integrate new materials" such as strained silicon and films for high-k metal gate and low-k back end of line (BEOL).

Farrar's comments preceded other Symposium discussions in which economist Dan Hutcheson of VLSI Research, Inc. asserted that Moore's Law will continue defying predictions of its demise, and a panel of industry experts expressed a cautious approach to 450 mm wafer conversion.

The second annual ISMI Symposium on Manufacturing Effectiveness was sponsored by the International SEMATECH Manufacturing Initiative (ISMI) to bring together technologists to work on solutions to

the industry's most pressing manufacturing issues. ISMI was formed in 2004 with a mission to provide solutions to current and future fab challenges for manufacturing-oriented chip-makers. ISMI's members are AMD, Freescale, Hewlett-Packard, IBM, Infineon, Intel, Panasonic, Philips, Samsung, Spansion, TSMC, and Texas Instruments.

In a keynote address, IBM's Farrar predicted that the development of new materials would continue to move beyond the familiar substances of silicon, oxygen, and nitrogen and toward more obscure chemistries. "We're going to use a lot more elements—maybe 80 on the periodic chart," he said.

To successfully develop and integrate new materials into manufacturing, Farrar said close collaborations with suppliers and other manufacturers are indispensable—but all parties must be willing to listen to other viewpoints and concepts. "The best idea is the one you get from somebody else," he added.

Farrar added that global alliances with organizations such as ISMI and SEMATECH have allowed IBM to innovate in films and immersion lithography more quickly than the company would have done working alone. "Innovation is the key challenge of the semiconductor industry," Farrar concluded. "For us at IBM, R&D partnerships have really helped us realize innovation."

During a subsequent talk, VLSI CEO Hutcheson declared that Moore's Law will continue to defy predictions of its demise, reasserting itself with new technologies while producing increasingly versatile microchips at continuously lower costs per transistor.

He added that the microchip industry is the main driver of the world's economic engine and that its growth will continue, even if limits to planar CMOS force a shift to unfamiliar and more expensive

technologies.

"Moore's Law is still alive and well," Hutcheson declared. "The show will go on…Just because there's a sunset doesn't mean there won't be a new day."

While acknowledging that product saturation since 1995 has slowed the industry's growth to 6 to 8 percent a year and that conventional CMOS may be coming to an end, he said the world isn't about to forsake microchips. Instead, chip manufacturing will migrate to new technologies, such as spintronics, carbon nanotubes, nanowire, and pattern self-assembly. According to Hutcheson, "there's plenty of room left at the bottom."

In defending the law first articulated by Intel co-founder Gordon Moore, Hutcheson recited several statistics that he said indicate its viability:

-- The number of transistors produced in the world reached 10^{18} in 2004, compared to just over a million in 1955. This reflects an increase amounting to 12 orders of magnitude in about 50 years.
-- Average price per transistor in “nanodollars” has fallen steadily from 1 million (one-tenth of a cent) in 1975 to about 100 (one ten-millionth of a cent) this year.
-- Chips' critical dimensions have shrunk from 5000 nm to 90 nm between 1974 and 2003

Even if Moore's Law eventually hits "Moore's Wall," that doesn't mean the end for the chip industry. According to Hutcheson, the early auto industry followed a Moore's-like path of declining unit prices and increasingly sophisticated products before maturing with slowly increasing prices in the 1920s. Nevertheless, the industry survived because it had become thoroughly integrated in society.

"The world didn't say, 'Cars are getting more expensive, so we're going back to horses,'" Hutcheson quipped.

Elsewhere at the Symposium, a distinguished panel of industry experts appeared to support a cautious approach to 450 mm wafer conversion and stressed the importance of collaborative solutions to manufacturing problems.

"If you fail to move fast, and you fail to collaborate, you may fail to exist," said Michael O'Halloran, director of technology for IDC. "The [companies] that are out there surviving are the ones that were involved in collaboration." Information-sharing has been critical for industry players in adapting to the demands of 300 mm manufacturing, other panelists said.

However, the consensus seemed to favor a deliberate approach on the introduction of 450 mm wafers, currently called for in 2011 by the International Technology Roadmap for Semiconductors (ITRS). Intel's Mani Janakiram, manager of Analysis and Control Technologies at Intel, called for the industry to develop a "strong, definitive economic model" to analyze the costs and risks of conversion.

Eric Englhardt, director of automation products for Applied Materials, said manufacturers should "look at ways of dramatically improving the efficiency of the factory" before trying to negotiate a new wafer size, and should consider alternatives to conversion. But he added, "Maybe we can't stop it… and we'll be driven to that, and there will be many changes in our industry. So I think we have to be prepared for both worlds."

On a related topic, Shige Kobayashi, Senior Engineer at Renesas Technology, said the equipment and information complexities of new 300 mm factories may require renewed emphasis on workforce development. "Engineers may need to be retrained," Kobayashi noted.

And Arieh Greenberg, Senior Principal at Infineon Technologies, said design for manufacturing (DFM) is becoming a larger issue in what he termed "the age of lithography."

"How do we integrate design into manufacturing, and what would be the role of the factory to improve design?" Greenberg said.