

Case Study #4: Semiconductors and Learning Curves

Silicon semiconductors have been the basis of computing technology for the past fifty years. As silicon materials technology advanced, the computing power and energy efficiency of computers also increased. Professor Toriumi gave a striking example of the advancements in energy efficiency; in 1999, a teraflop computer took up an entire room and required 500,000 watts of power while in 2007, the same computing could be done on a single 275 mm² chip while using only 62 watts. If silicon materials technology had not advanced, computers would have remained inefficient and would have taken large amounts of space, limiting the popularity and mass production of personal computers.

Professor Toriumi also talked about the Poisson equation, which is the dimensional scaling law for device physics. According to this law, even if one shrinks the components for electrical devices down to nanometer sizes, the internal electric field must remain constant. This allows us to miniaturize chips and electrical components down to sizes smaller than the width of the HIV virus.

Next in the lecture, Professor Toriumi discussed Moore's Law. Specifically, Moore's Law describes how the number of manufactured transistors will follow an exponential growth pattern, while the generalized Moore's Law describes a limitless exponential growth path for computing technology. This is related to Learning Curves, which also follow exponential growth patterns. Both Moore's Law and Learning Curves can have exponential growth because past progress helps create future development (positive feedback). In terms of Moore's Law, computers help design next generation computers, which will then help design the next next generation computers. For Learning Curves, acquired knowledge helps one explore and gain new knowledge, building a positive feedback loop.

Professor Toriumi then briefly mentioned the ITRS, or International Technology Roadmap for Semiconductors. This roadmap is sponsored by the five leading chip manufacturing regions of the world: Europe, Japan, Korea, Taiwan, and the United States. It identifies and sets challenges in chip manufacturing and helps ensure cost-effective advancements in the performance of integrated circuits. Two of the major materials challenges presented in the Roadmap are leakage current while integrated transistors are off and source-drain current while transistors are on. The leakage current is related to the miniaturization of dielectric thicknesses and can be mitigated by the use of high-k dielectrics. Current degradation can be decreased by increasing FET mobility through the use of materials like germanium and graphene as semiconductors.

Lastly, Professor Toriumi talked about Ray Kurzweil's concept of singularity. According to Kurzweil, if computing technology continues to follow the generalized Moore's Law, by 2020, artificial intelligence will rival human intelligence and consciousness. By 2030, nanobots will cure all human diseases. Finally, by 2040, all information in humans will be copied to computers, reaching singularity. After this point, we need to consider the relevance of the human race as computers surpass our knowledge and intelligence. Perhaps if we reach singularity, humans will become obsolete.

What we liked about Professor Toriumi's lecture was his organization. Professor Toriumi had a clearly defined outline in the beginning with checkpoints throughout the presentation. Both Professor Toriumi and Professor Fitzgerald were also dynamic, pausing when necessary and changing vocal tones to engage viewers. Additionally, both Professor Toriumi and Professor Fitzgerald used their Powerpoints solely as an aid to their presentation, and did not rely on their slides to relay all the information to viewers.

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