Using Simulation-Based Learning Systems for Training in Semiconductor Manufacturing Equipment and Processes

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OUTLINE

• EquiPSim for the learner
  – Vacuum, gas flow, heat transfer, chemical reactions
  – Operating equipment, troubleshooting, uniformity/yield, control

• EquiPSim for the teacher
  – Historian for demos, collaboration/consultation tools, authoring

• Discussion and feedback
  – What would be most valuable to you in EquiPSim?
EquiPSim for the Learner

• Current modules
  – Vacuum technology
  – Gas flow
  – Heat transfer
  – Chemical reactions (CVD)
  – Uniformity/yield
  – Control

• Numerous other possibilities
  – Furnaces
  – Recycling/materials systems
  – Plasma
  – Litho
  – ....

• Run the equipment

• Break the equipment

• Troubleshoot the equipment

• Do experiments

• Collaborate with peers and consult with teacher

• Lots of guidance
EquiPSim Learning Modules
(Equipment and Process Simulation)

Physics-based dynamic simulation

Active learning through exploration, anytime, anywhere

Powerful learning aides
Tightly coupled guidance
Learning histories
Distance collaboration & consultation

Extendible authoring architecture

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Learning Module – User Interface

- **Focus Window**
- **Control Bar**
- **Guidance Window**
Learning Module – Architecture

- Enhanced user interface (Delphi visual development platform)
- Dynamic simulator (VisSim simulation platform tool)
- Guidance materials (web site, html)
Guidance Materials

Folder/tab hierarchy for instructional scaffolding

Focus Window

Guidance window
Tightly Coupled Guidance

Graphical elements associated with technical term are highlighted in focus window.

Focus Window

Guidance window

Cursor placed over technical term in guidance window.
Hands-On Exercises

EXERCISE (use with Chemical Reaction Module)
Testing low temperature deposition rates

- Use chemical reaction module to achieve about 1 torr partial pressure of SiH₄ in the reactor
- Use manual temperature adjustment to fix the wafer temperature to about 450°C
- Observe the deposition rate in the chemical reaction module
- Change the temperature by about 50°C to see how much deposition rate changes
- Return to the original temperature and change the SiH₄ partial pressure by about 2X to see how much the deposition rate changes

Observation: The deposition rate at low temperatures depends on temperature, but not significantly on SiH₄
Experiments and Lab Notebook

Learner experiments freely with system design parameters

Learner annotates results of experiments into lab notebook

Lab notebook:
- automatic date/time and parameter settings
- learner’s comments
Experiments and Lab Notebook

Stop watch to time experiments

Learner experiments freely with system design parameters

Learner annotates results of experiments into lab notebook

Lab notebook:
- automatic date/time and parameter settings
- learner’s comments

Send results/questions to peer or instructor

Print lab notebook
Vacuum Technology Module
Gas Flow Module
Heat Transfer Module
Chemical Reaction Module
Uniformity / Yield Module
Process Integration and Yield Modeling

- Simple device (capacitor) example
- Illustrate
  - Process integration
  - Yield consequences
  - Statistical variation
  - Uniformity variation
Process Integration and Yield Modeling

- Excel-based learning system for process integration and yield
- Across-wafer nonuniformity
- Process centering
- Statistical variation
EquiPSim for the Teacher

• Module functionality
  – Do experiments
  – Record and revise experiments
  – Annotate and share results
  – Develop your own guidance materials
  – Revise simulator functionality

• Learning before teaching
• Demonstrations
• Develop exercises for students to do
• Answer student questions
• Improve guidance materials
• Add functionality
Learning Historian - Record of Events

- Record, revise, replay, and annotate event histories in simulation experiments
- Use for
  - tutorial generation
  - questions to teacher/expert
  - peer collaboration
Learning Historian - Replay of Simulation

In Pumpdown 1, you use the system. This has two limitations:

- Typically the bypass take a long time to approach.
- The base pressure achievable with only the mechanical pump is not low enough to remove sufficient reactive species and achieve low enough base pressure in the reaction chamber.

**Pumpdown 2. Open V1**

Here we opened valve V1 so that the mechanical pump operates to pump down the turbo pump volume.
Module Architecture for Authoring

• Enable independent authoring of
  – engineering/technical material vs.
  – user interface and software design

• Provide effective authoring tools to engineering expert
  – minimal if any software knowledge required
  – reusable library of simulator objects

• Provide effective authoring tools to software/interface designer
  – minimal if any engineering knowledge required
  – reusable library of user interface and software objects

• Anticipate sequence of learning modules which can bring learner from novice to knowledgeable practitioner status
  – learning tool becomes on-the-job assistant
Separable Authoring

Enhanced user interface (Delphi visual development platform)

Dynamic simulator (VisSim simulation platform tool)

Guidance materials (web site, html)

Software/user interface designer

Engineering content expert

DLL dialog
Guidance Materials

Guidance materials are all Web-based
- Written in html using standard software (Composer, FrontPage, etc.)
- Available in local installed module or directly from Web
- Images, audio, and video easily included
- Easily linked to simulator focus window (tightly coupled guidance)
Simulator: Local and Remote Control

Local/remote control switch on simulator:

Local - simulation controlled by “actuators” on simulator itself
   Useful for engineers with domain knowledge
   Enables continuous improvement of simulator’s physical fidelity

Remote - simulation controlled by “actuators” from user interface
   Allows simulator control from user interface
   Removes need for interface designer to have domain knowledge
Authoring - User Interface

Developer kit provides authoring instructions and flexibility to change pointers.

Developer’s pop-up facilitates definition of system parameters to be integrated on simulator and user interface sides.
Other EquiPSim and Related Tools
Water Recycling in Semiconductor Fabs
Discrete Event Simulation and Factory Operations

- Cluster tool simulators
- Factory logistics simulators
Discussion and Feedback
Conclusion and Invitation

• Technology and laboratory experiences can be brought to the student – in class, at home, or in the workplace
• Simulation provides the basis for active learning experiences
• Powerful software methodologies provide value to learning, collaboration, consultation, and authoring
• We invite input and collaboration to serve the learning constituencies in the semiconductor industry