Chapter 4. Computer-Aided Fabrication System Structure

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4.1 CAFE—The MIT Computer Aided Fabrication Environment

4.1.1 Research Goals and Objectives

CAFE (Computer-Aided Fabrication Environment) is a software system being developed at MIT for use in the fabrication of integrated circuits and microstructures. CAFE is distinguished by its use in all phases of process design, development, planning, and manufacturing of integrated circuit wafers. While still being actively developed, CAFE presently provides day-to-day support to research and production facilities at MIT with both flexible and standard product capabilities. CAFE provides a platform for work in several active research areas, including "technology" (process and device) computer aided design (TCAD), process modeling, manufacturing quality control, and scheduling.

4.1.2 Architecture

The CAFE architecture is a computer integrated manufacturing (CIM) framework for the deployment and integration of IC circuit and process design and manufacturing software. The CAFE infrastructure consists of supporting components such as the operating system or database that are independent of the application domain (IC fabrication). The integration architecture includes the conceptual schema and models used to represent the IC manufacturing domain in CAFE, and the user and programmatic interfaces to the various applications. Two important CAFE applications relate process simulation and actual wafer fabrication to the very same process flow representation.

4.1.3 Infrastructure

An early and deliberate design decision was to use an object oriented data model, including the development of an explicit schema to organize the data storage. A high degree of modularity was realized because we have developed a schema which consists of small groups of related objects. Our database schema is based on GESTALT, an object oriented, extensible data model. GESTALT is a layer of abstraction which provides a mapping of user defined objects onto existing database systems (e.g., a relational DBMS) and shields application programs from the details of the underlying database. The programming interface, supported for C and Common Lisp, includes a set of operators for accessing and manipulating persistent data.

Ease of use of any large software system requires a coherent user interface. We have developed FABFORM, a highly programmable and flexible textual interface generator supporting an event model of user interaction. A primary motivation for development of this common user interface was to simplify user training. It also has been proven to have other benefits which simplify the generation of application programs and development tools.

A most important part of creating a set of application modules is the creation or modification of the schema, i.e., the objects used to store information relevant to the application. Incremental changes to the schema are easily made by running a schema modification program which also uses a FABFORM user interface. The addition of new schema objects or the addition of attributes to existing objects rarely impacts existing programs.

A crucial architectural principle of CAFE is the requirement of programmatic, as well as user, interfaces to all application modules. Programmatic interfaces to application modules are necessary in order to integrate existing software into future, higher level applications.

A second important design decision was to concentrate on the development of a manufacturing process flow representation (PFR) that could be accessed and manipulated by computer programs, as well as by design and production engineers. Applications implementing fabrication, simulation, analysis, real time process control, scheduling, and planning all access and derive information from the same representation of the process. The PFR provides an extensible framework for knowledge about process steps, including instructions to operators and equipment, scheduling requirements, changes effected to the wafer product, and physical process model parameters.

4.1.4 Applications

In the following we briefly describe two important CAFE applications, integrated circuit fabrication and process simulation. The fabrication of wafers with a process represented as a PFR involves several steps. A suitable PFR for the specific process must be created and installed. Wafer lots must be created and associated with this specific PFR. These lots must then be "started" to create a task data structure which is isomorphic to the hierarchical structure of the PFR.

At this point, actual machine operations can be scheduled and reservations made for both machines and operators. Finally, the machine operations can be performed, instructions given to the operator and machines, and data collected from the operator or machine and entered into the database.

Process simulation is a critical function at several points in the life cycle of a manufacturing process flow, from early design, documentation, and optimization through to diagnosis and support of the process. We are using the PFR as a mechanism for achieving tight coupling between process design and fabrication. Process development takes place by incrementally generating a PFR for the process. Design may proceed on various levels, including change in wafer state, physical treatment, or machine settings. Process advisors aid the task of treatment level synthesis by providing analytic model based estimates for the initial choice of process parameters. A simulation manager helps the process designer to perform simulations by automatically generating input for target simulators from the PFR. Changes to the PFR are analyzed and resimulations are required only for the affected parts of the process. Simulation results can be interpreted by calculation of layer thicknesses, sheet resistances, threshold voltages, or plots of diffusion profiles.

Current work involves the implementation of hierarchical scheduling, real time process control using the PFR, and integration of a mechanical TCAD system using the PFR.

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