

Proposal # 3: Physical Cleaning of Submicron Trenches, a Modeling Study

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Goals and Objectives

The objective of the proposed work is:

- Develop an effective cleaning techniques for micro and nano scale trenches and vias with high aspect ratios.
- Use physical modeling to study the mechanism contaminant removal process in submicron deep trenches.
- Identify and control the key cleaning parameters for effective cleaning and high rinsing efficiency.
- Study the macro and micro features of the cleaning fluid interaction with a patterned wafer to identify the effect of cleaning fluid direction.

Project Description

In this proposal an advanced study, based on preliminary experimental and numerical studies of contamination removal from non-patterned silicon wafers and the effects of pulsating flow on convection into and from submicron trenches, of contaminant removal and transport from micro and nano size features with high aspect ratio is proposed. The effect of the fluid velocity, pulse frequency, trench geometry, surface tension and other properties of the oscillating rinse flow on contaminant removal will be investigated. According to anticipated device size reductions, the semiconductor industry (according to the International Technology Roadmap for Semiconductor) will face the challenge of cleaning 35 nanometer trenches with high aspect ratio (70-100) in the next 14 years¹. Effective pulsating flow rinse frequency was shown to depend on the trench width^{2,3}. Preliminary results showed that the ideal frequency depends on trench width and that a threshold frequency exists for effective contaminant removal. The effectiveness was also found to be a function of Strouhal number, which quantifies the extent of pulsating convection relative to steady convection. However, the effects of aspect ratio, surface tension and pulse intensity have not been investigated numerically, and no experimental studies of contamination removal from trenches have been attempted.

Megasonic cleaning is known as one of the most effective techniques in non patterned wafer cleaning. Busnaina *et. al.* have studied megasonic rinsing and cleaning process for blanket wafer⁵ and provided both experimental and modeling results. The rinsing of potassium chloride from a wafer in a megasonic cleaning tank is shown in figure 1. The figure shows the experimental and numerical results of the removal of potassium and chloride ions from the blanket wafer surface. The agreement between experiments and simulation is good for both stagnant bath and megasonic rinse. The figure shows that megasonic rinse flow dramatically reduces the rinsing time because the oscillation increases the transport rate of the contaminant.

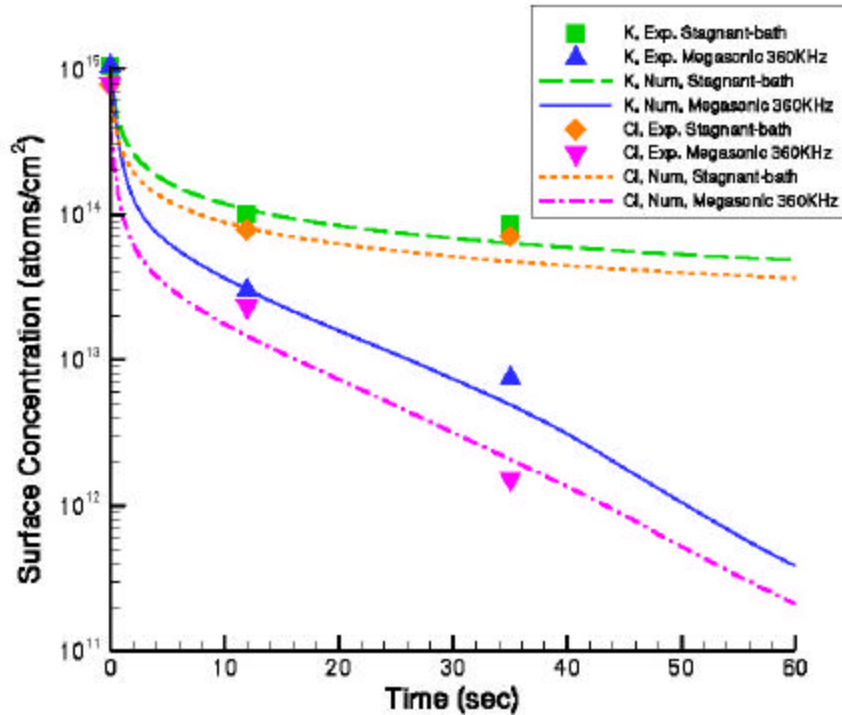


Figure 1. Potassium and chlorine contamination removal from blanket wafer surface

The cleaning processes for patterned wafers will be studied experimentally and with physical modeling. Experimental studies will include the use of fluorescent polystyrene spheres to quantify particle removal as well as the use of scanning electron microscopy. The fluid flow field and contaminant transport in the geometry will be modeled using a finite difference solution of the governing momentum and mass conservation equations with associated boundary conditions. Contaminant removal from patterned wafers with micro and nano size trenches and vias will be simulated using oscillating flow past a series of rectangular cavities. For the simulation of cleaning processes with surface reactions, surface chemical reactions with proper heterogeneous kinetics will be included in the model as a boundary condition.

1. Hattori, T., "Contamination Control: Problems and Prospects," *Solid State Technology*, vol. 33, no. 7, p s1 (July 1990).
 2. The National Technology Roadmap for Semiconductors Technology Needs, The Semiconductors Industry Association. 2000.
 3. Lin, H.; Busnaina, A. A.; Suni, I. I., Physical Modeling of Rinsing and Cleaning of Submicron Trenches, *Proceedings of the IEEE 2000 International Interconnect Technology Conference*, pp. 49-51 (June, 2000).
 4. Lin, H, Busnaina, A. A. and Suni, I, "Modeling of Rinsing and Cleaning of Trenches." International Sematech Wafer Cleaning and Surface Preparation Workshop 2000, April 11-12, 2000, Austin TX.
- Busnaina, A. A. and Gale, G. W, *Journal of Particulate Science and Technology*, 17(3), 1999.