Orthodoxies of Semiconductor Factories (A review as seen by manufacturing science)

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The Grand Design

The fabrication of semiconductors employs breathtaking solid-state physics. While packing super high function-density in each die (transistors, etc.), parallel with high die density in each batch (dies on wafer), the lots inchworm their way through a fabrication cycle. Capital costs of new facilities are around $10-20 Billions each, and the total capital investment ratio to revenue is around 40% on the global industry output of 700+ Billions (WSTS and Kinsey). The above high content density is expected to secure a return on the invested capital (ROI). With even further investments into capital assets efforts continue to increase batch capacity (substrate size) and to increase function density per die (nanometer race). Together, these activities fix the attention of investment decision makers almost entirely. With dominant concern of the industry being invested asset utilization.

Manufacturing at Least Risk

Following that, manufacturing and its own contribution to overall ROI are left for daily management to do, which operates with an incremental risk averse approach, relying almost entirely on the support and influence of a few dominant big-business suppliers. The culture sidelines internal considerations for some basic manufacturing principles [5] [6]. Absurdly, the massively parallel flow of production scores a low 60% cycle time efficiency (production cycle times of 40-120 days with half of that time the product in idle). This being partly due to a process of managing flow recursion, but to a large extent it is the result of ill-designed intra process logistics. Still, manufacturing efficiency (optimizing all given resources for maximum throughput) does offer a second, and significant, component to the overall ROI. While "investment" into the production process itself is running at 60% of revenue cost (of this total going into: direct labor 2%; indirect labor 18%; materials 20%; processing 15%; spare parts 10%; misc. equipment15%), the question arises: how much does the manufacturing process itself contribute to the overall ROI (which runs at 5-20% for the global industry — SIA)? The common denominator determining the efficiency of the invested capital and the efficiency of the production process itself is equipment utilization. **Specifically, as dispatch owns a major responsibility for equipment utilization, the ROI of manufacturing becomes significantly dispatch sensitive.**

Handicapped Dispatch

Save individual process yield and material (etc.) production costs, the efficiency of the fabrication cycle is hugely determined by dispatch. Dispatch is a workflow organization based on priorities and available process resources. Hundreds of process steps are linked into a sequence to comprise this fabrication cycle in a dance of opportunistic flow recursion. **Yet, in spite of the fact that executing dispatch is logistic infrastructure dependent, that infrastructure is mostly considered as a passive factory element.** (did you know that?). And, subsequently, that infrastructure is abandoned to supplier designs. The consequence is generally that dispatch overlooks the design of its executing infrastructure, even though the velocity of change in the state space of lots is heavily dependent on that infrastructure. Resigned to as given, providers of dispatch software just deal with an archaic lot distribution system. A system based on discrete and single lot transporter concepts, unchanged since the primitive days of the industry (single people/robots running around carrying single product lots) — did you know that?). This is contra to good intra process logistic principles [2]. The consequence is structural productivity loss, which could become an industry scandal as functional densities in dies increase.

Aiming dispatch to achieve high equipment utilization is to balance individual tool usage while managing impromptu product priorities based

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on their processing stage. Ideally, this dance of the wafer lots is best achieved if lot transfers are instantaneous. In practice, however, this is unachievable.

The Birth of Orthodoxy

In reality, dispatch needs to deal with delays between demand and execution. And in the current OHT type AMHS the delay is with a probabilistic uncertainty. This uncertainty exponentially grows into mathematical chaos, unless product flow is interrupted and reinitialized after every lot move cycle [1]. In practical terms this is flow interruption for temporary storage (or oversized buffers). And that, of course, generates the long cycle times.

At the turn of the century industry consortia demanded a uniform intra process material handling procedure, of which only conglomerate suppliers of Japan were ready to deliver. This coincided with the wafer format conversions to 300 mm, as globally synchronized. This embedded 300 mm material handling methodology today is irreparable (160+ existing fabs), due to the passive nature of monopolies of AMHS suppliers. However alternate solution today is proposed by insertions of fractional AMHS pockets (patches) into the existing host AMHS environment. These pockets employ an alternate technology, based on OHT parallel conveyor segments, with an immediate response to demand, to eliminate the large-scale storage requirements and thus reduce factory cycle times.

Conclusions

Enabling dispatch systems with a complimentary infrastructure patch promises substantial reductions in manufacturing cycle times. The value of this action is twofold, One, a reduction of invested capital into high value WIP stuck in a long production cycle (return on capital invested in production). Two, and most importantly, increase in production capacity by allowing a higher wafer start rate without the risk of creating unaffordable cycle times. Separate from the nature of monopolistic AMHS supply chains, the mindset change of the industry in reference to manufacturing science is also sought. The clear principles of factory physics, supported by data, advise the fact that AMHS is not a passive factory element but a significant contributor to the ROI.

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