ABSTRACT

Strategic Approaches for Further Development of SiC Rapid Prototype Production

Sabrina Anger[1], Volker Häublein[1], Markus Pfeffer[1], Martin Schellenberger[1]

[1] Fraunhofer Institute for Integrated Systems and Device Technology IISB, Erlangen, Germany

Presenter: **Sabrina Anger**
E-mail: **sabrina.anger@iisb.fraunhofer.de**

Presentation (oral and/or poster**): oral**

TOPIC:

Please select one or more fitting topic(s) for your contribution from the list. (1=first, 2=second etc. choice)

Process Level APC	**Fab Level APC**	**Manufacturing Effectiveness and Productivity**
☐ Plasma etch,CVD and ALD	☒ Digitization, data analytics, machine learning & AI, digital twin	☐ Unit process & equipment productivity
☐ Sputtering, P3I, and e--beam	☐ Fab level process control methods	☐ Factory productivity and automation
☐ Lithography	☐ Virtual metrology	☐ Factory modeling, simulation and optimization
☐ Thermal, wet processing & CMP	☐ Yield management	☐ Cost optimization and end-of-life equipment issues
☐ Backend	☐ Factory data analysis	☐ Environment and Green Manufacturing
☐ Metrology and R2R	☐ IT infrastructure & Equipment integration trends	
☐ APC for legacy tools		

Motivation

Increasing chip demand complemented by uncertainties in market development and thus fluctuating demand forecasts lead to chip shortages in various branches. According to Gartner, Inc. [1] the worldwide semiconductor shortage is expected to persist until 2022. For Europe, this is even worse, since the market leaders in semiconductor foundry business are located outside of Europe, especially in Asia. That is why there is a strong need to increase the production of semiconductors and enhance Europe's share of the world semiconductor market. The European semiconductor industry follows this aim also supported by a European policy, especially by establishing a resilient supply chain for SiC technology in Europe [2]. Major steps in this direction have been taken by the EU project Integrated Development 4.0 (iDev40) [3], which improved the digitalization of both single process steps and overall value chains by implementing digital transformation into development, planning and manufacturing. Lead by one of the market leaders, Infineon Austria, this project also focused on the SiC semiconductor technology, wherein Fraunhofer IISB's π-Fab® offers prototyping services for electron devices.

To continuously enhance π-Fab® towards a smart platform for rapid prototyping of custom-tailored electron devices, a three-fold approach was developed that covers concepts for baseline-modules, smart experiments and smart logistics. Details of this strategic also science-

ABSTRACT

driven approach as well as first implementation results are shared in this presentation, with focus on “smart experiments” and implications for research data management.

Description

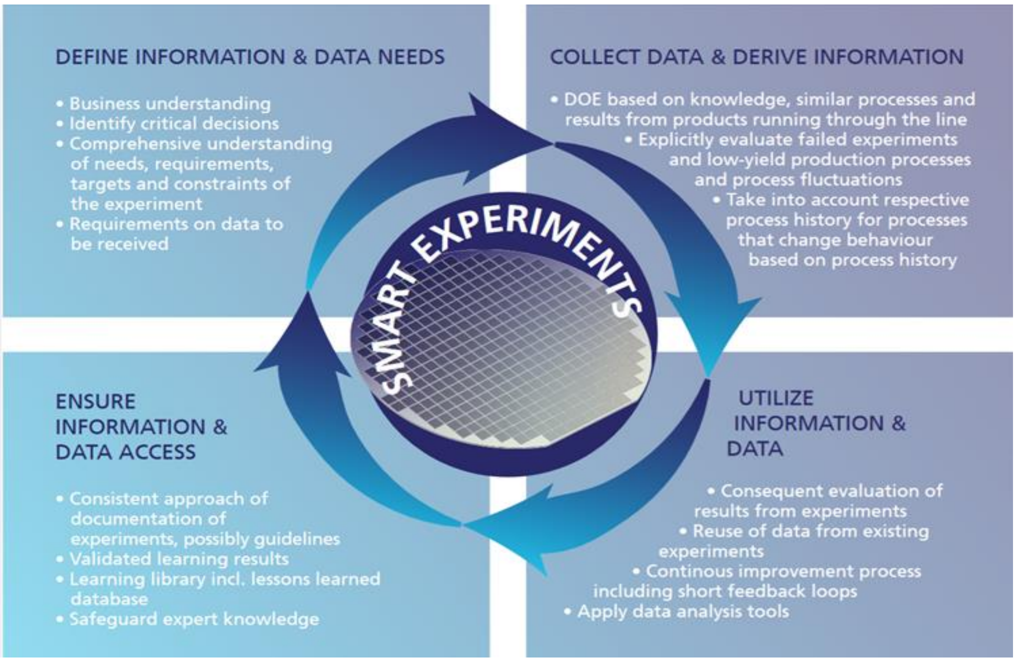
π-Fab® runs a SiC manufacturing line, including dedicated equipment for silicon carbide processing. This manufacturing environment interlinks process development, process services and low-volume manufacturing. Regardless of a significant focus on R&D and low-volume manufacturing, π-Fab® has to meet economic requirements imposed by the market and the costumers, e.g. process and product quality, on-time delivery and a high level of throughput, in order to be competitive in a booming SiC market. This is even more challenging in this rapid prototyping environment featuring a unique flexibility with regard to wafer size, semiconductor material and production processes in manufacturing.

To successfully meet these challenges of custom-tailored development and manufacturing, proven process technology must be adapted via effective learning for best quality results by innovation gained from variability and R&D activities in the line. Findings need to be quickly transferred into ISO-certified production while ensuring result repeatability in rapid prototyping.

Innovation

Three key solutions have been developed:

Baseline module concept: Baseline modules allow to operate a proven framework of stable and controllable process flows while maintaining the high flexibility of the line.



The smart experiments concept: A broad-based holistic approach considering the whole lifecycle of data and information in the fab (© Fraunhofer IISB)

ABSTRACT

Smart experiments concept including data analytics for small data: Problem solving practices were combined with machine learning methods to result in the holistic smart experiments concept. The concept is not restricted to the conduction of experiments, but suggests to consider the whole lifecycle of information and data in the fab. It proposes to integrate, evaluate and link existing data and information aiming to provide active decision support in prototype manufacturing. In rapid prototyping this implies data analytics for a small amount of data in total, which in particular features a high variability within the data. Safeguarding of related process knowledge and context information thus becomes even more relevant.

Smart logistics concept based on a flexible custom-tailored commercial MES system: In order to facilitate smart logistics in rapid prototyping, a flexible, custom-tailored commercial manufacturing execution system is currently implemented in parallel, whose requirements and specifications have been elaborated for the prototype manufacturing environment, where one-of-a-kind material is processed on one-of-a kind equipment in very small quantities. This new MES system therefore provides improved production control capabilities including adaptive flow planning and process execution.

Results

Implementation of the described innovative solutions contributes to improving from a low level of standardization and data utilization in R&D resp. rapid prototyping. The process of alignment marks etching in SiC served as the first use case for concept implementation into rapid prototyping [4]. The respective process understanding was enhanced while defining the accordant baseline module. The procedure was validated with the help of elements taken from the smart experiments concept. Thus, the achievements are also based on findings from data analytics, including a simplified way of retrospective visual inspection of process data as one of the most fundamental steps in data analysis, where time savings of up to 90 % have been achieved.

Dealing with data analytics in rapid prototyping implies the analysis of small amounts of data, which in particular feature a high variability, leading to challenges in regard of data quality. Current practices of storing manufacturing and research data in the prototyping environment have been investigated and improvement potential has been identified not only with respect to the quality of the stored data itself but also with respect to fulfilling the FAIR principles for data in general [5]. Implications for on-site research data management were derived, that will be utilized in the further implementation of the three solution concepts, e.g., a widespread use of available templates and documentation of best practices, and especially the full implementation of the MES system. The latter is currently done in parallel to manufacturing, thus considering e.g. naming and storage conventions.

When fully implemented, the set-up time of a device process is expected to be reduced by 70 % by the application of baseline modules, thus also reducing product cycle time in total while reliably fulfilling process specifications. The knowledge gain from the solution development phase moreover enables the creation of a better data basis for future applications, i.e., there will be an increased amount of data with enhanced quality for process control and data analytics in rapid prototyping. Therefore, reduced learning cycles are expected in a flexible manufacturing environment due to the combination of the presented innovative key solutions.

ABSTRACT

Acknowledgment

This research was supported by the EU project iDev40. The project iDev40 has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 783163. The JU receives support from the European Union's Horizon 2020 research and innovation program. It is co-funded by the consortium members, as well as grants from Austria, Germany, Belgium, Italy, Spain, and Romania. The information and results set out in this publication are those of the authors and do not necessarily reflect the opinion of the ECSEL Joint Undertaking.

References

[1] Gartner (2021, May 12) Gartner says Global Chip Shortage Expected to Persist Until Second Quarter of 2022 [Press Release, online] https://www.gartner.com/en/newsroom/press-releases/2021-05-12-gartner-says-global-chip-shortage-expected-to-persist-until-second-quarter-of-2022

[2] Bosch (2021, November 9) From wafers to power electronic applications: new consortium to create European supply chain for silicon carbide semiconductors [Press Release, online] https://www.bosch-presse.de/pressportal/de/en/from-wafers-to-power-electronic-applications-new-consortium-to-create-european-supply-chain-for-silicon-carbide-semiconductors-234624.html

[3] Integrated Development 4.0, [online] http://www.idev40.eu

[4] Anger, Sabrina, Klingert, Felix, Häublein, Volker, Pfeffer, Markus and Schellenberger, Martin, Smart Platform for Rapid Prototyping: Solutions in the Dilemma of Flexibility and Standardisation. In: ICIT 2021: 22nd IEEE International Conference on Industrial Technology (ICIT), Valencia, Spain/ Virtual Event, 10-12 March 2021,
DOI: 10.1109/ICIT46573.2021.9453566

[5] OpenAIRE (2018, May 3) The Four Basics of FAIR, [online] https://www.openaire.eu/what-is-fair-data?highlight=WyJmYWlyIiwiJ2ZhaXInIiwiJ2ZhaXIiXQ==