Harnessing the Capacity Model Simulator For a 200mm III-V Greenfield Fab Strategic Planning

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Abstract

This paper discusses how a capacity model, MAXFab™ can be used to quickly calculate CAPEX, Cycle time, floor space, X-factors and tool quantity required to plan for a given demand across a time horizon either for a Greenfield or fab expansion. Data input requirements for the equipment, tool configuration, tool and auxiliary space, tool cost, process flow and others are also discussed. One of the important features of this capacity modelling tool is the ability to also simulate "Learning curve" when the fab is doing pilot, prototype or short loop testing to a mature fab and ramp for production.

INTRODUCTION

All models are wrong, but some models are useful. So the question you need to ask is not "Is the model true?" (it never is) but "Is the model good enough for this particular application?" [1]

At the midst of the COVID-19 pandemic, AR/VR applications for consumer use are being aggressively pursued, driving high demands for new LED technologies about to be commercialized. Several of our III-V Clients are developing novel solutions in that space looking to build new greenfield Fabs to satisfy demands. Since most applications rely on first time LED technologies (e.g. MicroLED) we face several challenges right from the beginning. Special equipment, new process flows, funky starting material, and uncertain performance characteristics to name a few. This requires a methodical approach and robust modelling tools to plan such new factories. This abstract will detail a case study completed during the COVID-19 pandemic months with such a Client.

We were tasked to help simulate capacity and CAPEX profiles for a large 200mm greenfield factory that would be able to mass-produce a large number of LED wafers within 10 weeks. Strategic "Go / No Go" decisions and internal risk assessments were dependent on the outcome of our analysis. We began by deploying one of our remote expert teams, well experienced in these types of efforts, and deployed our MAXFab™ Capacity Simulation Suite to overcome this challenge piece by piece.

OUR WAY-OF-WORK WITH COVID-19 RESTRICTIONS

Due to tough COVID travel restrictions we had to use a new approach to complete this mission in no more than 10 weeks!

1. We set up very effective daily 30min joint Client-MAX check-point team meetings, review progress and gather feedback / data required for simulating capacity scenarios. Further Senior Management team reviews were conducted weekly.
2. We setup a virtual data-room like tracking structure to consolidate all information from the Client for tools, flows, performance factors, demand profiles, and RPT distributions, and provided a revision control tracking system so no information would be lost and all
3. Since many processing parameters were uncertain, each performance parameter source data was thoroughly analyzed by subject matter engineering experts from the Client side for historical variation, limits and constraints and benchmarked with our internal equipment performance databases.
4. For data integrity and completeness, the MAXFab™ suite provided a strict revision control feature that enabled the team to continuously refine every data element while automatically recording each change the user performed and thus saving a ton of administrative tracking of many changes made.
5. Once the model revision was complete and demand profiles uploaded, "what-if" volume ramp scenarios were generated and analyzed to simulate CAPEX, Cycle Time, and OPEX requirements. All model assumptions were documented and capacity detractors such as

waiting time, percentage of lots on hold, rework factors and sampling rates for metrology tools accounted for.

6. User training and licensing took place remotely using the MS Teams® platform and effectively transferred the software suite at the end of the process. Remote support is routinely carried out.

CAPACITY SIMULATOR OVERVIEW

The integrated capacity model consist of 4 main modules that provide a complete capability to simulate a new greenfield Fab for CAPEX, OPEX, floor space and cycle time constraints. It uses state-of-the-art algorithms to balance capacity and cycle time considerations, and forecasts total space and cost behaviors based on user preference.

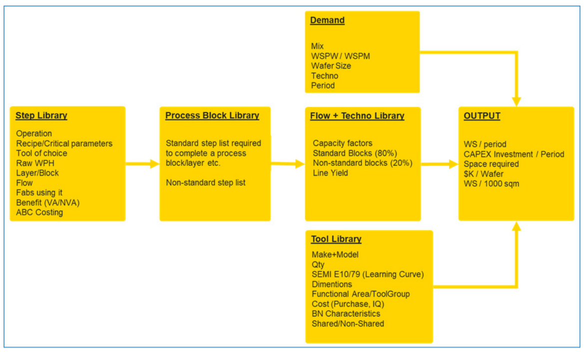

Fig. 1: Modules Overview

DATA INPUT EASILY DONE

Data input for equipment types, and capacity parameters' assumptions are inputted in the Tool Library module which stores all the tool information, for example, make and model, tool dimension and service space requirement, availability and gap factor, CAPEX for the tool and auxiliary

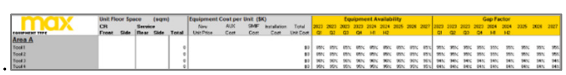

Fig. 2: Tool Library Module

The step and technology libraries module details all the steps required for the product flow. This includes, step name, description, recipe name, tool type assigned, raw process time (RPT) or machine rate (WPH), step type (process or metrology), sampling rate in the case of metrology steps.

Step ID	Layer	Area	Tool	RPT / Run (m)	UPH	1/UPH	Wafer Size	Tool ID	Step Description
1	Layer1	Area A	Tool 1	200.00	3.00	0.33	200	ETOO1	Step description 1
2	Layer1	Area B	Tool 2	158.00	9.49	0.11	200	MABC1	Step description 2
3	Layer1	Area B	Tool 3	70.00	21.43	0.05	200	MABC2	Step description 3
4	Layer1	Area B	Tool 4	25.00	60.00	0.02	200	MFNG1	Step description 4
5	Layer1	Area C	Tool 5	12.50	120.00	0.01	200	HAND1	Step description 5
6	Layer1	Area B	Tool 6	250.00	300.00	0.00	200	MEPP1	Step description 6

Fig. 3: Step and Technology Libraries Module

Multiple process flows (some call them process routes) can be grouped into Technology level blocks with providing an additional grouping level and toolset-level process parameters such as rework (e.g. for photolithography), load size (for batch processing tools), surge and sampling (for metrology) factors. Technology blocks allow for implementing learning curve assumptions for almost every parameter over a predefined planning horizon. This is critical for simulating Fab efficiency improvements from start-up to full production.

Demand planning and smoothing algorithms are a key feature of this platform. The user can input different demand profiles and instantly refresh the model to display CAPEX and OPEX requirements given cycle time constraints. We will then use this data to analyze CAPEX utilization profiles for each different demand scenario.

Technology Family	Flow	2023 Q1	2023 Q2	2023 Q3	2023 Q4
A Tech	A Flow 1	1,000	1,000	1,250	1,500
	A Flow 2				
B Tech	B Flow 1	2,100	2,100	2,200	2,500
	B Flow 2				
Total Tech Family 1		1,000	1,000	1,250	1,500
Total Tech Family 2		2,100	2,100	2,200	2,500
Total		3,100	3,100	3,450	4,000

Fig. 4 Demand Horizon Module

BALANCING CYCLE TIME CONSTRAINTS

Cycle time simulations are consistent with the operating curve model (Queueing Theories). They are calculated at the process step level in each flow and give us the most granular view for cycle time contribution at that level. Lot transportation times and percentage of lots on hold are also accounted for to simulate a realistic fab environment. Our model simulates the "price" of balancing output with cycle time performance by limiting utilization gap factors and applying surge factors for selected toolsets (e.g. metrology tools) and therefore increasing their CAPEX investment required. "What-if" analysis comes handy in this case.

EQUIPMENT CONFIGURATION OPTIMIZATION

While putting data into the tool library or step library may be a mechanical exercise, multi-chamber (cluster) tools require significant optimization to efficiently process all different processes and minimize CAPEX investment. This will eventually minimize spares required per tool, facilitate technician training and provides a systematic way to increase tools as the fab expands. Our team spent a considerable time working out the right chamber configurations for PVD and Wet chemistry tools which were CAPEX intensive and complex to model. "Mini Throughput" models were developed with the Client engineering team that once completed, a better understanding of clustering was produced and CAPEX utilization was significantly increased.

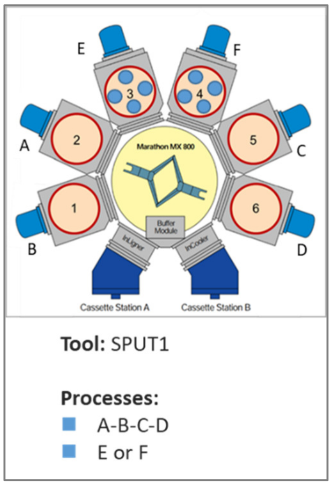

Fig. 5 PVD optimized Tool Configuration

RESULTS

The Client goal was to simulate CAPEX investment requirements for their planned greenfield Fab while understanding OPEX and floor space requirements behaviors. Special attention was given to $$ per wafer and CAPEX Utilization metrics (defined as total CAPEX investment required x equipment utilization x equipment bottleneck index), typically targeted at 85% for a greenfield Fab. In this case, our model ran an incremental CAPEX investment scale for 5,000 to 25,000 WSPW where for each point it determined the CAPEX Utilization vs. target and if it was a CAPEX investment "sweet-spot" or an optimum investment point along that scale. This was extremely important for the team to right-size the Fab and allow for correct business ramp phases as time progressed.

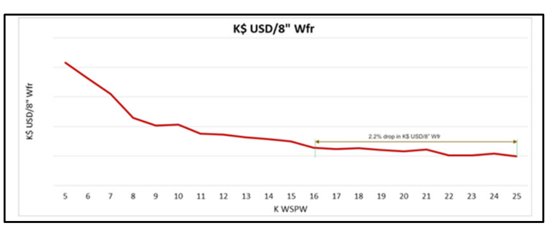

Fig. 6 CAPEX investment / Wafer

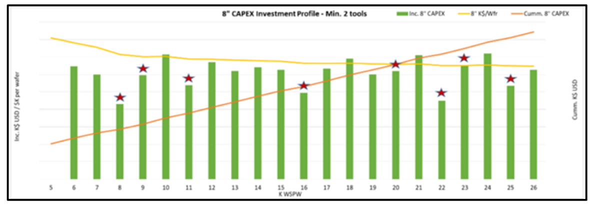

Fig. 7 CAPEX Sweet-Spots

Our model total CAPEX estimates were approximately 20% lower when comparing to initial estimates made by the Client. ~10% CAPEX savings were attributed to the equipment configuration optimization models. This novel way of modelling provides a Step-by-Step approach to CAPEX required for any demand. This itself will easily save ~ 40% of man-hours if calculating from scratch.

CONCLUSIONS

Using a collaborative way-of-working to successfully deliver accurate, complete and timely Fab sizing parameters during this "new normal", we had to enhance our robust simulation tool so we could input data quickly, it could be easily understood by any person not even totally familiar with these types of modelling tools, and have it integrating a complete view of CAPEX, OPEX and floor space requirements for the new greenfield Fab. We delivered a CAPEX profile at an 83-85% CAPEX utilization, and easily saved about 50% of the typical personnel-hours required to build this type of a simulator.

REFERENCES

[1] Box, G., Luceño, A., Paniagua-Quiñones, C. M. d. *Statistical Control By Monitoring and Adjustment.* Wiley 2009.

ACRONYMS

AR/VR: augmented reality / virtual reality
LED: light emitting diode
RPT: raw process times
CAPEX: Capital Expenditures
OPEX: Operating Expenditures
WPH: Wafers per Hour
PVD: Plasma Vapor Deposition
WSPW: Wafer Starts per Week