Task ID: 425.021
Task Title: Low-Water and Low-Energy Rinsing and Drying of Patterned Wafers, Nano-Structures, and New Materials Surfaces
Deliverable: Report on the drying model for data analysis and process applications

Summary and Abstract:
An electrochemical sensor technology was developed to detect the chemical residues in micro/nano structures. A sensor for monitoring rinse and drying process was designed and manufactured. Some rinsing experiments were performed at Freescale. A number of other applications in surface preparation were also investigated with the help from Samsung. The results indicate that the sensor technology is suitable for monitoring rinsing and drying processes in semiconductor fabrication plants.

Technical Results and Data:
A rinse curve shown in Figure 1 perfectly shows that a rinse process may have two stages, a quick transport control initial stage which is fast, and a slow cleaning which controlled by desorption.

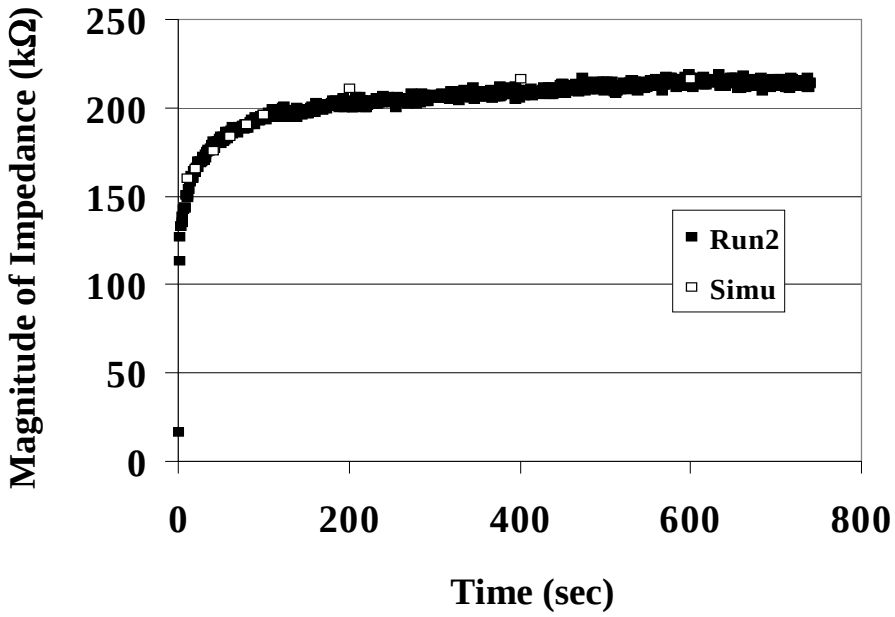

Figure 1: Sensor output showing the progress of rinsing off sulfuric acid from the wafer surface at 49 ℃

A rinse model was also developed to describe all major transport phenomena and the chemical reactions of the rinse process. There are some details of the phenomena that

still are unknown. For example, the thermodynamic parameters are known, but the kinetic parameters are still unknown. Therefore, some assumptions and estimations are required for the model to give reasonable results without distorting the mechanism.

The transport phenomena of rinse processes include diffusion, convection, and migration. However, the rinse tank fluid dynamics is not the topic of this research. To simplify the model, the following equation is chosen to describe the transport phenomena inside the laminar flow boundary (Figure 2):

$$\frac{\partial C_i}{\partial t} = \nabla \cdot (D_i \nabla C_i + z_i \mu_i F C_i \nabla \varphi)$$

D_i in this equation is not diffusion coefficient but is the effective transport coefficient representing both diffusion and convection.

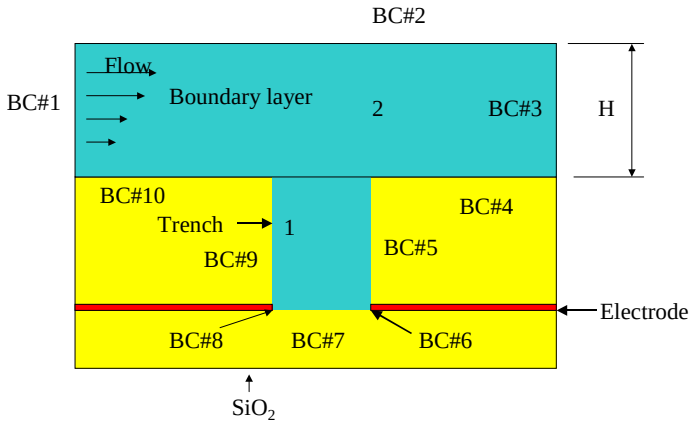

Figure 2: Schematic of the rinse simulation domains and boundaries

This model also includes the adsorption and desorption, as well as some surface reactions which lead to surface charging. Using sulfuric acid solution and silicon dioxide surface as example, the surface interactions are as follows:

$$10SiOH + SO_4^{2-} + H^+ \rightarrow (SiOH)_9 SSO_4^- + H_2O \quad \text{surface reaction}$$

$$SiOH \xleftrightarrow{K_{SiOH}} SiO^- + H^+ \quad \text{surface charge forming.}$$

Conclusions:

The experimental data and simulation results match in Figure 3. This shows that the simulation results agree with the experimental phenomena reasonably well.

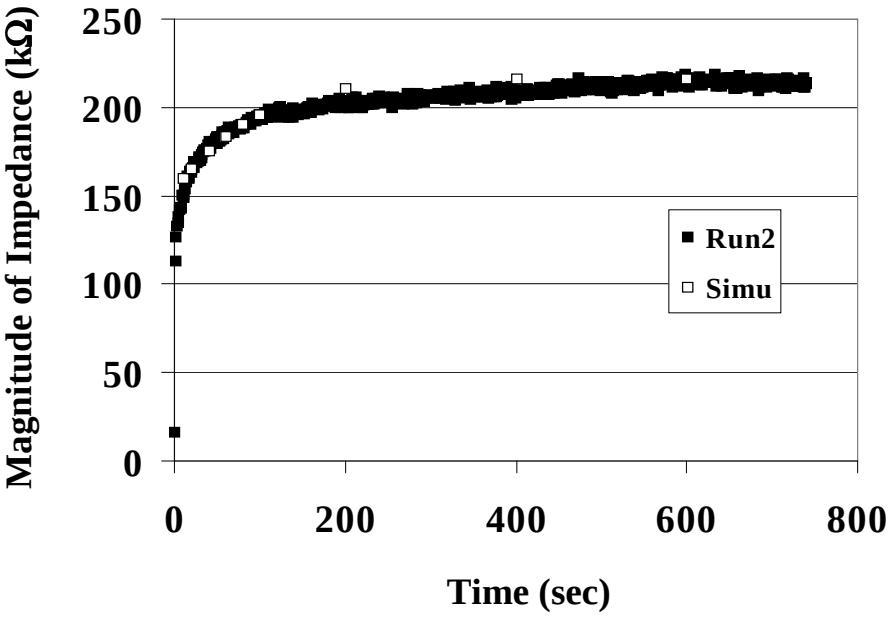

Figure 3: Comparison of data with rinse simulation results at 49℃