

Dynamic Simulation of Water Recycling in Semiconductor Manufacturing

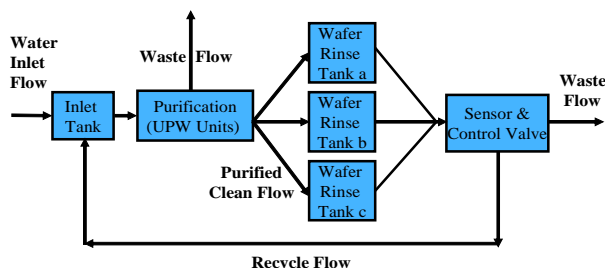
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Overview

1. Physically-based dynamic simulation reveals time-dependent and time-integrated process behaviors:
 - (i) Evaluate ESH, manufacturing and technology metrics change under process changes for integrated ESH assessment
 - (ii) Exploit simulation-based learning system: Water recycling process simulator (WaterSim)
2. Apply to engineering analysis and optimization of water recycling systems, as done for CVD and ALD processes.
3. Completely rebuild educational module for water recycling
 - (i) More powerful and flexible simulation model
 - (ii) More advanced learning software platform (latest SimPLE)

Simulator Structure

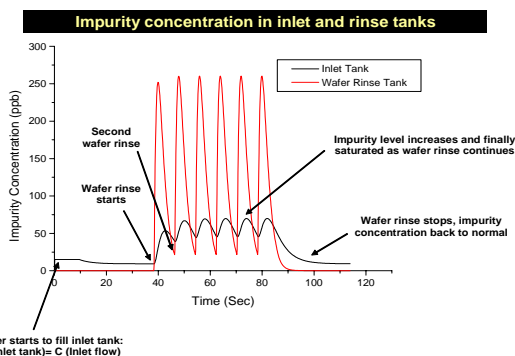


- New features:
1. Interchangeable UPW unit models
 2. Multiple rinse tanks
 3. Multiple impurity species

Simulator Basic Features

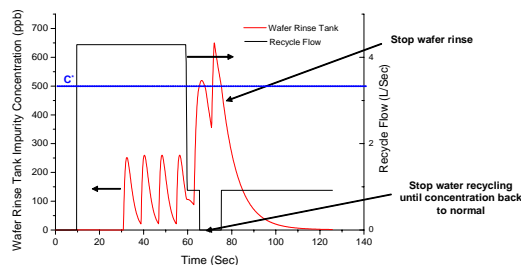
1. Use of vector variables and embedded function for structural simplification/organization;
2. Multiple and expandable UPW Models:
 - (i) Manual UPW model selection;
 - (ii) Automatic UPW switch based on impurity concentration;
3. Multiple wafer rinse tanks;
4. Multiple impurity species;
5. Implementation of process control algorithm:
 - (i) Tank water level control:
 - water level too low → close outlet stream
 - water level too high → close inlet stream, open exhaust
 - (i) Impurity concentration control:
 - high impurity concentration in rinse tank: $C > C^*$ → stop wafer clean, stop water recycling, refill tank with clean water

Normal Operation

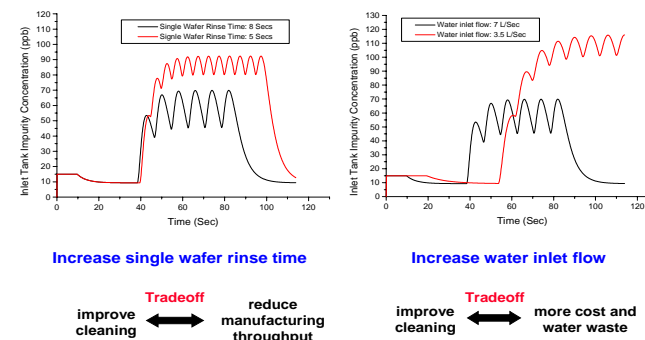


Transient Response & Control

Upset: sudden impurity increase in wafer rinse tank
Triggers control response: when $C > C^*$ (Maximum allowed concentration), stop wafer rinse and stop water recycling



Tradeoff Analysis



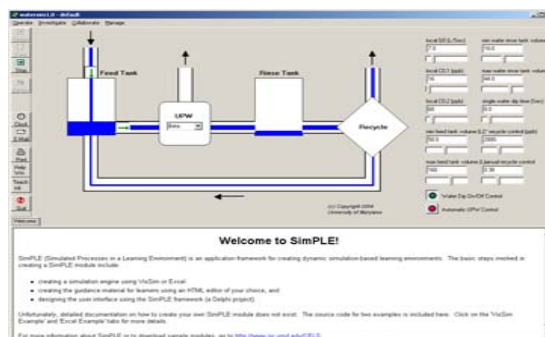
WaterSim 4.0 Development

- WaterSim 3.0, a physically-based dynamic simulator on water recycling process integrated with advanced learning platform (SimPLE), has been developed;
- The new version of dynamic simulator on water recycling has better structural organization, more robust control algorithm and better expansion capability;
- WaterSim 4.0, which uses the new simulator version, is more powerful and flexible, and will be available for use and partnering:

- (i) Engineering
 - Significantly enhanced analytical and design capability
 - o Interchangeable UPW components
 - o Multiple rinse tanks
 - o Transient/upset analysis
 - o Development of optimized and robust sensor/control systems and algorithms
- (ii) Education
 - WaterSim 3.0 has been used in UA classes

Watersim 4.0 Development

WaterSim 4.0 User Interface



Conclusion

- Complete rebuild of a physically-based dynamic simulation model for water recycling process to optimize model design and versatility
 - Interchangeable components, flexible control algorithms, multi-component impurity streams, reusable model elements, distributed rinse tanks,...
- Dynamic simulation reveals essential behavior of water recycling process:
 - (i) Simulation can be used as virtual experiment to test new UPW modules, justify process changes and optimize control algorithm
 - (ii) Time-dependent and time-integrated behaviors of technology, manufacturing and ESH metrics generated from simulation can be used for integrated ESH assessment
- WaterSim 4.0, which is based on the new simulator, is more powerful and robust than previous version and can be used for both engineering and education purposes