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Integration of the APC Framework with AMD's Fab25 Factory System

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ABSTRACT

This paper discusses the integration and development of advanced process control technologies with AMD's Fab25 factory systems using the Advance Process Control Framework. The Framework is an open software architecture that allows the integration of existing factory systems, such as the manufacturing execution systems, configurable equipment interfaces, recipe management systems, metrology tools, process tools, and add-on sensors, into a system which provides advanced process control specific functionality.

The Advanced Process Control Framework project was formulated to enable effective integration of Advanced Process Control applications into a semiconductor facility to improve manufacturing productivity and product yields. The main communication link between the factory system and the Framework is the Configurable Equipment Interface. It interfaces through a specialized component in the framework, the Machine Interface, which converts the factory system communication protocol, ISIS, to the Framework protocol, CORBA. The Framework is a distributed architecture that uses CORBA as a communication protocol between specialized components.

A generalized example of how the Framework is integrated into the semiconductor facility is provided, as well as a description of the overall architecture used for process control strategy development. The main development language, Tcl/Tk, provides for increased development and deployment over traditional coding methods.

Keywords: Advanced Process Control, CIM, APC Framework, Control Systems, Run-to-Run Control, Fault Detection and Classification, Systems Architecture, CORBA

1. INTRODUCTION

Advanced process control (APC) is the technique of manipulating recipe parameters in batch processing to achieve a desired target. In semiconductor manufacturing, the most common implementation is to perform run-to-run control on each batch, or lot, of wafers. AMD identified the need for a standard software integration solution to support APC in the facility, and so pursued a NIST ATP grant to facilitate the development of the Advanced Process Control Framework Initiative (APCFI).[1, 2, 3, 4]

In Fab25, the APC Framework has been used in several control projects, including run-to-run control of oxide thickness after the chemical-mechanical planarization process and minimizing overlay errors in the photolithography module. It has also been used to emulate the controller used to control critical dimension in the polysilicon gate process. The framework capability can be extended through the use of plugin modules for third party packages such as Matlab and Mathematica, providing the control engineer the flexibility and capability of implementing advanced algorithms through a familiar interface. On the manufacturing side, an operator interface component is available to allow interaction with the factory floor via customizable dialog boxes.

2. APCFI PROJECT

The goals of the APCFI were outlined in the program proposal presented to NIST (National Institute for Standards and Technology) in October 1995. These goals were to: enable effective integration of "Advanced Process Control" applications into a semiconductor facility to improve manufacturing capital productivity, product consistency, and product yields; establish integration technology for multi-supplier "Plug-and-play" APC applications; and to demonstrate commercial viability of the APC Framework and its components. To sum up, the main goal of the APCFI projects was to develop a

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system that would significantly reduce the time, cost, and integration efforts needed to deploy APC solutions. A conceptual view of the Framework's role in the facility is shown in Figure 1.

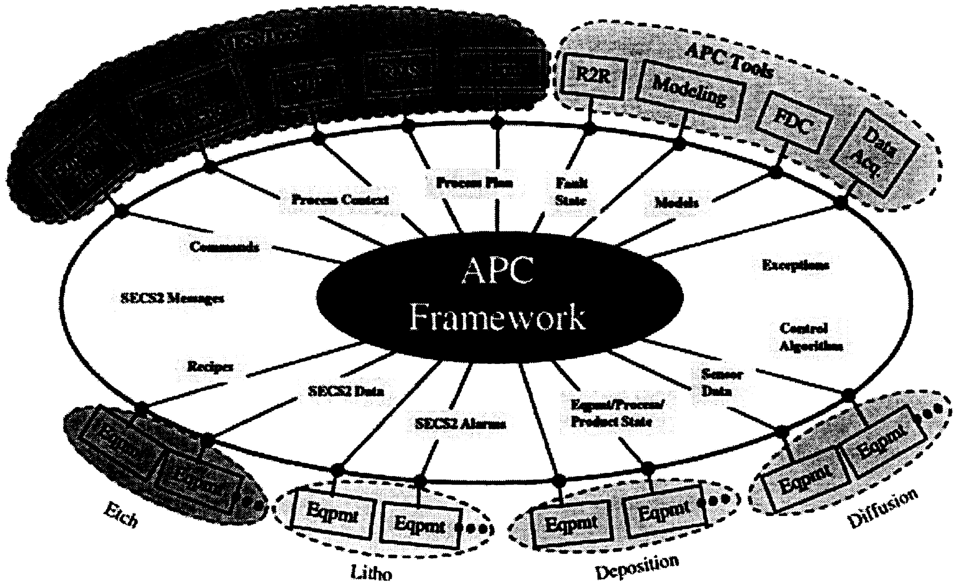

Figure 1: Overview of the APC Framework in the MIS.

In order to ensure compatibility with equipment in use today and in the future, the APC Framework is based on the SEMATECH CIM Framework specifications and allows for machine communications through the SEMI/GEM Semiconductor Equipment Communication Standard (SECS). This feature of the APC Framework allows for easy integration with legacy manufacturing equipment.

The scope of the APCFI projects includes support for Feed-forward and Feedback Run-to-Run control and Fault Detection applications spanning multiple processes and fabrication tools and utilizing 3rd-party control software, such as Modelware®, Matlab®, Matlab Toolkits, Mathematica®, and LabView®.

Although the original NIST funded APC Framework Initiative has been completed, several other projects with multiple companies have been announced -- including a second NIST project with National Instruments which will build on the APC Framework.

3. OVERVIEW OF APC FRAMEWORK

The APC Framework has been designed to work along with a factories' MES (Manufacturing Execution System -- for example, WorkStream by Concilium) and Configurable Equipment Interface (CEI) to provide APC functionality. It is composed of not one large program, but a number of smaller, specialized pieces that work together in a distributed architecture. The "interchangeable parts" of the APC Framework are called components. These components are analogous to stereo components, where each component is

1. An independently running entity
2. Provides a subset of the overall APC Framework functionality
3. May be provided by a different vendor

The APC Framework standard describes the functionality, interface, and behavior of each component. The components of the APC Framework communicate via the CORBA protocol, and are shown in Figure 2.

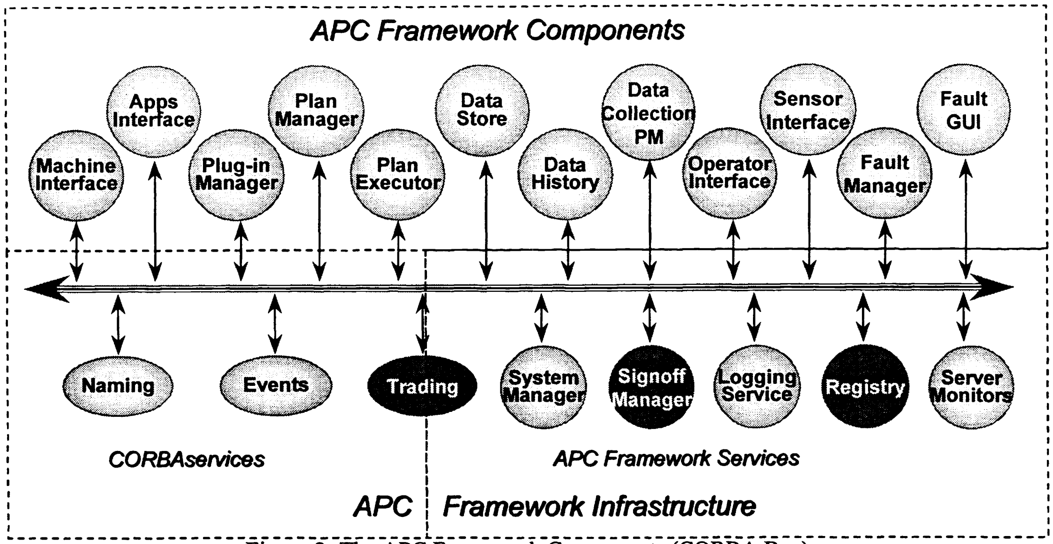

Figure 2: The APC Framework Components (CORBA Bus)

The main components of the framework include the Plan Execution Manager (PEM), Plan Manager (PM), Machine Interface (MI), Operator Interface (OI), Plugin Management (PIM), and Data Store (DS). The PEM coordinates the execution of user-defined process control plans among all the APC components for a given semiconductor machine. Its main responsibility is to interpret the Tcl/Tk commands in a given control script, performing the operation defined by the script. Although the script can perform a number of different functions, in most cases they perform two main objectives: 1) generation of controlled settings for a processing tool, or 2) manipulation of data from a metrology tool. Each of these scripts can call other components in the framework, such as the plugin manager (PIM) or the operator interface (OI) to perform a specialized function. It is also common for the script to store and retrieve data from the APC database, symbolized by the Data Store (DS) component.

Other than the main components listed above, there are a number of components that serve as infrastructure for the CORBA services, such as the Naming service, the Registry, and the Signoff Manager.

4. INTEGRATION WITH THE FACTORY

In AMD's Fab25, the main communication link between the equipment and the factory system is the Configurable Equipment Interface (CEI). Each of the factory systems, whether the Manufacturing Execution System, for example, Workstream, or the Recipe Management System (RMS), interact with the physical equipment in the facility through the CEI. The APC Framework system also communicates through the CEI through a specialized component called the machine interface (MI). The CEI makes two connections to the ISIS bus -- one to support communications to Workstream and RMS, and the other to support interactions with the APC Framework, as shown in Figure 3. The function of the MI is to translate between the ISIS protocol used by the CEI and the CORBA protocol used by the rest of the APCFW. When the CEI wants to talk to the APC system, it communicates to the MI, and the MI relays the message on to the rest of the APC system. In a similar manner, when the APC system needs to send information to the CEI, it also must go through the MI.

During the specification process for a process control strategy, the engineer specifies the data to be measured at metrology tool and the recipe parameters that will serve as manipulated variables for the processing tools. The standard CEI baseline code used at AMD contains the required support for communication with the APC Framework, and generally the only modifications which are required are changes to support receiving or setting the appropriate information on the tool, i.e., implementing recipe modifications. To enable communication with the MI, a configuration variable is set to 'true' and the CEI is restarted. The name of the MI on the ISIS bus is given by <entity>MI. Once enabled, the standard interaction with the MI is performed through the 'run_apc' command.

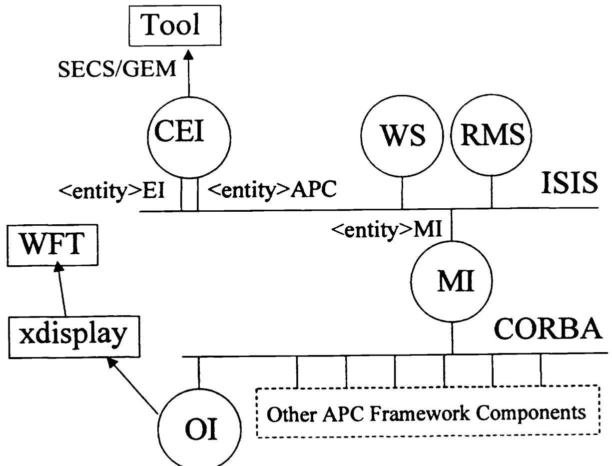

Figure 3: The CEI and MI Communication Path (ISIS Bus)

Communication between the CEI and MI occurs after the recipe information has been retrieved from RMS, but before the process or metrology equipment is setup (step 0 and 1). The CEI then passes the context and parameter set information to the MI with the 'run_apc' command, as shown in Figure 4. The MI passes the information to other APC components for action -- either preparing to receive data from metrology equipment, or to calculate recipe parameters for processing equipment. The context information is used by the Plan Manager to determine which APC Plan will be used (step 2). The Plan Executor then runs the Tcl/Tk script defined associated with that plan. The APC components return parameter set information to the MI that is passed to the CEI through the 'apc_data' command (step 3), and also communicates when the APC system is prepared to receive data, if appropriate (steps 4 and 5). The CEI downloads the recipe to the processing tool with any parameter updates and begins processing (step 6). If data events are returned from the tool (step 7), they are communicated to the APC system through the MI.

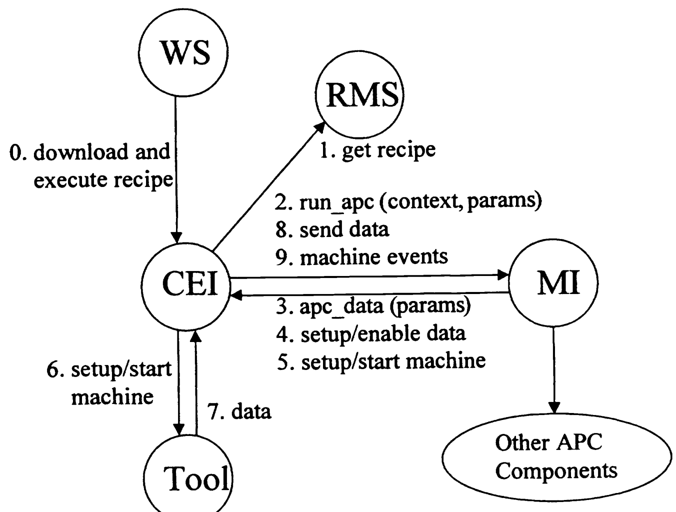

Figure 4: Interaction Diagram between CEI and MI.

In addition to the communication described above, interaction between the factory floor and the APC Framework can be performed through the Operator Interface (OI) component. Part of the context information passed to the APC system contains the display ID for the X-Terminal used by the operator and the OI can popup dialog boxes on the factory floor, if required, as in Figure 3.

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