Improved DOE and Process Modeling with Generative AI

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Abstract: Small volume semiconductor, photonic and materials manufacturing largely uses One-Factor at-a time (OFAT) to discover process window instead Design of Experiments (DOE). We demonstrate, *Panmo Confab,* a Generative AI based DOE and process-flow-design platform to accelerate process window discovery.

1. Introduction

Large volume semiconductor, photonic and materials automation tools have relied on statistical process control (SPC), design of experiments (DOE) and yield modeling techniques which are fairly manual and depend on specialized tools and deep knowledge [1,2] when such tools are not used we get a sub-optimal outcomes for process development teams through using one-factor at a time (OFAT). In this article we report, and demonstrate, *Panmo Confab* a Generative AI based process flow tracking and design of experiments platform to accelerate flow designs and generating DOEs. Previously our tool was used without Generative AI, features to show improvement in process discovery for plasmonic nanocavity fabrication [4].

The unique innovation of our tool is to use the emerging technology of large language models (LLM), like BERT or ChatGPT [5,6] and science of causality [3] to enable generation of process flows with a description. Our tool is presented in both on-premises and Software-as-a-Service (SaaS) formats.

2. Generative-AI based Design - Confab Pilot

We have developed Confab Pilot, an LLM based tool to generate a process flow or a DOE from a description by integration of the vanilla large-language models (LLMs) with PanMo Confab engine to provide a first draft of process flow or design of experiments from an existing process flow, and a large repository of process related data fine-tuned for the application of interest - memory, logic, solar cells, LED, bio/nano tech., etc.

2.1 Process Design with LLMs

Large Language Models (e.g. LLAMA2, ChatGPT4 etc.) have inference capabilities on human text and can be used for creating guided experiences for novice and intermediate users to guide them through Process/Flow creation.

1. LLM will ask users questions about their process or experiment planned to infer the steps required in the process based on the text description and equipment used.
2. LLM has a prebuilt knowledge base of recipes for sub-domains (Pharma, Semiconductor, Wet-Lab, synthesis, manufacturing or lithography etc.) and can generate a list of steps.
3. Users may accept or tweak the steps for the recipe.
4. Our tool can then generate acceptable independent and dependent variables.
5. LLM can connect to vendors of process and generate process flow, vendor schedule etc.
6. At each step in 3 the LLM will be prompt-engineered to ask clarifying questions.

2.2 DOE creation with LLMs

1. For the same reasons in section 2.1 the LLMs can also be used for generating DOEs.
2. LLMs ask users questions about their process or experiment planned to infer the dependent and independent (factor) variables and infer levels of factors.
3. Design DOE based on this information for target design of experiments using our tool.
4. LLM designed DOE will use a best guess technique and provide tables with randomization.

5. Users can accept or restart the DOE design process.
6. At each step in 3 the LLM will be prompt- engineered to ask clarifying questions.

2.3 MOSCap Modular Process Flow Generation

Two types of Process Flow - Modular and Steps based Process Flow are supported in the Generative AI support.

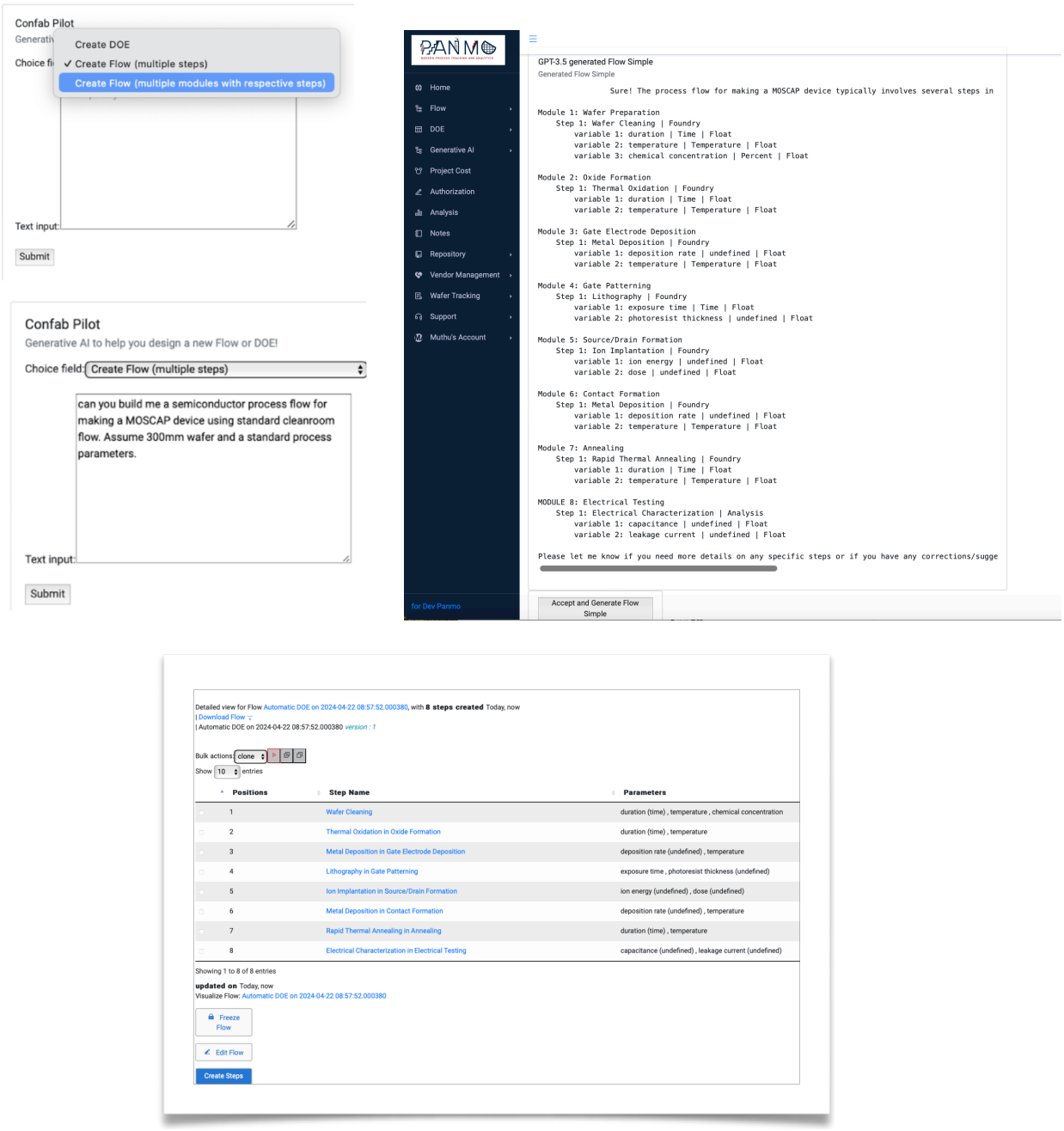

FIG. 1. (left): Confab Pilot tool options to create III.A Process Flow, or III. B DOE; (right): description to create a process for MOSCap; (bottom): proposed MOSCap process flow generated by Confab Pilot.

Upon accepting the flow you will import it into the Panmo Confab system. The generated process flow looks like the Figure. 1. (Right). Similarly the tool can generate a process flow for a modular system. To generate a DOE from

a processing description requires specifying the process description in full and then selecting the ranges for factors identified by the Confab Pilot in an iterative flow.

3. Results

Our software platform is being at one production site as well as under evaluation by multiple teams and used to quickly identify process window with smallest number of runs and wides adoption; we believe this novel technology reduces barriers of entry for PIs and researchers in the industry alike to explore process-flows using new instrumentation which are not traditionally available to them due to complexity of engagement and provide estimates of operation in a quick manner. This tool also addresses the problem of reducing complexity barriers for creating DOEs by using common language to extract factors, levels and response variables from a textual description of the process.

References

1. Montgomery, D. C. Design and analysis of experiments. (John Wiley & sons, 2017).
2. May, G. S., & Spanos, C. J. Fundamentals of semiconductor manufacturing and process control. (John Wiley & Sons, 2006).
3. Pearl, Judea, and Dana Mackenzie. The book of why: the new science of cause and effect. (Basic books, 2018).
4. Annamalai, M., Rathi, S., Methodology for robust process window discovery in plasmonic nanostructures", Proc. SPIE 13111, Plasmonics: Design, Materials, Fabrication, Characterization, and Applications XXII, 131110A (2024).
5. Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., ... & Polosukhin, I., Attention is all you need, Advances in neural information processing systems. 30, (2017).
6. Brown, T., Mann, B., Ryder, N., Subbiah, M., Kaplan, J. D., Dhariwal, P., & Amodei, Language models are few-shot learners. Advances in neural information processing systems, 33, 1877-1901, (2020).
7. Panmo Confab Documentation v1.0, Panmo LLC, Santa Rosa, CA, USA; URL: https://cdn.panmo.cloud/docs/confabpilot.html (accessed March, 2025).