A Manufacturing-oriented Design Environment for Fabrication Processes

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Introduction

Increasing variety of semiconductor fabrication processes in production, increasing process complexity, and shrinking product design cycles each place great demands on the designers of semiconductor fabrication processes. We present the Process Design Aid (PDA), a process design environment based on a new process representation, which:

- encourages reuse of well-characterized parts of a fabrication process;
- permits automatic generation of consistent simulation results and run-sheets;
- supports numerical optimization of simulation results; and
- simplifies and accelerates design of new processes.

Hierarchical Process Representation

An object-oriented, hierarchical process representation is presented. Key attributes of process objects providing for parameterizable and reusable process modules, simulation, and mask data are described. Two dimensions of hierarchy have been found to be important for process representation, a process step hierarchy and a process sequence hierarchy. The process step hierarchy is useful as a classification system and provides a rich collection of default values, simplifying process specification. Attention is focused on critical parameters, and reasonable defaults are provided.

A hierarchical representation of process sequence is also employed in the PDA. This permits conceptually related subsequences of the full fabrication process to be dealt with as single entities. For example, a standardized isolation module (a sequence of steps for forming the region which provides electrical isolation between active devices) may be included in a new process by referencing a single object with four critical parameters. By making this simple specification, a complex and well-characterized sequence of 27 process objects with a total of 96 default parameters is included in the new process. All information required for manufacturing specification and process simulation is included at the same time.

Simulation Interface

The PDA's direct interface to the SUPREM III process simulator is presented. The link accomplished thorough an object-oriented representation of SUPREM III commands including syntax; command documentation; and parameter names, units and defaults. Any process object may have one or more simulation objects associated with it, and SUPREM III parameter values may be inherited directly or computed from process parameters. Thus correct simulation code is automatically generated by default simulation objects in the manufacturing-oriented process representation.

SUPREM III is a one-dimensional simulator, considering a single region of a wafer. Photolithographic masking steps in a fabrication process differentiate numerous regions, several of which will typically be simulated and analyzed. A simple 1-D representation of masks enables automatic simulation of all regions of interest. The PDA employs efficient incremental simulation techniques, sharing the results of a simulation among all applicable regions. Simulation results are automatically extracted, making them available for use by other programs.

An optimization algorithm is included in the PDA, relying on the efficient, incremental simulation management provided by the PDA. Aside from the obvious application of process parameter optimization, numerical optimization has proven to be useful for determining process parameters in terms of specified effects such as oxide thicknesses or junction depths and for calibration of simulation results given measured data.

Results and Conclusion

The PDA has been implemented in an object-oriented extension to Common LISP. Graphical display of objects, on-line documentation, and a menu-based interface make the PDA easy to use. A BiCMOS process has been represented in the PDA. Use of the PDA to add to the process, optimize a parameter and generate full simulations of the process is described.

The PDA, using a hierarchical process representation, simplifies process design by making explicit the structure of fabrication processes and encouraging reuse of existing technology. Simulation results and manufacturing specifications are automatically generated from the same manufacturing-oriented process representation.

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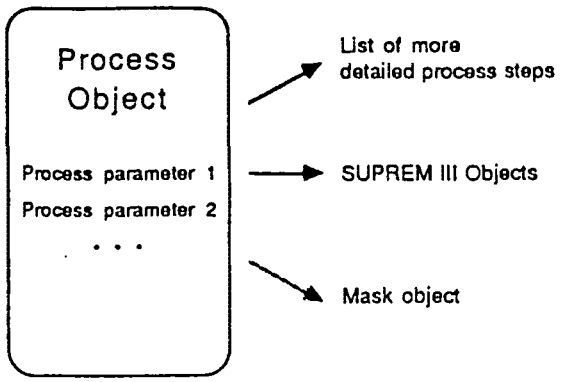

Figure 1. A process object may represent a single processing operation or a sequence of operations defined in terms of lower-level process objects.

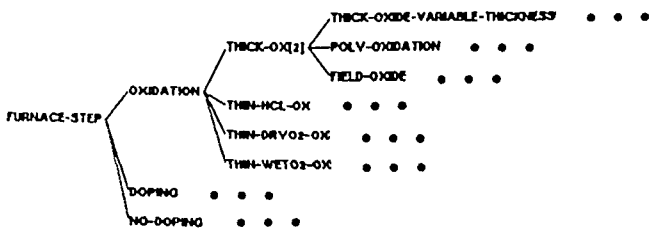

Figure 2. A portion of the process step hierarchy. Moving to the right, more specialized process steps are shown.

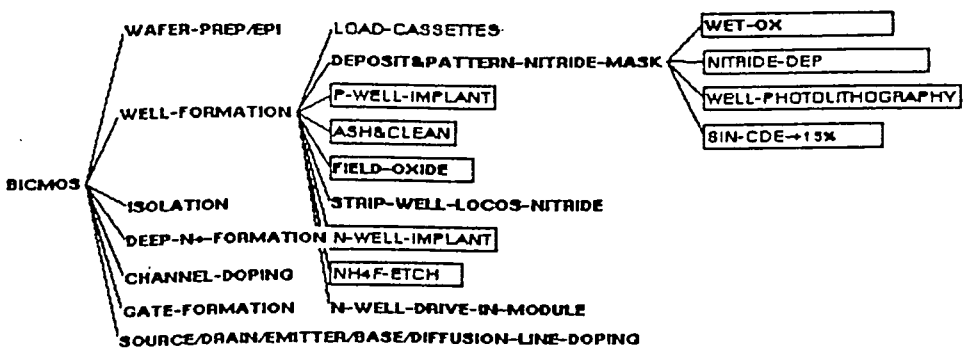

Figure 3. A hierarchical process representation. Moving to the right shows the more detailed process objects which implement a process module. Bold-type nodes may be expanded to show more detail. Boxed nodes have simulation information associated with them.

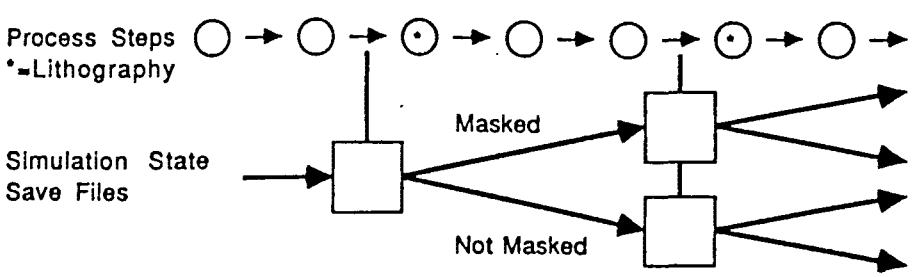

Figure 4. The PDA incremental simulation algorithm saves a binary simulation state file before each photolithography step. This information is used by two subsequent simulations, one for regions which are masked and one for regions which are not masked. Multiple regions are simulated from a single, manufacturing-oriented process representation.