Chapter 2. Computer-Aided Fabrication System Structure

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2.1 CAFE—The MIT Computer-Aided Fabrication Environment

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2.1.1 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. The distinguishing feature of CAFE is that it can be used in all phases of process design, development, planning, and manufacturing of integrated circuit wafers. This manufacturing software system is unique because a process flow representation is developed and integrated into actual fabrication operations.

Presently CAFE provides day-to-day support to research and production facilities at MIT with both flexible and standard product capabilities. This software system 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.

2.1.2 Architecture

The CAFE architecture is a computer integrated manufacturing (CIM) framework for the deployment and integration of integrated circuits and process design and manufacturing software. CAFE uses an object-oriented database model which is implemented in a layered manner on top of a relational database. Our database schema is based on GESTALT, an object-oriented extensible data model. GESTALT is a layer of abstraction which maps user defined objects onto existing database systems (e.g., a relational DBMS) and shields application programs from the details of the underlying database. The integration architecture includes the conceptual schema and models used to represent the integrated circuit manufacturing domain in CAFE, and the user and programmatic interfaces with its various applications. Two important CAFE applications relate process simulation and actual wafer fabrication to the same process flow representation.

2.1.3 Process Flow Representation

During the past year, progress in process flow representation (PFR) was made in three major areas: fundamental modeling, application to fabrication at MIT, and cooperative efforts with industry to define and test a process representation standard.

A high level conceptual model for describing and understanding semiconductor manufacturing process knowledge is a crucial component both of the research program and CAFE implementation. Driven by the needs of process control and optimization research, including sophisticated modeling, design, and experimental model verification, our fundamental conceptual process model has evolved from a two-stage generic process model into one which is part of a more general process modeling framework. The two-stage model is treated as a special case.

To take advantage of an opportunity to apply our research, extensive effort was directed toward industrial efforts in Technology (process and device) CAD Framework (TCAD) to define a broadly applicable semiconductor process representation (SPR) standard. Based largely on the conceptual process model described above, a high

level information model of semiconductor processes is being developed in conjunction with Motorola, IBM, and Texas Instruments, as well as other representatives from industry and universities. A prototype SPR implementation and programming interface was developed and employed in the TCAD Framework demonstration in August 1991.

2.1.4 CAFE Applications

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.

An experimental fabrication run of the MIT baseline CMOS process was made in which all operations were driven by the CAFE system using a PFR representation of the process. We have been evaluating the results of this experiment, performed in conjunction with the Integrated Circuits Laboratory staff, and preparing a plan for expanding use of PFR in the lab to other processes including research processing.

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

2.1.5 Publications

Boning, D.S., M.B. McIlrath, P. Penfield, and E. Sachs, "A General Semiconductor Process Modeling Framework." *IEEE Trans. Semicond. Manufact.* Forthcoming.

Ko, W.-Y. *Graphical Framework for Computer-Aided Fabrication Environment's Process Flow Representation.* S.M. thesis, Dept. of Electr. Eng. and Comput. Sci., MIT, 1991.

McIlrath, M. "A General Semiconductor Process Modeling Framework." Presentation at the Semiconductor Research Corporation (SRC) Computer Integrated Manufacturing of Integrated Circuits (CIM-IC) Workshop, Raleigh, North Carolina, August 21-23, 1991.

McIlrath, M. *Current Concepts in Semiconductor Process Representation.* CFI Document No. 91-T-2. Austin, Texas: CAD Framework Initiative, 1991.

McIlrath, M. "Semiconductor Process Representation (SPR) Server Prototyping." Presentation at the Technology Computer-Aided Design (TCAD) Working Group, San Francisco, California, June 21, 1991 (see CFI Document No. 91-M-8).

McIlrath, M. "Report on SPR Prototyping." Presentation at the TCAD SPR Working Group, Palo Alto, California, August 10, 1991 (see CFI Document No. 91-M-10).

McIlrath, M. "TCAD Framework Architectural Issues." Presentation at the TCAD Framework Plenary Session, Palo Alto, California, August 10, 1991 (see CFI Document No. 91-M-10).

McIlrath, M. "Mini-SPR Prototype Programming Interface." Unpublished technical report delivered to the TCAD SPR Working Group, June 21, 1991.

McIlrath, M. "TCAD Framework Architectural Issues." Unpublished technical report delivered to the TCAD Framework Group, Palo Alto, California, August 10, 1991.