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Plenary

R&D Challenges and Chance in Today's Japan

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Crisis in Japan's Semiconductor Industry Only a short while ago, Japan's semiconductor industry was ranked number one in the world. However, Japan quickly lost its competitive edge as the yen grew too strong against other currencies. In addition, technical excellence diffused internationally as equipment makers became the technology suppliers and the providers of process recipes. Thus the number one position for DRAM manufacturing shifted from Japan to Samsung in Korea, and Micron in the US. The US regained strength with the help of a weak dollar and a strong PC business led by Intel. TSMC and other Taiwan companies started a foundry business based on ASIC manufacturing service for fabless design companies, and have subsequently established themselves as the world's standard in logic technology. Europe also, has been gaining strength through a series of co-operative projects coordinated by the EC government (ESPIRIT). In 1998, three European companies were listed among the top ten in the world, and at this rate, Europe may soon be able to challenge the US.

R&D Reduction Japan on the other hand, is now forced to maintain cost competitiveness among these emerging countries. The Japanese semiconductor industry suffers from loss of market to the emerging countries and huge losses due to cheap DRAM prices. In response to this crisis, the Japanese industry has been restructuring by cutting new investment for research projects, to reduce product cost.

Urgent Alliance Research and development is necessary for Japan's future competitiveness. In order to offset the reduction of investment in R&D, an alliance among industries is the only solution. Some cooperation between companies has already been observed. Establishing these relationships is not easy, because gains by cooperation may not be immediate, and conflict over market shares may be caused instead. But it is necessary to build alliances on an even larger scale, considering today's competitive global environment. Once an alliance has been formed, source of funding is next issue. If the alliance is lacking funds, then it needs to turn to the private and/or government sectors.

R& D Funding by Private Sector, Japan v.s. US In the United States, risky research and development projects are constantly initiated by new ventures, because investors chase dreams and are forgiving of failures. Also, the success of a few companies such as Netscape, Yahoo, Broadcom, and Rambus can make up for several billion dollars of other investment losses. Recently, the Japanese government has begun to sponsor university faculty and students, with hopes of yielding such new billion dollar ventures in Japan. But it is not popular to change jobs in Japan, and the lack of experienced resources, and the lack of interaction with industries, and the conservative nature of Japanese investors, as well as the consumer's taste for brand names, make it difficult to launch a successful "over-night" venture. Social culture in Japan has been changing, but the investor's culture remains conservative, especially considering recent *banking* sector restructuring. Here the enviable Chinese investor's attitude should be noted; emphasis is placed on collecting profit, and there is less concern for the original investment money. This attitude is also ideal for new ventures.

Government Role For large-scale projects, which are outside of the scope of individual companies and private investors, it is important that the government intervenes and funds activities to at least the same level as in the European Community. In Europe, the availability of government-assisted funds encourages cooperation between industries and companies. Also, these funds (blood tax money), should be directed to industries and universities in order to work towards enabling main stream technology for the next generation, not only on the pure academic interest projects of the past. The total sum of R&D resources in industry is below a critical level, so it is especially important that the resources and activities of universities supplement industry's need. Communication between industry and universities could be improved if industry is responsible directly for the government funded university activities. The strength of such an arrangement has been successfully demonstrated by the growth of Europe's industry in the recent years.

Immediate Co-operative Project The conventional silicon gate structure of today's CMOS technology can be extended from 0.18u to 0.13u by simple improvements in lithography. However development of new device structure is needed beyond 0.1u, in order to solve fundamental problems such as resistance at the shallow junction, silicide of the poly gate, and current drive at low voltages. Development of this new <0.1u device structure is tremendous task, suitable for a joint co-operative effort. Because the large capital is needed for such a project government funding and authority is necessary for large-scale technology development.

Culture Change Needed and Search for New Resources Effective utilization of all resources, students, women and early retirees is also important, especially as the average age of the Japanese population is increasing. The number of female engineers in Japan is especially low compared to other countries. In the US, almost half of the new engineers at IBM and Intel are female. In order encourage female engineering talent, social culture and education during youth needs to change. It is also important to utilize the increasing population of retired engineers. A hands-on retraining program from private and government funds, prior to retirement, may create experienced resources.

Importance of Anticipating Change Finally, correct anticipation of changes in technology trends is necessary for survival. Continuing along the extension of a current path is relatively easy, but it is very difficult to predict the right strategy when technology changes direction. The right decisions are essential for survival, and may have great financial potential, but wrong decisions can be fatal.

Lost Opportunities For example, let's look at Japan's recent DRAM crisis. Although DRAM business has always been cyclical in nature, a closer look at technology trends shows that over the past twenty years, DRAM chip density has been increasing by four times every three years, in accordance with Moore's Law. The system memory size of a PC on the other hand, has been increasing at only half of that rate. Considering these two trends, the system memory sizes of some sets will be smaller than the chip memory size around the year 2000. Thus, embedded memory and logic on a single chip has been emphasized recently. However in business, a time lag is required to establish new markets. Over capacity and the subsequent price drop should have been anticipated, especially when new capacity was added in Far East Asia and Europe. But management in most companies wasn't able to foresee the technology and market situation correctly, and so Japan's economy rose and fell with the DRAM market.

Another example of wrong strategy occurred in the 1980's. While IBM and Japanese industries were fighting for dominance of mainframe computing and bipolar technology, Intel was able to subcontract its XT-CPU 8086 over IBM's internal CPU. IBM and Japanese industries lost a significant opportunity in their failure to recognize the importance of the CMOS CPU.

Personal Opportunities in IBM In 1983, I was working on CMOS within IBM. At that time, PC's based on FET were almost two orders slower than mainframes based on bipolar technology. Then the performance improvement of FET based systems was increasing at a rate of two times per year, and the mainframes were improving more slowly at two times every four years. Despite the disbelief of the bipolar group, according to the trends, the cross-over between FET and bipolar performance was expected around 1990. At that time, the advantage of the bipolar device came the short channel length of the base ~0.2u, which was formed by the diffusivity difference between boron and arsenic. We worked hard to define a shorter FET channel to match the bipolar base width. Although the minimum lithography feature at the time was 1.2u, by developing a side wall spacer technique, a channel length of 0.35um could be defined. Punch through effects were contained by addition of boron pockets, thus the present day halo LDD structure was invented.

At about the same time, lithography suffered from depth of focus due to wafer warping and device topology. My boss Jack Riseman asked me to utilize Chemical Mechanical Polish process, when he learned that big astrology telescope lenses, several meters in diameter, could be polished to an accuracy of within a quarter of a wavelength. I did not think then, that warping of only a few microns was a significant problem, but Jack anticipated a future in which the CMP process would eventually be needed. We developed the first Shallow Trench Isolation and Damascene processes for metal wiring, and our SRAM which utilized Halo LDD and STI, was able to match bipolar performance, convincing us that that ultra short channel CMOS technology with lower power, would someday prevail over bipolar. But it took some time for this idea to gain acceptance within IBM, because IBM was busy struggling against Japan for mainframe dominance. Thus, although CMOS was already under development within IBM, IBM lost the PC business to Intel.

Right Action at the Right Time If wrong decisions are lost opportunities, then detection and focus at critical changing points are vital business chances as well. For example, several years ago in the United States, e-mail services started by using open lines during off peak hours to deliver over two orders more information for the same price as a voice phone call. At the time, I personally did not believe such a service could be extended to the general population, because the line capacity was too limited. However, other more far-sighted people recognized this contradictory phenomena as the opportunity of a life time, and thus the Internet Age was begun as almost overnight, new communication ventures were established. Illinois University students capitalized on the ordinary household user's demand, and added function and convenience to what was once a shareware GUI browser, to build Netscape, which is now a billion dollar company. Many other hardware and software companies were started up and spun off, featuring new techniques for data compression, and data transfer, to support higher data rates.

Responsibility for Anticipation is Everybody's! The Internet Age was able to begin in the United States, not only because venture capital was available, but also because individuals took on the responsibility of anticipation, to form successful companies. In Japan too, more emphasis should also be placed on the individual researcher. New ideas and innovations are most likely to be achieved by the hands-on worker, so it is important for researchers to be aware of trends and to anticipate shifts.

Personal Anticipation After retiring from IBM, I started a company based on a new idea for flash memory. The role of flash memory has been increasing with the popularity of portable products and rapid market expansion is expected. However, unlike DRAM's stack capacitor cell, there are many different types of flash device structures, and a universal solution has not yet been reached. Also flash applications suffer from high voltages, slow program time and limited endurance. A great opportunity will be rewarded if a fundamental solution can be found. In certain applications, DRAM could be replaced and other new applications could be enabled. Our new venture challenges these fundamental issues in two parts, the first part consists of fast read and fast program at low voltages for embedded application and the second target is fast program, high density flash for mass storage applications. Time will tell if our anticipation and assessment of trends are correct.

For Today and Tomorrow Regarding the future of Japan, let's look at the trend of PC sales. Until now, each new CPU generation has been more powerful than the previous generation. Recently however, Celeron-based notebooks are outselling the new Pentium III desktops. This performance reverse shift may be indicative of a major change- from the Age of the PC, to the Age of the smart consumer product. Strong activity on intelligent wireless and mobile systems supports this idea. Clearly, system size has been decreasing, from mainframe to PC, and PC to notebook. In network computing, the decentralized local intelligence paradigm is replacing central computing. Japan's strength in consumer electronics may be a significant asset for this new trend.

Summary In order to reactivate the Japanese industry, an alliance among industries, and collaboration between universities and industries are important. More activity is needed for 0.1u main stream technology R&D and tax money is needed to fund for these activities. Success will depend on focusing these efforts on winning technology elements. The winning technology is a product of constant re-evaluation, comparing of alternative options and continuous improvement by individual researchers.