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A CASE STUDY FOR MODELING THE ECONOMICS OF FOUNDRY OPERATIONS

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ABSTRACT

This case study presents a novel approach for modeling a fab, which allows for more rapid results than traditional simulation, while optimizing various variables like tool count or throughput, and capturing equipment sharing between co-produced devices. This modeling method was applied at InchFab, a foundry that uses ultra-small substrate sizes to allow for more flexibility and lower costs when fabricating small production quantities. The new approach was used to find the cost-optimal rate achievable for a primary product on certain tool counts - and then the cost-optimal rate of a secondary product, without any changes to equipment count. Using novel types of analyses and sensitivity figures, we demonstrate that it can be economically sensible under certain conditions to add a product to a fab that is already producing the cost-optimal quantity of a base product. This is an important finding, as some fabs consider offering additional foundry services on existing equipment.

1 INTRODUCTION

Foundries routinely have to make the decisions that affect shared equipment. Sometimes fab owners may consider if extra capacity may be used for additional foundry services. As fab operations become more modular, faster ways to model fab operations are needed.

For our analysis we used a novel production system modeling software that can accurately optimize a system configuration with many unknowns for a target rate, and determine rates that would minimize unit costs for different products that share equipment (LineLab 2023).

InchFab has a modular, agile approach to the fab, based on a low-cost, scalable, “micro-sized” fab platform (InchFab 2023). InchFab uses unique equipment allowing for highly flexible operations with a relatively small 2” (50.8mm) substrate diameter, rapid changeover times, and relatively low equipment costs. This makes InchFab a low-cost, quick-turnaround option for fabrication of small production quantities, compared to foundries working with 300mm substrates.

2 MODELING

2.1 Methods

LineLab is a software tool for modeling production systems, which is based on mathematical models. It has been used extensively for modeling and optimizing production systems in the aerospace industry (Nill 2018), showing high accuracy compared to traditional simulation with an error of 0.64%. It has also previously been used for modeling semiconductor fabs (Nietner 2022) validated against a typical fab production flow with reentry, batching, and 377 processes on 52 tools, based on a 300mm fab model (Campbell & Ammenheuser 2000).

We modeled derivations of the MUMPs (Multi-User MEMS Process) processes as implemented by InchFab. Cycle times were estimated based on design data using InchFab's design tools.

2.2 Model

For each product, the Piezo MUMPs and the SOI MUMPs, data for the process flow including: process name, process time, tool name, tool batch size were imported from spreadsheet. Batch sizes were set as maximum values, so the optimizer could find a lower batch size if that would be cost-optimal, since all tools allow for partial batches if needed. Tool cost inputs were defined with uncertainty using min/max and min/max/likely values. We added a substrate cost per wafer so the optimizer would correctly consider the cost of inventory in its optimization of both tool count and WIP inventory count. We did not specify tool count inputs, allowing the software to optimize tool count as variables.

We created a "Shared System" model and added both products. 14 tools were shared between both products, 4 tools solely used by the Piezo MUMPs product, 3 tools solely by the SOI MUMPs product, for 21 tools total.

We first solved the Piezo MUMPs by itself to let the optimizer find the rate that can be achieved with a given tool count. We then added the tool count as well as the respective target rate for the Piezo MUMPs to the model. For the SOI MUMPs, we did not add a rate requirement, so the optimizer would find the maximum rate of SOI MUMPs that can be co-produced on the same equipment.

3 RESULTS & DISCUSSION

When solving the Piezo MUMPs model by itself, we let the optimizer design the optimum fab for just this product, or find the cost-optimum throughput for a fab when the product is run by itself. Consequently, some equipment is highly utilized. In this case the deep reactive ion etching was identified as the bottleneck. This was an important finding.

These tool counts were then set as inputs for the Shared System model, to which the SOI MUMPs were added. We used two different ways to determine that adding this product would be economically sensible: when entering a low target rate for this additional product, the sensitivity to this target rate was negative, meaning a higher rate would result in lower overall production costs. And when the rate input for the SOI MUMPs product was left empty, the optimizer automatically optimized this rate, minimizing overall production rates - the resulting throughput for the additional product was nonzero.

We can also see that overall costs per wafer go down, but the rate variability of the base product, the Piezo MUMPs, goes up. Additional analyses were conducted regarding cycle time improvement and cycle time limitation: The optimizer allows for a "maximum flow time" constraint, which we made use of to evaluate the potential cost of a lower cycle time, and to make sure adding more products would not lead to an increase in turnaround time for customers of the primary product.

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