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Background

Although semiconductors account for only a small portion of electronics industry sales, they are crucial to all electronic products and to the global and internet economy. Semiconductors are used in computers, consumer electronics and telecommunication equipment including wireless networks and handsets, industrial machinery, transportation equipment, and military hardware.

Semiconductor materials can be altered to be either a conductor or an insulator. The products are primarily one of two types: an integrated circuit (also called a "die" or chip), and discrete devices. A discrete semiconductor is an individual circuit that performs a single function affecting the flow of electrical current. A chip is a collection of microminiaturized electronic components, such as transistors and capacitors, placed on a tiny rectangle of silicon. A single integrated circuit can perform the functions of thousands of discrete transistors, diodes, capacitors, and resistors [1].

Typical functions of semiconductors in electronics include information processing, information display, power handling, data storage, signal conditioning, and conversion between light and electrical energy sources.

Semiconductors have allowed for great advances in diverse areas, but manufacturing consumes significant resources and uses hazardous chemicals. Production requires an ultra-clean process. Water, energy, bulk gases, chemicals, metals, and other materials are also used.

A 1997 study estimated that resource inputs for production of one six-inch wafer are 3,200 cubic feet of bulk gases, 22 cubic feet of hazardous gases, 2,275 gallons of deionized water, 20 pounds of chemicals and 285 kilowatt hours of power. Wastes produced by that same six-inch wafer are 25 pounds of sodium hydroxide, 2,840 gallons of wastewater and seven pounds of miscellaneous hazardous waste [3].

Significant improvements have been made in semiconductor manufacturing processes since 1997. As the industry has moved to larger-size wafers and ever-decreasing die sizes, increased manufacturing efficiencies have resulted since more semiconductors can now be produced per wafer. This has enabled the industry to reduce the amount of resources and energy needed to manufacture semiconductors.

For example, in 1997, approximately 5 kilowatt hours (KWH) of electricity were needed to produce 1 die. By 2003, this energy requirement was reduced by 28%. Even larger improvements were seen with water use. Data has been published showing a 45% reduction in ultra-pure water (UPW) use on a per-die basis [6] These results were based on eight-inch wafer data. The conversion from 6-inch wafers to 8-inch wafers helped enable these reductions in materials / energy use. As the industry moves to 12-inch wafers, these improvements in manufacturing efficiencies are expected to continue.

Market Overview

Leading the global demand for semiconductors is Asia, at 40% of worldwide consumption as reported in 2004. China is the largest market for cellular handsets, representing 20% of demand, and second largest market for personal computers [4].

In 2002 and 2003, wireless local access networks (WLAN) were an especially strong market for the semiconductor industry, with growth rates greater than 35 percent forecast through 2005, according to the Semiconductor Industry Association (SIA).

Along with a proliferation of wired and wireless information appliances, the cellular handset market was also an important growth category for semiconductors in the early 2000s. This category achieved double-digit growth in the fourth quarter of 2002, fueled in part by new subscribers in Asian nations, especially China, where the SIA reported that some 5 million new wireless users were being added monthly.

Despite the growth afforded by demand from the communications sector, PC sales in the early 2000s remained an important factor in the growth of the semiconductor industry.

Pockets for strong future growth in demand of semiconductors include digital TVs, digital cameras, color displays, and wideband data capability; and for PCs, streaming video and broadband connectivity.

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Industry Overview

The industry is international, with major manufacturers in the U.S., China, Japan, Korea, and Europe. The top three U.S. manufacturers in 2002 were Intel Corporation, Motorola, Inc., and Texas Instruments, Inc. [1]. U.S.-based semiconductor manufacturers are located all over the world. According to the SIA, as of 2003, their member companies had approximately 70 fabrication facilities in the U.S., 68 in foreign countries and a handful in China [2].

Other countries also manufacture semiconductors and, according to the SIA president, "have recognized the strategic importance of leadership in the semiconductor industry and are becoming formidable competitors."

The SIA reported a record year for the industry in 2000, with global revenues of $204 billion. Lower revenues and flat sales occurred from 2001 through 2003, followed by another record year in 2004, at $213 billion [5].

To give a snapshot of the U.S. semiconductor industry, here are the 2005 statistics from the SIA [4].

- U.S. 2005 Sales = $110 Billion
- Worldwide 2005 Sales = $228 Billion
- 2005 World Market Share = 48 percent of $228 Billion Market
- U.S. Jobs = 225,000
- Percent of Sales Outside U.S. Market = 77 Percent
- Capital Equipment = $11 Billion, 10 Percent of Sales
- R&D Investment = $18 Billion, 17 Percent of Sales
- More than 30 Percent of Revenues Invested in the Future

The semiconductor industry is noted for its innovation and rapid change. Perhaps no other industry has such a pressing need to make continuous changes to stay ahead of rivals in a furiously competitive business. In 2003, the industry considered itself evolved from microelectronics to nanoelectronics.

This fast rate of product, process, and tool evolution provides strong incentive to incorporate efficiencies, especially with the massive investment. As efficient methods and processes are developed, manufacturers implement them when they retool for the next product cycle. The next product cycle is dictated by faster devices, smaller device geometry, and larger wafers.

In 2004 and 2005, companies began and implemented conversions from 200mm wafer size to 300mm wafer size. Larger wafers allow increased chip productivity but also required a very high investment in R&D to make the change happen for the entire industry. The industry is discussing converting to a 450mm wafer size sometime between 2008 and 2010, but there are as many opponents as proponents for this change, due to the challenges of going from 200 to 300mm.

These innovations require new tools that allow for the printing of small lines and the handling of larger wafers. As a result, the semiconductor industry tends to maximize efficiencies about every five years, as opposed to every five, 10, or 20 years in other industries. Because this industry is constantly evolving, there are opportunities for the semiconductor industry to continuously implement pollution prevention measures and provide demonstrable results.

The NAICS and SIC code for the Semiconductor (and Related Device Manufacturing) are 334413 and 3674 respectively.

Sources:
[1] Encyclopedia of American Industries. 2003. SIC 3674 - Semiconductors and Related Devices
[2] Semiconductor Industry Association (SIA). 2005. Environment, Safety and Health.
[3] Silicon Valley Toxics Coaliton and Corpwatch. 1997. The Environmental Cost of Computers.
[4] SIA. 2005. Industry Facts and Figures.
[5] SIA. 2005. Economy.
[6] Yao, M.A.; Wilson, A.R.; McManus, T.J.; Shadman, F.; Electronics and the Environment, 2004. Conference Record. 2004 IEEE International Symposium on 10-13 May 2004 Page(s):97 - 103

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