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JUNE 6-8, 1995／**KYOTO**

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DIGEST OF TECHNICAL PAPERS

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□ The Japan Society of Applied Physics □ The IEEE Electron Devices Society

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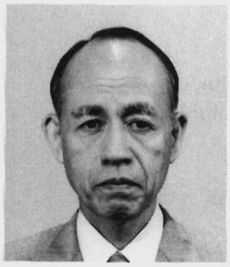
FIFTEENTH ANNIVERSARY
1995 SYMPOSIUM ON VLSI TECHNOLOGY

For the fifteenth anniversary of the Symposium on VLSI Technology we have brought the Symposium to Oiso, Japan. At this occasion, as we look back at the fruitful years after the tenth anniversary of the Symposium, we have requested the chairmen of the past five years to give us their perspective of the Symposium. We would like to recognize and appreciate the dedication and hard work of these people in shaping the Symposium on VLSI Technology into one of the leading meetings in our industry.

Takashi Tokuyama



Chairman,
1991 Oiso

First Symposium was held in Maui in 1981 after three years of careful preparation from the original proposal of Prof. Tanaka and Prof. Kosonocky in 1978. The primary aim of the Symposium was to exchange information between Japan and US VLSI engineers and scientists. However, the other side of the purpose was to create personal friendship between Symposium attendants. I recollect the discussions made at the 10th anniversary (1990) Symposium in Honolulu on the future issue of VLSI technology. The recognition among attendants was an urgent necessity of R&D collaborations between the companies since big amount of investment is expected unavoidable in the future VLSI developments. Today, five years past since then, international collaborations between the companies are becoming common. The success of these collaborations, unnecessary to say, depends very much on the human relations between engineers and scientists, which I would like to emphasize, were being built during 15 years of personal relations among Symposium attendants.

The development of 1GbitDRAM prototype was already reported. The cost of information processing should be improved continuously in the next 5~10 years through the realization of low cost distribution of such highly integrated ULSIs. On the other hand, future semiconductor industry should be developed in the form gentle and friendly to the living earth since environmental requirements and resource preservation will become more and more important. I believe our Symposium will continuously play an significant role in the evolution of VLSI technology.

Dirk J. Bartelink

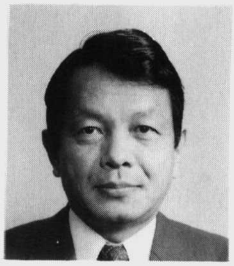
Co-Chairman,
1991 Oiso

Chairman,
1992 Seattle

The ancient traditions of Kyoto present an excellent backdrop for reflecting on the history and future of the VLSI Technology Symposium. The globalization of the semiconductor industry is proof of the wisdom in launching the Symposium 15 years ago. It is now widely recognized that the penetration of VLSI in our society is too pervasive and its economic impact too great to prevent the semiconductor industry from spreading around the globe. What is not so widely recognized, other than by the specialists gathered here for the VLSI Symposia, is that only mainstream standardization provides the ability to solve the many nearly insurmountable barriers to progress. Therefore, cooperation is critical. Cooperation amongst companies is just as important to keeping the whole industry moving forward as competitiveness is critical to advancing the individual company. This cooperation begins with the informal exchange of views as provided at the Symposia and succeeds through the friendship and trust generated by years of repeat encounters. Congratulations to the organizers of this 15th Anniversary meeting in maintaining the proven traditions of the VLSI Technology Symposium.

As the world semiconductor industry tries to maintain its momentum in providing ever improving cost per function, new concepts will be required. These concepts must respect the manufacturing experience that is central to VLSI. Through their focus on VLSI and now ULSI, the Symposia provide a unique forum for assessing alternative device technologies in the full light of manufacturing and design concerns. There is no better way of shedding this light than through the traditions of cooperation established at the VLSI Symposia.

Shojiro Asai



Co-Chairman,
1992 Seattle

Chairman,
1993 Kyoto

Anything that can be called a world-class success underlies an open-minded philosophy that calls on all possibly available talents from all over the world. The Symposium on VLSI Technology has been successful because it could get the cream of world's VLSI engineering community to contribute over its entire history. It has served, as envisioned by Professors Shoji Tanaka and Walter Kosonocky, as a forum of exchange of information on the most advanced technology and as a meeting place for those who are making all that happen. Everybody who has participated has had the sense of excitement and reward being part of the growth of a very important technology—the VLSI. I hope that the Symposium will keep playing the role it has played over the past fifteen years, and that its spirit will outlive the physical limits of the technology.

James T. Clemens

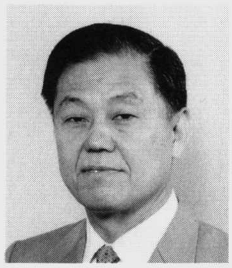
Co-Chairman,
1993 Kyoto

Chairman,
1994 Honolulu

It is indeed interesting to reflect back on the VLSI Symposia and my personal involvement with it. Silicon technology has grown exponentially for the past thirty years. VLSI ($>10^6$ components per circuit) began to develop in the late 1970's, and it was at this time that Prof. Tanaka and Prof. Kosonocky perceived the need for an international forum, where individuals could exchange their ideas concerning the wide variety of issues facing this industry. VLSI is now embedded in essentially every part of our daily life. And the technical challenges of the future are clearly in front of us. There is much to be done. As with VLSI technology itself, the Symposia have grown in a profound manner during the past fifteen years. The VLSI Symposia are now truly the premier symposia in the field of microelectronics, with its yearly attendees representing the dynamic international nature of this scientific field.

In 1987, I was asked to present an invited paper on deep ultraviolet lithography in Karuizawa, and my affiliation with the Symposia's organizational effort then began. I feel honored to have met and collaborated with a such a distinguished, international group of individuals. Each year at the Symposia, we witness new technical advancements and new technical leaders emerge. It has been a privilege to serve this Symposia and help disseminate the technical information that has so positively affected the quality of life. At its fifteenth anniversary, I would like to offer my congratulations to everyone who has been involved, from the attendees, to the authors, and to the organizers, and to extend my wishes for continued success. Finally, I would like to thank the Symposia for enriching the experiences of both my personal and professional life.

Hiroyoshi Komiya



Co-Chairman,
1994 Honolulu

Chairman,
1995 Kyoto

Since the tenth anniversary of the symposium in 1990 in Hawaii, a rapid increase in the production cost of VLSIs has been being given more attention. This increase might result primarily from the increase in the difficulty of VLSI technology, although the progress in DRAM generations has been continuing with the same rate as that in the past. We must make a big breakthrough in the next five years to overcome this problem. VLSI Symposia have been ones of leading conferences for the progress in the technology of the semiconductor industry and growing together with its expansion. I believe that VLSI Symposia would play an important role to make this breakthrough and will continue to keep their high position in the field of VLSI technology. In such circumstances, however, the number of papers which describe the technology having the high novelty but low usefulness or little feasibility of industrialization often tends to increase. For keeping a position of VLSI Symposia high, we shall have to make more effort to gather high quality papers in future.

This year, we had a big disaster due to the earthquake in Kobe area. Fortunately, however, there occured little and relatively small damages in Kyoto and Osaka areas, respectively. I am very happy as the chairman to hold the conference with little trouble.

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1-2 (Invited)

Semiconductor CIM System ; Innovation Toward The Year 2000

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1. Introduction

The business environment around the semiconductor industry has been rapidly changing compared with other industries. The prospect around the year 2000 will probably be as follows. First of all, devices in terms of DRAM, 256MDRAM will be in mass production and 1GDRAM will be at an earlier stage of production. 300mm wafers are sure to be used in the production. Equipment with single wafer processing are expected to be dominant for larger wafers and more cluster tools would be used in the production. Yield and device monitoring during the production rather than at the end of the whole processes on final chips may also be more commonly practiced for the earlier detection of failures. Insitu monitoring with single wafer processing may be used for finer process control. To reduce the ever increasing cost of clean rooms including the running cost, mini-environment technologies will be applied more to production in clean rooms. Material handling automation will be essential for dealing with heavy load of larger wafers. To share the higher investment such as for equipment and facilities, international alliance among foreign companies will be accelerated, and production environment needs to be global. Technology trends toward the year 2000 are shown in table 1.

Under these circumstances, the role of CIM systems in the semiconductor industry has become increasingly important for dealing with new technologies as well as with their difficulties. Their importance and expected roles are discussed in this paper.

Table 1. Technology Trend

	1993 1994 1995 1996 1997 1998 1999 2000 2001
Feature Size	0.5 μ m → 0.35 μ m → 0.25 μ m → 0.15 μ m
DRAM	16 MD → 64MD → 256MD → 1GD
Wafer Size	150mm φ; 200mm φ; 300mm φ
Equipment	Stand alone → Small Scale Cluster → Larger Scale Cluster
Material Handling	By Lot → By Wafer

2. Requirements for CIM systems

The roles of CIM system are basically the same as today. Not many new roles are required but their importance will be more acute in the field of integration to get the total effect on production and yield improvement. This also means that the domain of the problems is getting wider and more complicated so that CIM system needs to provide total solutions rather than local ones.

(1) Shorter "Time-to-Market"
For marketing the new and advanced semiconductor devices like 256MDRAM and 1GDRAM, shorter lead time from the design cycle, process development and mass production ramp-up is the key for competitiveness. For the future devices, it will be more difficult and take longer to improve their yield because the longer process steps and more complicated device structure as well as the finer process are required. The development stage is also expected to be longer and more difficult than today. At the moment, contribution of CIM system is largely focusing on mass production and automation. To realize the minimum "Time-to-market", however, CIM is required to solve a different problem domain. That is , how to speed up the design and process development cycle and transfer to mass-production smoothly. More CIM support should be required for linking device design and process development as well as the integration of development cycle and mass-production.

(2) Flexibility for changes
The variety of products becomes ever wider. Even in DRAM, several generations are produced within the same factory for maximum utilization of facilities and equipment which leads to the frequent re-configuration of production lines. To cope with these changes, CIM system needs to be flexible and re-configurable. As is often the case with CIM system that once it is in operation for production, it is not allowed to stop so as not to disturb the production. Plug-in characteristics are preferable to add-in new functions, or refine existing functions without stopping entire system.

(3) Efficiency in large volume data handling
In 300 mm wafer fabrication, wafer by wafer processing data for process control and analysis will be necessary. From the quality assurance(QA) point of view, chip level data are more and more required for traceability. As for the yield improvement, failure detection at an earlier stage and quicker analysis for finding the cause of failure require

the handling of large volume of data in real time and quick judgment. These are the requirements lead us to the higher level of data base integration with the capability of efficient data handling. Automation in data handling, especially that of data analysis, involves the replacement of human judgment to a certain extent. Expert system capability is necessary in this field. Efficiency of data handling is sure to be one of the keys for achieving quick device development and speedy yield improvement.

(5) Productivity enhancement

Efficient lot scheduling and improvement of equipment utilization are the major contribution of CIM system to enhance productivity. Considering that cluster tools are expected to be widely used in 300 mm production, more detailed scheduling down to chamber level as well as equipment performance monitoring at chamber level will be necessary for higher utilization of cluster tools.

3. CIM solutions for requirements

3.1 Time to market

Total speed of yield improvement from device design, process development to mass production ramp-up is the key for minimizing "Time-to-Market" . Fig. 1 shows the scenario of yield improvement throughout the development and the mass-production phases. The following are the points of improvement.

· Reduction of mismatches between process and device design by earlier detection of failure and quick feed back at the development phase.

· Quick tuning of process and design at the earlier stage of mass production to improve the process and design margin.

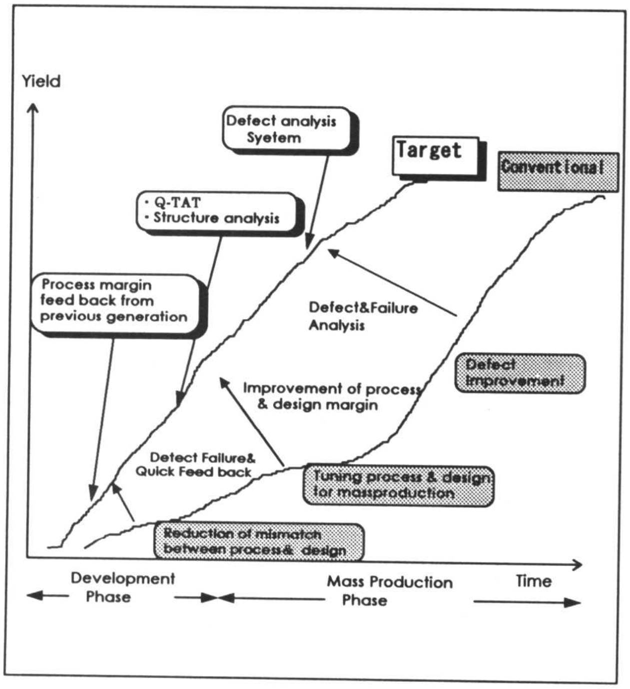

Fig.1 Senario of yield improvement

· Defect improvement for farther yield ramp-up in mass-production.

3.2 Yield domain integration

To realize the previous scenario, the device design, process, and manufacturing should be integrated by CIM. It can be called " yield domain integration" in which the wider range of yield improvement cycle is performed. "Production domain integration" is more commonly practiced which combines the production with sales for mass-production marketing. As achieving higher rate of yield ramp-up seems to be more and more difficult for future devices, "device and process domain integration" will be the important direction in CIM application to establish the yield improvement cycle. Fig. 2 shows both domains of integration.

Fig. 2 also shows the outline of the integration. Device design provides target process specification based on device and process simulation to fulfill product specification. In process development, process flow, processing condition with recipe for equipment are prepared. Then processes are evaluated in development lines. Their results are inspected with in-process and in-line analysis. Failures are detected in earlier stage and fed back to device design and process development quickly. To shorten the development cycle, Q-TAT for trial production is important. After the trial production, new product are passed on to mass production. At the initial stage, process tuning for equipment is necessary. To realize short turn around cycle for development and yield improvement, CIM can provide the following.

(1) For quick development cycle

· Share the process data between trial production and mass-production and make use of data in mass production of a new product in the trial phase.

· Support for device design and process development by providing production data.

· Earlier detection of failure by in-process analysis.

· Data integration from device simulation, target process specification to process condition and process recipe.

(2) From trial to mass-production

· Standardized data for process condition and process flow for smoother process data transfer.

· History of trial production and equipment condition as well as the result for process tuning.

(3) For the yield ramp-up

· Thorough data collection .

· Yield analysis tools for detecting the defect and causes.

· Expert system for analysis to deal with large amount of data in a short time.

(4) Common structure

· Common database shared among production lines. Standardization of data and user interface for accessing it.

· Sufficient networking for remote access.

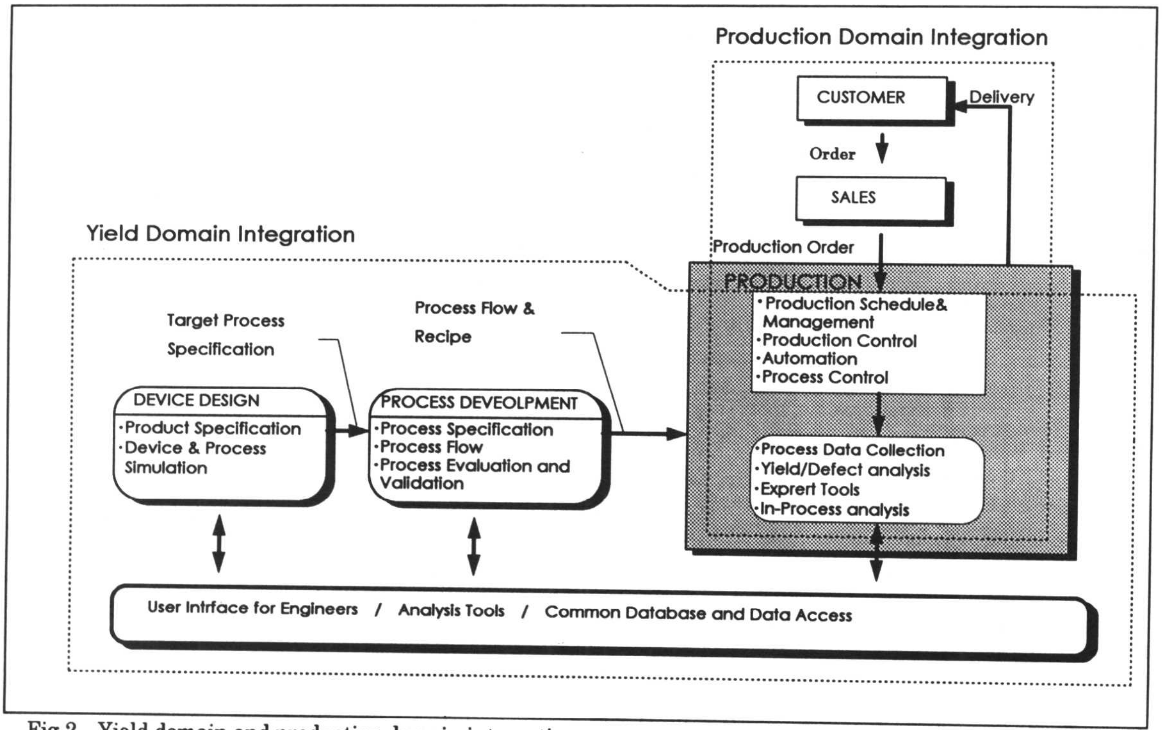

Fig.2 Yield domain and production domain integration

3.3. Productivity enhancement

The major contributions of CIM to productivity are lot scheduling and equipment utilization. Lot scheduling is largely dependent on products and on any factory's own application so that it is difficult to generalize. Wafer by wafer scheduling in cluster tools, however, is a different matter because it greatly affects equipment efficiency. Scheduling is basically the role of the host, but it is rather difficult for the host to deal with wafer by wafer scheduling to process modules within cluster tools, because it is closely related to real time control. The scheduling capability may need to be provided by cluster tools if they intend to supply higher efficiency and flexibility within them. This implies equipment with higher intelligence which is more closely involved taking part in the CIM system. Other subjects of the intelligence for cluster tools are the automated process tuning and maintenance management which are closely related to wafer scheduling. The former is necessary for adjusting recipe parameters to module specific values at the assignment of wafers to modules in real time which cannot be pre-determined by the host. The latter is dependent on module utilization which should be taken into account at module assignment in scheduling. All cluster tools cannot be expected to be able to provide these intelligent services. If not, hosts should provide them instead. In any case, as wafer by wafer scheduling would affect productivity, a host needs to monitor the performance and the utilization of modules for productivity enhancement and stable operation. Fig. 3 shows the example of wafer by wafer scheduling within a cluster tool.

4. Supporting System Technologies

Distributed system technologies and networking make it possible to integrate various systems which otherwise function separately, and enable us to get total effect on semiconductor development and manufacturing. This integration is expected to be extended and continue on a wider scale for efficiency and competitiveness.

There are two system technologies acknowledged in semiconductor CIM field, framework technology and object oriented method. Framework is an integration technology which provides the integration goal and baseline by showing how each sub-system and system component should fit in[1]. The object oriented method realises the "Plug and play" concept which can add flexibility to systems by putting in or changing sub-systems and system components without affecting the rest of the system. It is also increase the re-usability of sub-systems and system component. Recently, SEMATECH proposed to use both of them for a semiconductor CIM system, and SEMI standard has started to use these concept[2]. This is the right direction for technology to take because they are addressing for the system integration, flexibility, and re-usability are sure to be key issues for CIM systems.

Another important technology is human and system interface for data processing. Wider integration enables us to access and use of various information and data through networks. On the other hand, the volume of data needing to be handled has been getting ever larger. In this situation,

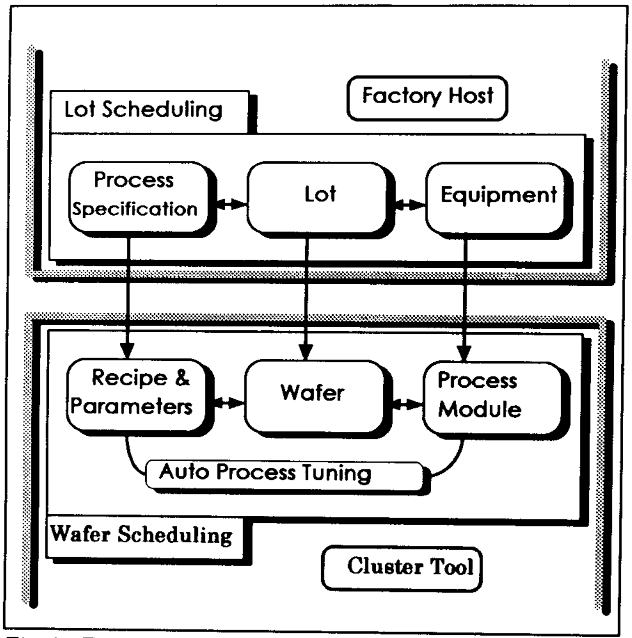

Fig. 3 Example of wafer by wafer scheduling in cluster tools

data utilization will be another key for making full use of CIM. One way is to automate data handling and analysis like the application of expert systems for yield analysis. The major part of data processing, however, will still be done by people so that user interface with easier and friendlier operation as well as end user computing will be more important for this purpose.

5. Summary and conclusion

To break through the difficulty in realizing the speedy device development and yield improvement in future devices , which is the key for quick "Time-to-Market" , yield domain integration is necessary, as well as the efficiency in large volume data handling. Wafer by wafer scheduling for cluster tools will be one of the important factors for productivity enhancement. Framework and object oriented technologies will be accepted for system integration and flexibility. A wider scale of system integration will be practiced for total system solution and contribution.

As the larger and wider scale of CIM system integration proceeds, cost and time as well as resources for system development will be serious problems. The appearance of intelligent equipment which takes charge of some roles within CIM system adds more complication to the relationship between host and equipment. International business alliance requires certain standards as a common base. To address these issues, international standard should play an important role, especially to avoid unnecessary duplication of system development considering that these duplication will be more and more time, cost and resource consuming. To maintain the lead of semiconductor industry, industry wide agreement is necessary to make the maximum use of resources for developing new technology and innovation.

6. References

(1) " Computer Integrated Manufacturing(CIM) Application Framework Specification 1.1", SEMATECH (1994).
(2) " SEMI Standard ballot #2156A, Cluster Tool Module Communication(CTMC)", SEMI (1994).

1–3 (Invited)

Manufacturing Technology Challenges for Low Power Electronics

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Introduction

Portability of electronic systems has become a critical issue in many product areas. A new class of wireless, portable consumer electronics has been enabled by advances in IC manufacturing and innovations in design. The capabilities of these new electronic products include completely integrated functionality, embedded signal processing, high-speed data processing, and high bandwidth communication channels. However, limitations of practical battery sources and thermal management are being reached since the greater computational capability and throughput of leading-edge ICs has also led to increased electrical power dissipation. System size and weight, along with functionality and cost, are the factors that define portable electronics. Substantially reducing IC power dissipation will allow smaller batteries with longer useful lifetimes, reduce packaging costs, and decrease the need for heat sinks or forced air cooling.

Recently, the Advanced Research Projects Agency, working with the semiconductor industry has begun an aggressive program to develop fully-depleted silicon-on-insulator (SOI) substrate technologies for low power applications. SOI offers significant advantages in operating low voltage, short-channel transistors from a speed-power perspective. SOI technology may also provide process simplification as compared to conventional bulk CMOS technology. However, SOI for future leading-edge microelectronics technology generations will require the development of high-quality, thin buried oxide (BOX) layers and growth of gate oxide films near the tunneling limit. These and other requirements will challenge the capabilities of future fabrication processes.

Low Power System Drivers

Portability of electronic systems has become a key driver of advanced semiconductor technologies. Advances in both battery technologies and electronics has enabled the emergence and huge growth of the portable electronics industry. Although battery form factors, energy densities and battery lifetimes have improved tremendously over the past decade, revolutionary improvements for very long-life compact power sources are still over the horizon. In spite of this, there are very promising semiconductor technologies for VLSI applications that can provide high functional performance and extremely low power dissipation, orders of magnitude lower than conventional technologies.

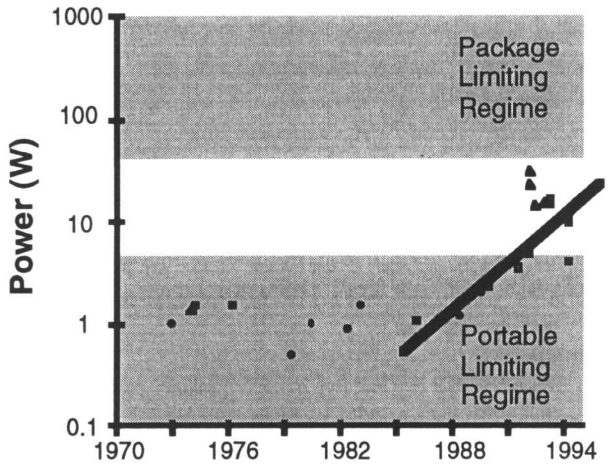

Figure 1: Power trends in microprocessors

Some trends in power dissipation of commercial volume microprocessors are shown in Figure 1. The microprocessors shown in this figure were fabricated in bulk CMOS technologies. As microprocessor performance has improved through integration and architecture, power dissipation has tended to increase as well, resulting in shortened lifetimes of practical battery sources. Over the past few generations, microprocessor power dissipation has nearly tripled every 3 years. The trends for random logic, gate arrays, and ASICs are similar. With current product trends toward mobile portable electronic systems, it is clear that it will be necessary to decouple, or at least decrease the constant of proportionality between power dissipation and performance/functionality.

Two limiting regions are indicated in Figure 1 as well. In the portable-limit, it becomes difficult to carry systems that dissipate over 5W. There are cooling and energy storage issues that preclude easy portability. In

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