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Solving future fab facilities challenges

Article was originally printed in *Solid State Technology*, 2-2016

What does the future hold for the next generation wafer fab?

Tracing its steps back over 100 years as an innovator of cleanroom technology from the very beginning, M+W Group has established itself as the world leader for fab building, facilities and process tool installation requirements.

In this article, Hartmut Schneider, Vice President Technology for M+W Group, focuses on three topics that, he argues, will dominate a highly lucrative and ever-changing market related to wafer fab designs of the future.

Innovation is based on success and failure! Some call this the school of 'hard knocks'. The trio of topics provides an exciting insight into where this dynamic industry is heading, and the implications and opportunities for users and manufacturers alike.

Firstly, there are challenges and possible solutions to those challenges that will determine the future trajectory of global cleanroom technologies. For example, our priorities to engineer a more practical or ergonomic cleanroom will determine the investment of future production facilities.

Secondly, implementation of new wafer fab designs is already under way to meet the complex challenges of the future. In recent years, M+W Group has been involved in the development of next generation 450mm/EUV-capable wafer fab concepts and has recently completed two of

the world's leading-edge semiconductor research and development institutes, at SUNY in Albany in the USA and IMEC in Leuven, Belgium.

Finally, the industry demands technologies within controlled environments to be more advanced than ever before, whilst also reducing consumption and carbon footprint. Furthermore, sustainable manufacturing is becoming an important strategy practiced by numerous semiconductor manufacturers. M+W Group has pioneered research and development into a 'Green Fab' that can modernize future cleanroom facilities and controlled air circulation at reduced rates.

The semiconductor industry

According to the International Data Corporation, the semiconductor industry is expected to grow exponentially to be worth \$389.4bn by 2019.¹⁾ Although, as this suggests, growth will be steady, there are changes being made by virtue of consistently rising costs. For example, research and development costs increase disproportionately with every new technological advancement. Moreover, the high cost of owning and maintaining a fabrication (fab) facility is becoming a larger burden to handle. A fab requires a relatively high percentage of utilization in order to break even due to the significant fixed costs, including depreciation and personnel. This has led to the emergence of new ways of thinking when it comes to fab designs.

1) <http://marketrealist.com/2015/09/led-emergence-fabless-foundry-model/>



Current concepts and alternative approaches

The demands placed on cleanroom production concepts are constantly changing. Today, many wafer fabs incorporate the implementation of various modifications such as off-waffle table manufacturing areas or even processing areas in the subfab located on the ground level. This is due to the growth in the size of wafer fabs, from 5,000 to 8,000 m² in the 1990s, to 20,000 m² or larger in the current state-of-the-art 300mm wafer fabs.

As a result, the construction of up to two subfab levels beneath the main cleanroom was driven to increase the ratio of auxiliary equipment to the process tool main frames. Welcome to the “2+1” fab – a common concept for 300mm fabs, which includes a classified subfab beneath the main cleanroom and a support level on the ground floor.

With the implementation of mini-environments and 200 mm Standard Mechanical

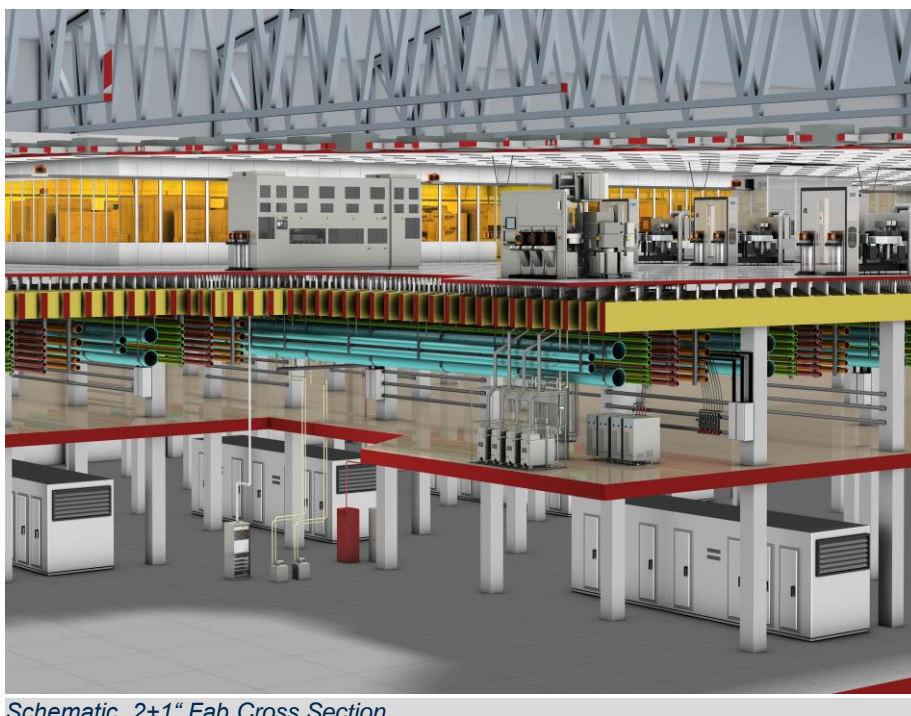
Inter-Face (SMIF) / 300 mm Front Opening Unified Pod (FOUP) carriers and interfaces, the cleanroom classification could be substantially relaxed and should not require revisions in the future according to the current ITRS roadmap. However, with ever-increasing requirements for high precision operations such as metrology and lithography, temperature and humidity control specifications must be adequately maintained to ensure the appropriate inlet supply of air to the environmental chambers of process tools.

Filter Fan Units (FFUs) have developed and gained broad acceptance, thereby overhauling other recirculation air concepts in the main production cleanroom. Modern return air FFUs enable segregation between recirculation air in the cleanroom and the sub-fab. This has rethought the customary process of air passing through the raised floor and the structural waffle table into the subfab before being returned up to the interstitial.

The segregated subfab concept has started to be implemented and offers the user both CAPEX and OPEX savings. However, the justification of this concept is not conclusive and can only be determined for specific wafer fab projects at this stage.

Drivers for the fab concept evolution and potential solutions

Besides the non-linear increase in research



Schematic „2+1“ Fab Cross Section



and development costs for advanced process technology nodes, the manufacturing costs for scaling will also continue to grow, driven by increasing process technology complexity and the related number of mask layers. This increase is being further compounded by the need to implement multiple patterning for selected mask levels before Extreme Ultraviolet Lithography (EUV) economics reach the break-even point for large scale implementation. Furthermore the introduction of new process materials may cause significant environmental, health and safety repercussions, additional facility supply and disposal systems, and the increased need for segregation of product, materials, areas or personnel. Wafer fab design considerations are therefore becoming progressively more complex due to new design criteria and the persistent increase in fab size.

With facilities and equipment being constructed on a larger scale, the transition to a 450mm wafer size is expected to occur when a manufacturing cost advantage can be realized. However, the implications of substantially larger process equipment and automation systems will have a direct impact for certain design parameters for the building, cleanroom and facilities systems, in particular for next generation EUV scanners. For example, the load-bearing capability of the raised floor is strengthened, both along the scanner's move-in path, as well as around the scanner for major maintenance and service operations. Furthermore, the heavy duty panel's load-bearing capability has increased by 100% to 30kN from the 15kN industry standard to resolve this. For operational reasons, the heavy duty load panels can be separately color-coded for quick visual identification.

The size and structure of a cleanroom is also configured based on the Automated Material Handling System (AMHS) that is typically suspended from the cleanroom ceiling. In fact, current developments for 450mm AMHS solutions are similar to 300mm "unified" concepts with overhead undertrack and side track buffering. An additional ceiling load is generated by process equipment maintenance cranes, driving the total minimum cleanroom height toward a range between 5.5 to 6 meters. This height also provides a vacant space beneath the cleanroom ceiling for lighting installations, sprinklers and other systems. Due to the loads imposed by the AMHS and such maintenance cranes on the cleanroom ceiling and roof trusses, substantial bracing is required, which distributes the increased loads.

Opportunities for energy reduction

In parallel to the advancements in process technology to surpass industry benchmarks, semiconductor wafer fab engineering and construction companies are being challenged to provide solutions that are eco-friendly. Both future and current cleanroom technologies will be assessed by their effectiveness with regard to energy conservation. An important engineering solution to achieve this is a detailed fab energy tool that includes secondary and tertiary interactions between facility systems and their components. This tool is able to measure and analyze the intensity of energy fluxes within the facility systems and to either propose energy-saving scenarios, or even recommend downsizing of selected facility plant equipment. Using this, it is possible to continuously monitor and calculate what energy savings can be made throughout the design

and construction of the wafer fab.

In parallel, the industry is continually examining the requirements to implement more efficient components or introduce new systems. For instance, a noticeable improvement in overall energy efficiency can be achieved by reducing volumes of external air being distributed in a cleanroom's recirculation air system. Heat exhausted from risk-free process tool connections is an example, and does not have to be extracted and discharged via the general exhaust system, but can rather be discharged into the subfab for local or area cooling by dedicated units. Such a concept has already been implemented in some wafer fabs as well as in the flat panel display industry.

Meanwhile, sustainability cannot be ignored, driven by the dual issues of environmental responsibility and cost efficiency. Cleanroom experts are exploring possibilities in adopting renewable energy resources as part of their operation. The use of high energy efficiency solutions such as LED lighting luminaries or re-generable AMC carbon or ion exchange filters can improve efficiency by up to 50% and

dramatically reduce waste and CO₂ emissions with the objective of operating greener fab cleanrooms.

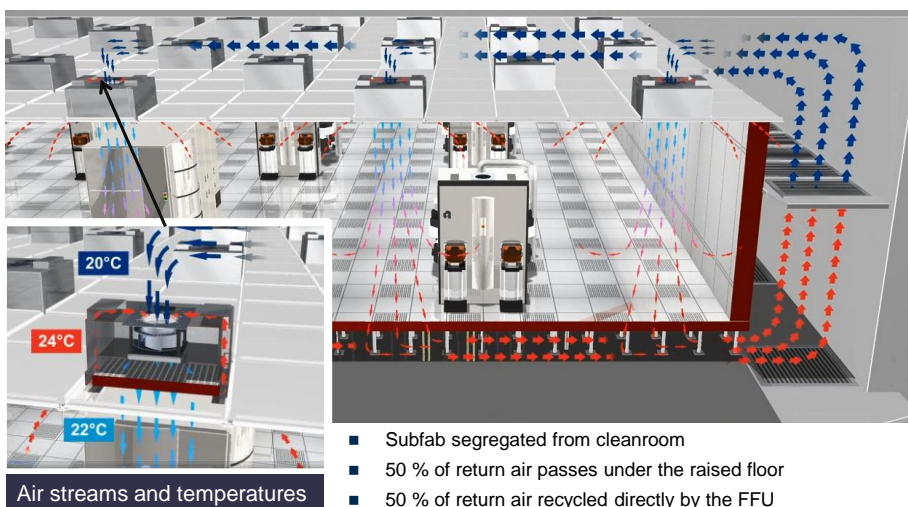
In summary

The future of the cleanroom concept will be highly geared towards development of the 450mm / EUV-capable wafer fab and solutions with sufficient flexibility for diversified new processing materials and continuous process scaling. Selected topics are being addressed by global initiatives and consortia such as the Global 450 Consortium and ENIAC.

Although the fab size is driven by economies of scale as process complexity and product mix increases, a multiple subfab cleanroom concept is the most common option when considering a segregated subfab utilizing return air FFUs. This does not rule out new wafer fabs, which will continue to be designed and manufactured at a faster rate through new collaborative approaches during design and construction.

Detailed overall mass and energy flow modelling to identify primary, secondary

and tertiary effects to improve energy efficiency and reduce carbon emissions provides a data-driven methodology to achieve the new modern 'Green Fab'. The opportunities are indeed exciting for a 'Fab Future'.



Return Air Filter Fan Unit Concept



Hartmut Schneider is Vice President Technology of M+W Group and responsible for the industrial engineering activities for the semiconductor industry. This includes a range of services to define the fab concept, the process equipment layout of the cleanroom, support areas, utility requirements and the automation concept as well as to consult on operational and process-related design issues. He joined the company in 1991 and has a degree in solid state physics from the University of Stuttgart, Germany.