Semiconductor International

New Fab Construction

Flexible facility architecture, safety and energy usage concerns become paramount as costs soar.

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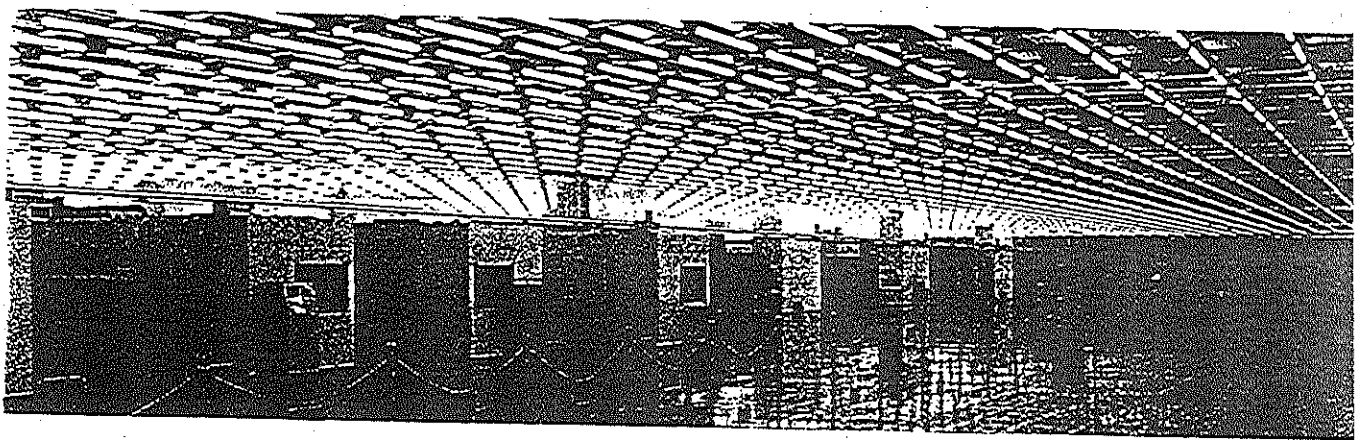


This 480,000 ft² fab, located in Buchon, Republic of Korea, has an open ballroom configuration. *(Source: Amkor)*

Currently, 127 new fabs are in various stages of planning and construction, with total expenditures exceeding $115 billion. New fabs cost more than $1 billion, and 300 mm fabs may be more than double that amount. While fabs are being built worldwide, the Pacific Rim is seeing the greatest growth, with Taiwan the hottest place, noted George Burns of Strategic Marketing Associates (Santa Cruz, Calif.).

A device fabrication facility is a multiuse building consisting of office space and a mechanical area located below the manufacturing floor for support equipment, distribution ductwork, piping and power systems, all built around a production area or cleanroom. Chemical and gas storage along with waste collection zones are located outside this area. Each area has its own particular functions that have to be addressed in the design and construction of the facility. The production area is the focus of this article, typically a supercleanroom.

A Glance ...

The cost of building a fab has increased tremendously over the past two decades to more than $1 billion. Because of the sizable investment, facility architecture and energy consumption concerns become more critical. These issues and others will be discussed.

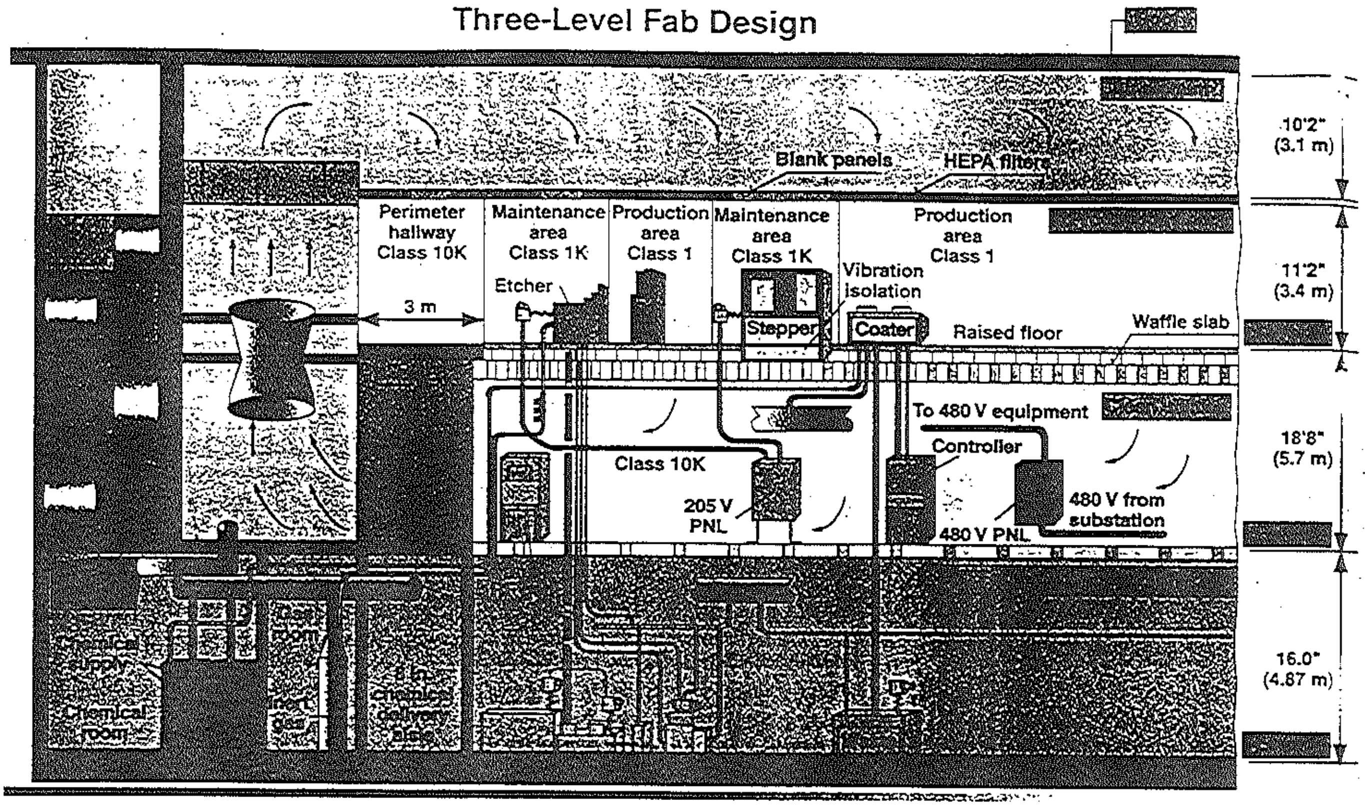
Architecture

The facility architecture is essentially a compromise of efficiency for today's process technology and flexibility to rapidly and inexpensively adapt to meet new process technologies and flows. Fabs traditionally are built around a ballroom-style cleanroom where process bays are connected to a central aisle and wafers are transported via an interbay rail system. This simple architecture offers a cost-effective manufacturing facility with optimal flexibility, according to John Weekley, vice president of marketing at Amkor Wafer Fabrication Services (Santa Clara, Calif.). Anam Semiconductor of Buchon, Republic of Korea, for example, has recently completed a 67,000 ft² open ballroom-style cleanroom with waffle floor infrastructure (Fig. 1).

The open architecture imposes no physical constraints, and the underlying waffle floor provides feedthrough of all utility support from the basement and subbasement. The equipment can then be placed virtually anywhere in the facility and still have access to electricity, water, gas and waste disposal.

Minienvironments are expected to increase above the present ~10% for fabs built since 1995, according to Burns. Such was the choice at the Class 10 Anam facility. The wafers, housed in a SMIF pod, are kept in a Class 0.1 environment. The facility can be adapted to changes in a multiprocess mix supply and upgraded with the addition of new process nodes.

An architecture that is attracting interest is the modular fab. The most common approach has two modules. One shell encompasses both units, but only one side is initially facilitized. Another concept



3. *A trend toward three-level fabs could mean reductions in particles and molecular contamination.* (Source: Weissner-Wurst)

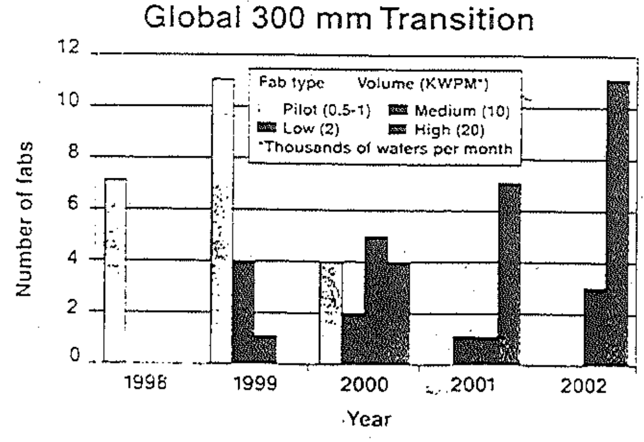
through a series of 1/2 in. diameter tubes with ~1/8 in. holes, spaced 1 in. apart. Generally, there is one HSSD system per bay, with tubing in the path of the return airflow stream, positioned under the flooring or in the side wall return. Because of its high sensitivity, this technology is not suitable for use in dirty environments, noted Phil Ricker, manager of electrical and instrumentation design at Jacobs. In the fab, however, smoke is a major contamination event, requiring work-stoppage. While catastrophic loss is insurable, smoke shutdowns may not be, even though they can critically impact production flow and productivity.

Energy efficiency

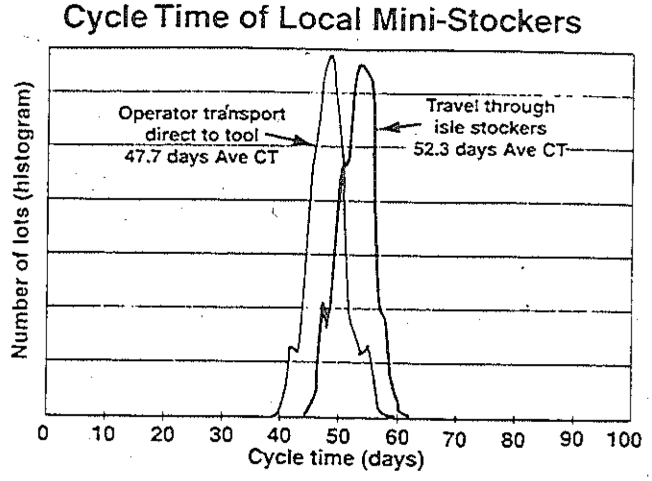
This year has seen greater attention to semiconductor manufacturing energy consumption and efficiency than previous years. SEMATECH, Electrical Power and Research Institute (EPRI) and the Environmental Protection Agency's Atmospheric Pollution Prevention Division are sponsoring studies and seminars in search of more energy-efficient solutions. It is currently estimated that as much as 800 kWhr of electrical energy is consumed for all manufacturing related to semiconductor devices from a single 200 mm wafer, which is enough energy to supply the typical household for two months, stated Charles VanLeeuwen of CAVLON Associates (Rio Rancho, N.M.). More than one-third is used by the fab with the balance going to the manufacture of the raw wafer, back-end processing, chemicals, materials, equipment and facilities.

Cleanroom heating, ventilation and air conditioning (HVAC) are the major energy consumers in the fab, accounting for 50% or more, while wafer processing tools account for 30-40%. There may be as many as 150-300 20,000 cfm air recirculation fan units in a typical large fab, each with 15 horsepower motors. One solution has been developed to drop the motor size by a factor of 3, to 5 horsepower. In addition, two technologies becoming more prevalent in new fabs may also prove to be energy savers — minienvironments and full material handling automation. According to VanLeeuwen, minienvironments and automation could substantially reduce the total amount of ultrapure air that has to be conditioned and circulated.

The manufacture of [illegible] 300 mm wafers could become the most significant energy consumer if ways are not found to dramatically improve current polysilicon to finished wafer material



4. *The transition from pilot lines to full-scale production can be seen over the next five years.*



5. Motorola's 300 mm program used AutoSched simulation to determine average cycle times for direct transport to tool vs. through stockers. (Source: AutoSimulation)

efficiency, Van-Leeuwen noted. For 200 mm wafers, the current overall conversion efficiency is believed to be <20% and ~6% for 300 mm wafers using today's technology. It is anticipated, however, that changes such as going from 100 kg to 300 kg crystal-puller charges could significantly increase the manufacturing efficiency of 300 mm wafers if ways can be found to maintain crystal structure with the large ingots.

Construction of 300 mm fabs

The past year has seen more activity worldwide in the 300 mm arena than anticipated. The advantages are clear — enhanced productivity. First, 300 mm construction is expected to begin in the 1999-2000 time frame, and judging from accumulated information from the device community, new 200 mm fabs construction is expected to cease after 2000-01, according to George Lee, director of the 300 mm Initiative at SEMI. Figure 4 displays the timeline of new building schedules and pilot lines of 27 device manufacturers worldwide. These figures are consistent with those of I300I and SELETE. While there is currently no change in stated plans, present economic conditions in the Asia/Pacific Rim could possibly cause delays.

A cost-effective alternative to new fab construction is conversion of current fabs to 300 mm. This is primarily a facilities upgrade of utilities and waste water. At this time, 300 mm fabs will most likely use more water than 200 mm — as much water in a year as a city of 60,000 people. Numbers ranging from 1.5X to 2.5X greater water usage than 200 mm have been bantered around depending on dry vs. wet etch and the amount of recycling intended. Estimating the utility needs of the 300 mm facility has yet to be determined because much of the wet equipment that will dictate the amount of water consumption is just coming into place, noted Frank Robinson, president of I300I.

Faced with higher costs of building new 300 mm fabs, chip manufacturers are making greater efforts to maximize productivity by minimizing fab space. To support these efforts, Lam's (Fremont, Calif.) approach has been to scale up the transformer coupled plasma (TCP) source and chamber size of its metal, oxide and poly etch technologies, while maintaining the 200 mm footprint by optimizing the space typically required for components. This approach eases overall fab space requirements, lowers the risk of transition to new technologies and achieves enhanced capital productivity, according to Sanjay Tandon, product marketing manager for 300 mm at Lam.

Software

For the past 10 years, fab modeling software has provided a tool for the design of the most advanced fabs. Today, a billion-dollar fab investment makes 3-D simulation software a necessity. Advanced Micro Device's Fab 25, for example, used AutoSimulations' AutoSched software to analyze alternative material handling systems. The company was able to study interbay and intrabay handling in terms of the amount of time a tool spent waiting for material in the simulation. The Fab 25 model became the benchmark for other decisions such as tool set, layout, traffic intensity, stocker and track sizing, plus location, staffing analysis, training and ramp up. Even before construction was completed, the building team could observe factory operation in 3-D animation.

Motorola (Austin, Texas) is currently re-evaluating some of its fab design concepts to provide better operational performance to the end-user and to be responsive to management's need for better cycle time and optimized cost of ownership, said Phil Naughton, part of Motorola's new construction team. This optimization includes performing analyses of conventional cleanroom designs with large ballrooms using fan towers and fan deck designs vs. modular designs using fan filter units and/or minienvironments. Also being evaluated are the most effective techniques for 300 mm fab designs that require simulation to determine average cycle times, for example (Fig. 5).

A challenge in new fab design and construction are finding ways to shorten ramp-up times. One solution is software, such as Triant's ModelWare/RT, which aids in new equipment ramp up by providing "visibility" into the machine. The equipment's learning process is accelerated by the software, thus shortening the time it takes for a fab to bring its equipment up to production-ready speed. Advanced modeling technology and proprietary algorithms are used to solve complex process control problems. Data, such as temperature, pressure, RF power and residual gas levels, are collected from good runs and automatically turned into a comparison model. Every variable is correlated with each other to determine any deviations in the overall health of the equipment, at which point an equipment fault is indicated and location identified. ☐

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