Post Tungsten CMP Cleaner Development with Improved Organic and Particle Residue Removal on Silicon Nitride and Excellent Tungsten Compatibility

Ching-Hsun Chao, Chi Yen, Ping Hsu, Eugene Lee, Paul Bernatis

EKC Technology, DuPont Electronics and Communications

Ken.Chao@dupont.com; Paul.R.Bernatis@dupont.com

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Summary

Problem statement

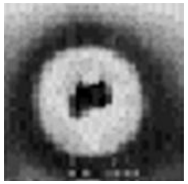
Clean efficiency on SiNx

Tungsten compatibility

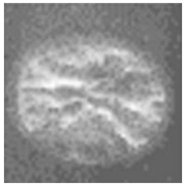
RESIDUAL SLURRY

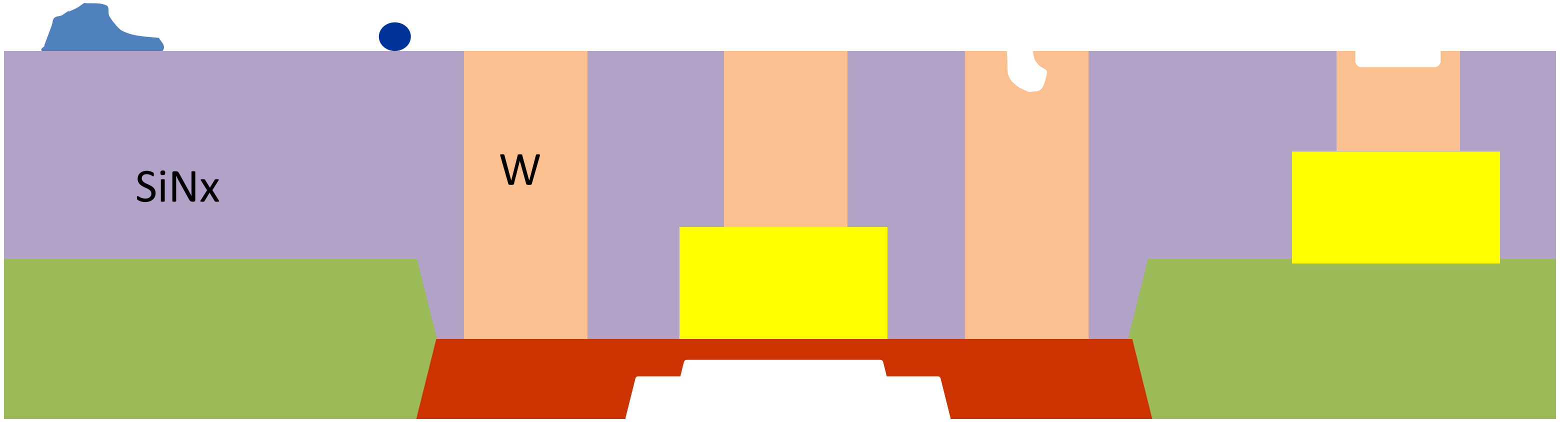
SURFACE PARTICLE

W PLUG CORROSION



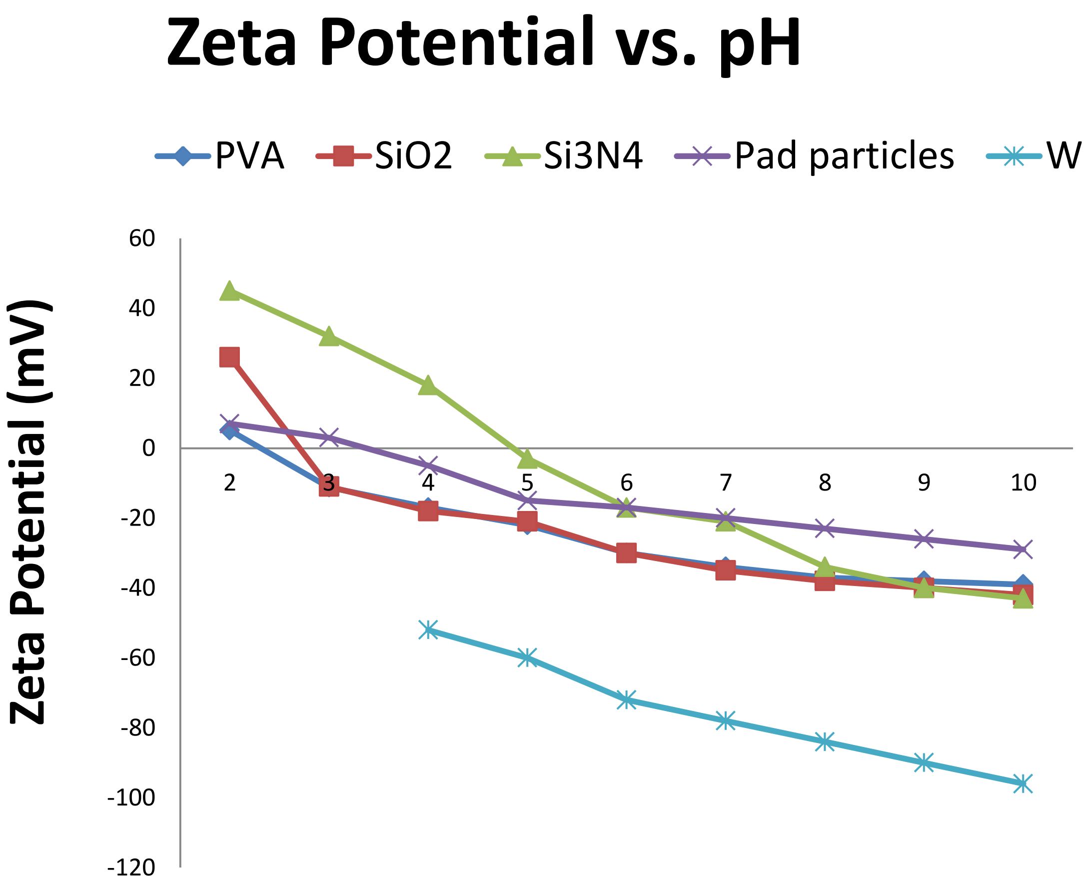
RECESSED W PLUG





- There are four types of defectivity after post tungsten cleaning.
- Improve tungsten compatibility and cleaning efficiency to improve defectivity.

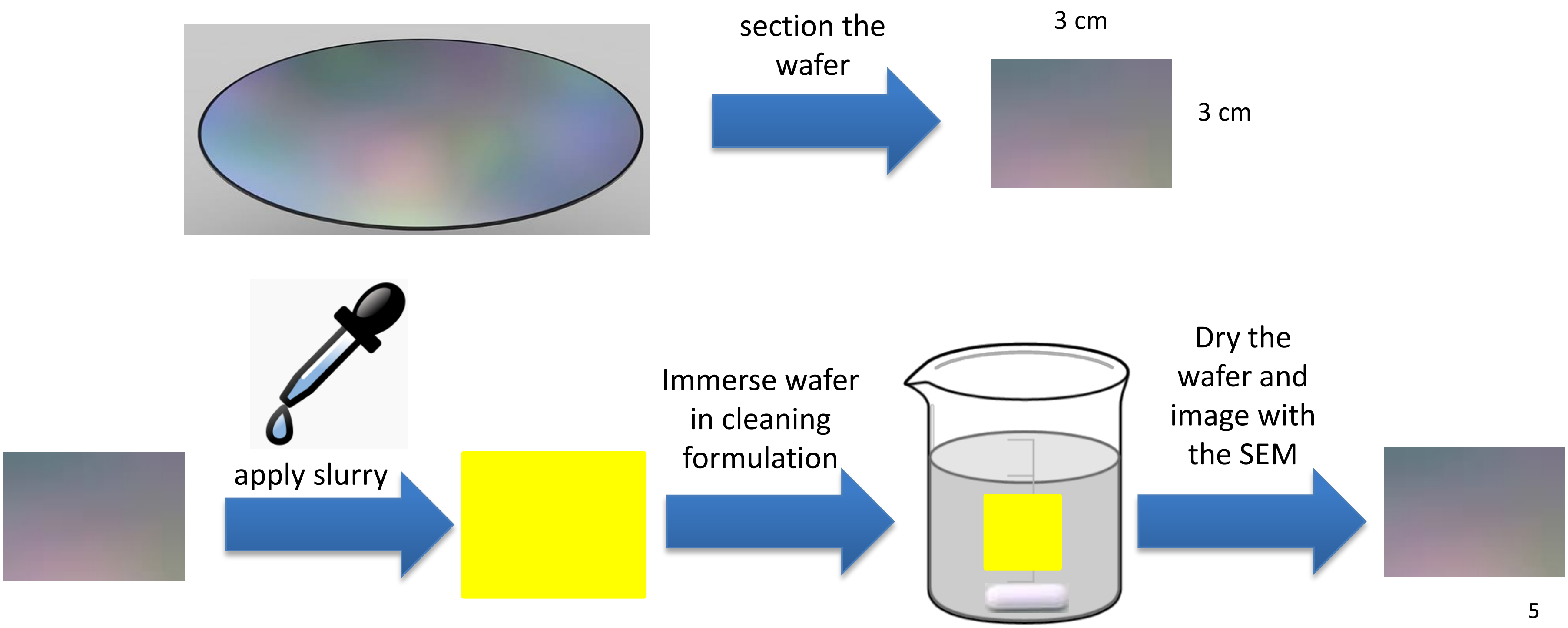
Zeta Potential Measurements on Wafer Substrates and Defect Sources



- Adjust formulation pH to measure zeta potential
- High pH value provides higher electronic repulsive force between contaminant particles and SiNx and tungsten wafers

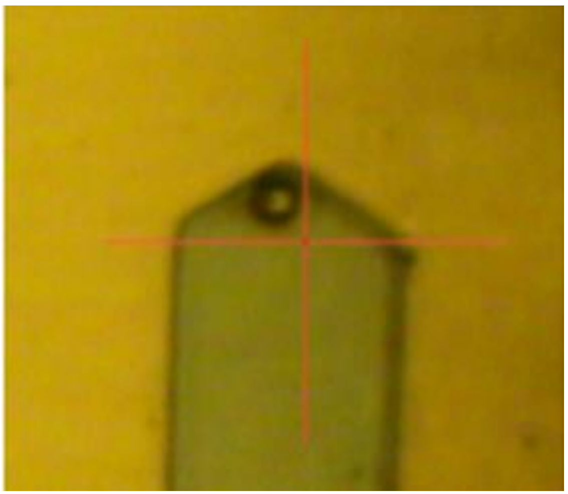
Method to Estimate Cleaning Efficiency

- W & SiN wafer pre-treatment method:
  - Cut 3 cm square cubic area wafer coupons
  - Apply the slurry (with or with out centrifuge) on the W & SiN wafer coupon surface and allow it to dry it overnight.
  - Put the wafer coupon in 100 mL of post-CMP formulation for 1, 5 or 10 minutes. (500 RPM @ 50^{o}C). Dry the coupon and analyze by SEM

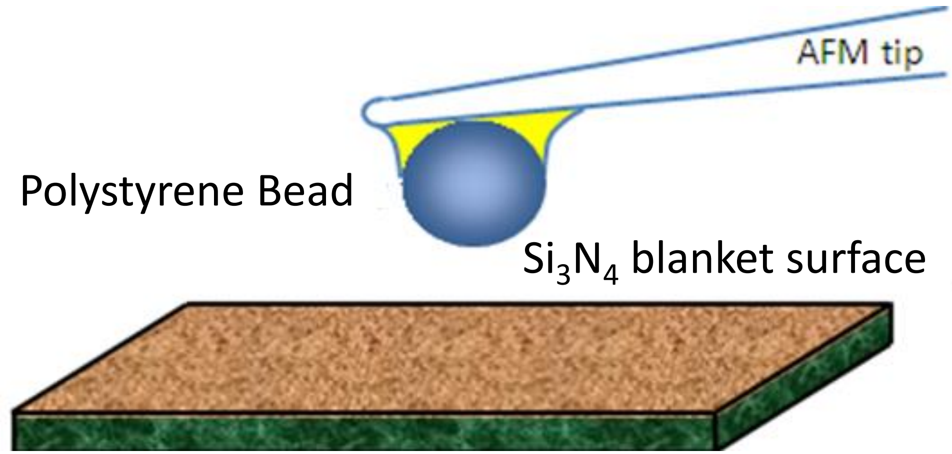


Atomic-force microscopy

Image of the cantilever mounted a bead



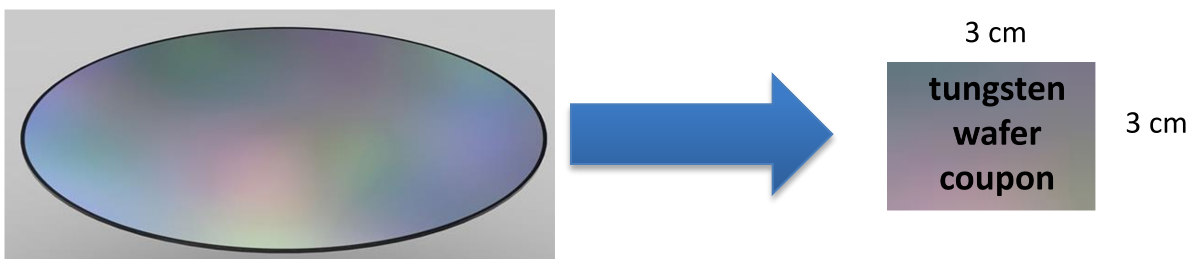
A schematic of adhesion measurement

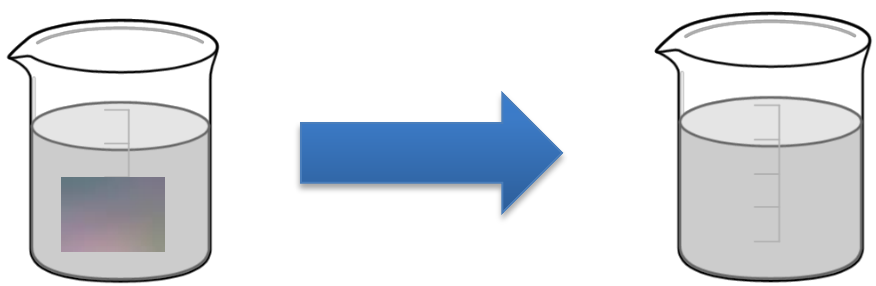


A technique using AFM (atomic force microscopy) was developed to measure the adhesion forces between colloidal silica particles (50 – 80 nm) and wafer surfaces in the cleaning solution. Additionally, by attaching a polystyrene bead (~5µm) to the AFM cantilever and measuring the force-distance curve to Si_3N_4, Cu and W wafers the adhesion force between polystyrene and the wafer substrate was obtained.

Tungsten compatibility analysis

- Pretreatment tungsten wafers
  - Cut 3 cm square cubic area tungsten wafer coupons
  - Immerse the coupon in 100 mL formulation for 10 minutes.
  - Measure the amount of tungsten dissolved in the formulation with ICP-MS

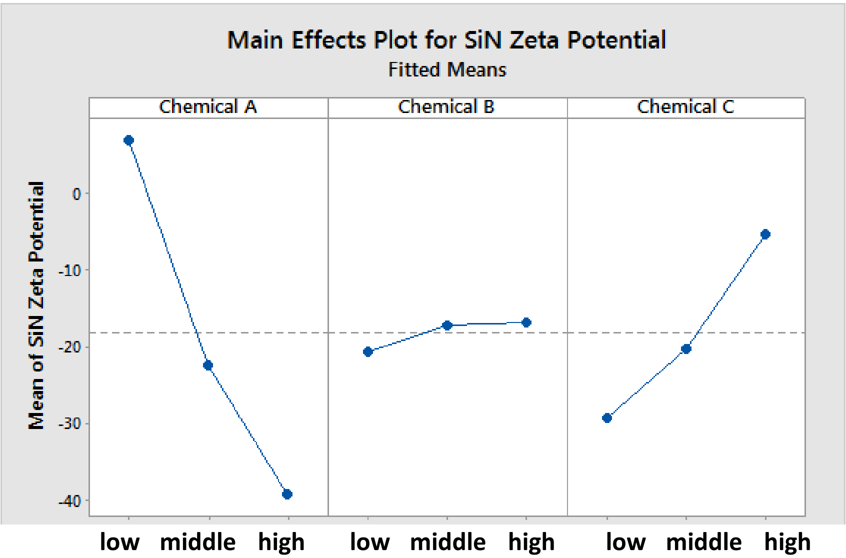


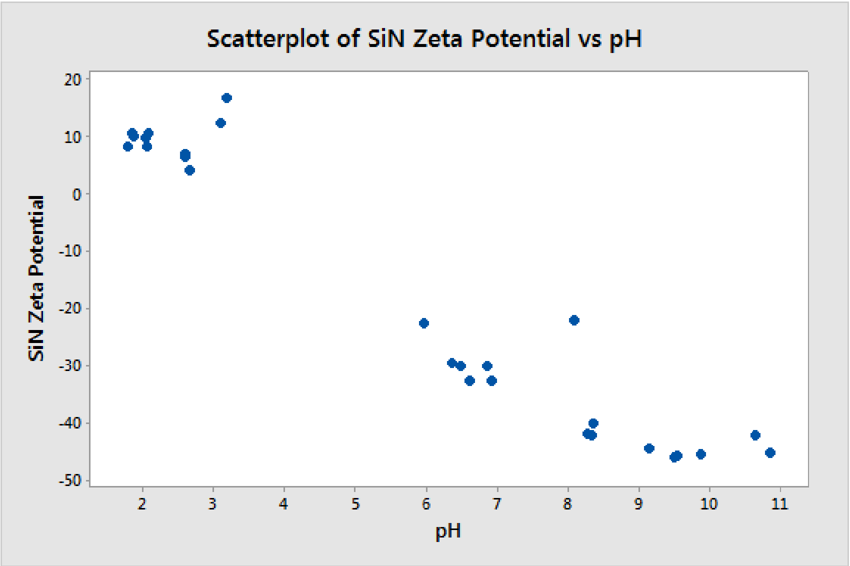


Immerse the tungsten coupon for 10 minutes in the cleaning solution

Remove the coupon and analyze the tungsten ion concentration by ICP-MS

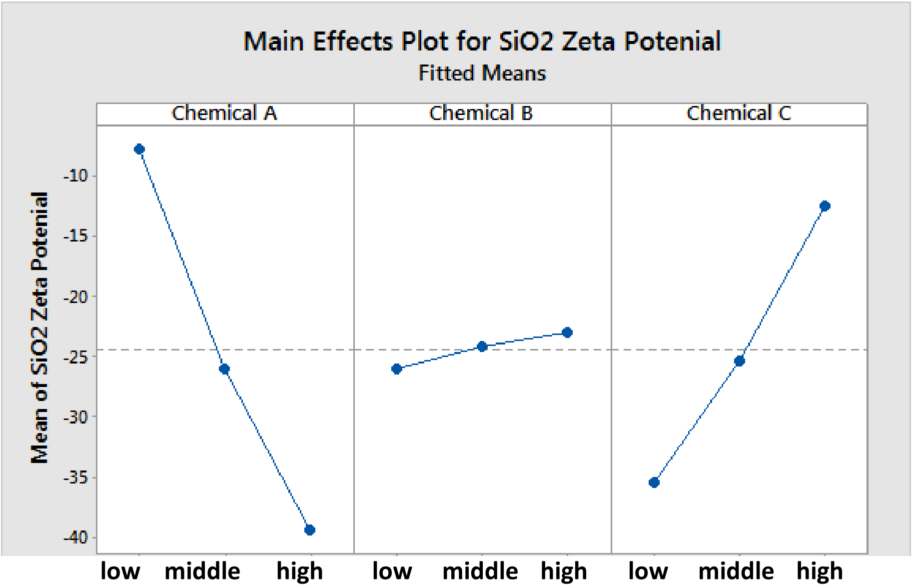
pH & zeta potential of Si_3N_4 relationship

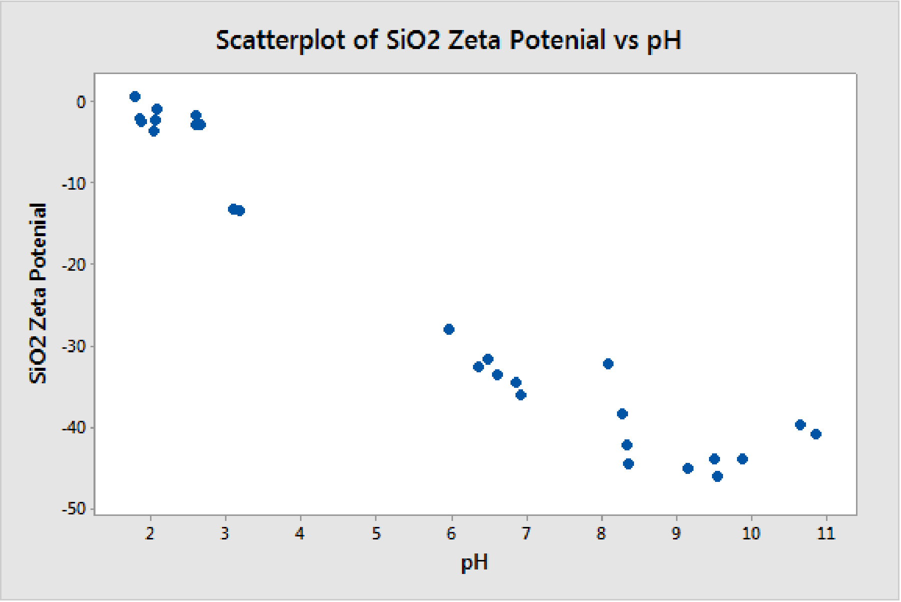




- **Chemical A** and **Chemical C** shifted the zeta potential of SiN_x. Increased levels of **Chemical A** raised the pH of the formulation and the zeta potential of SiN_x became more negative. **Chemical C** decreased the pH of the formulation as its concentration was increased and the zeta potential of SiN_x was increased.

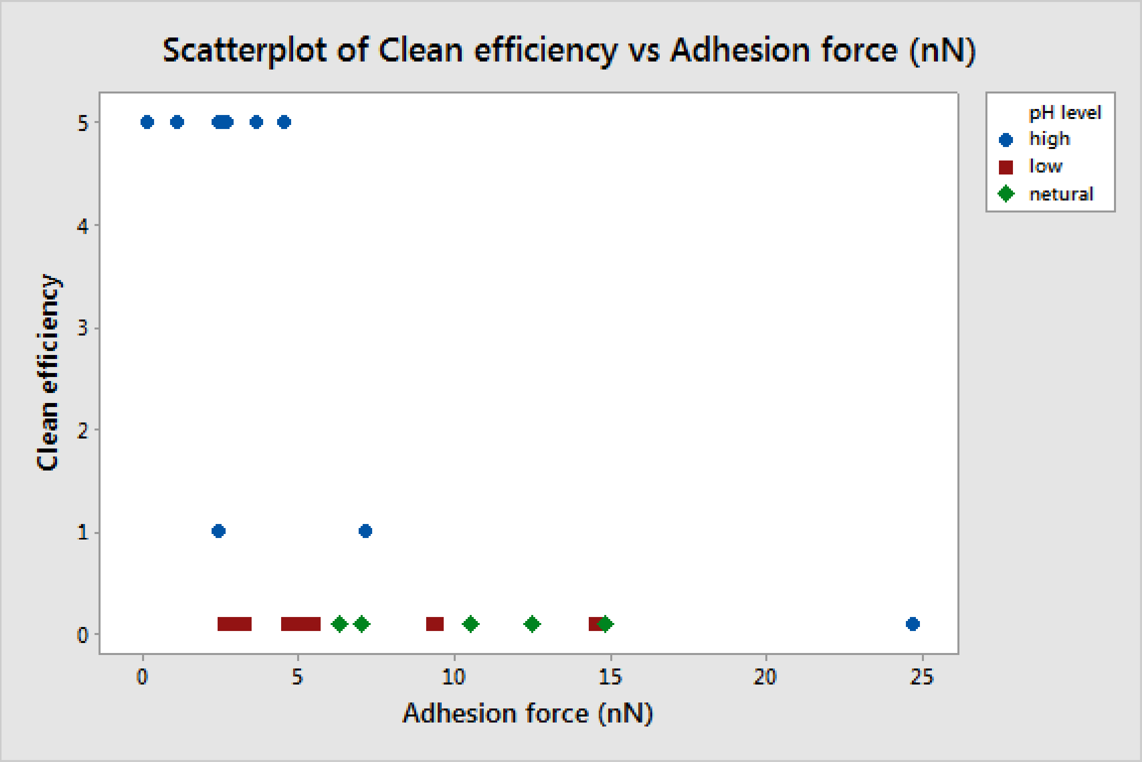
pH & zeta potential of SiO_2 relationship





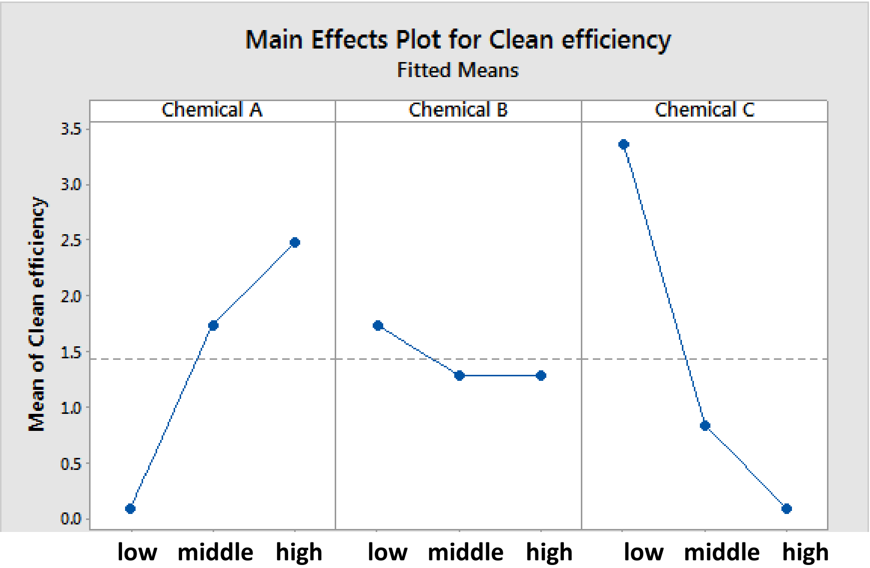
- **Chemical A** and **Chemical C** concentrations affected the zeta potential of SiO_2. Higher concentrations of **Chemical A** raised the pH and the zeta potential of SiO_2 became more negative. **Chemical C** had the reverse behavior and decreased the pH and increased the zeta potential of SiO_2.

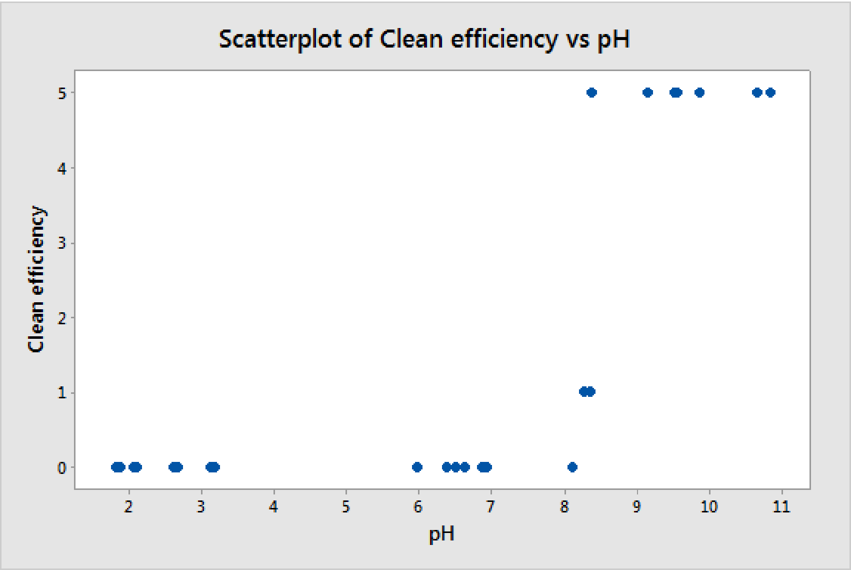
Adhesion Force & Clean Relationship on Si_3N_4

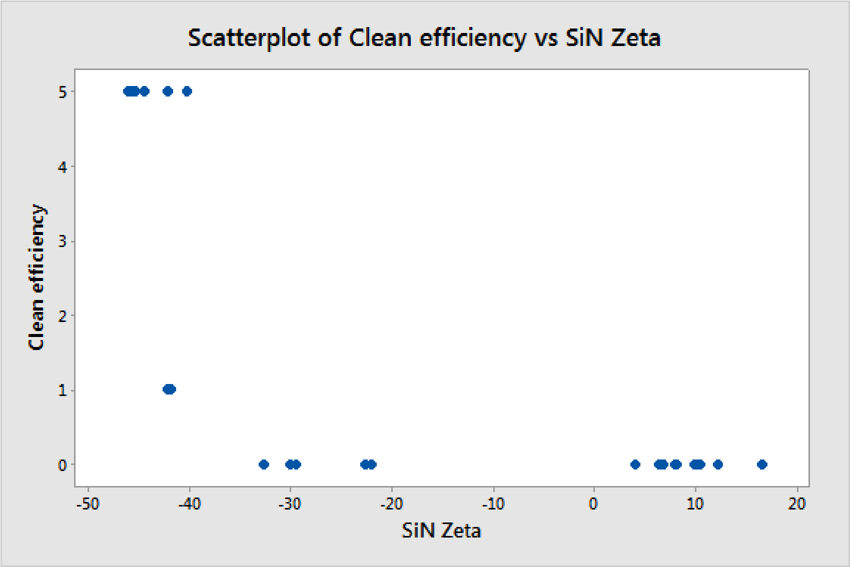


- The best cleaning efficiency was observed at high pH where the adhesion force between polystyrene and Si_3N_4 was reduced. Slurry residues would be more dissolved in an alkaline environment and the lower adhesion force will facilitate particle and organic residue removal.

pH & zeta potential relationship with clean efficiency on Si_3N_4

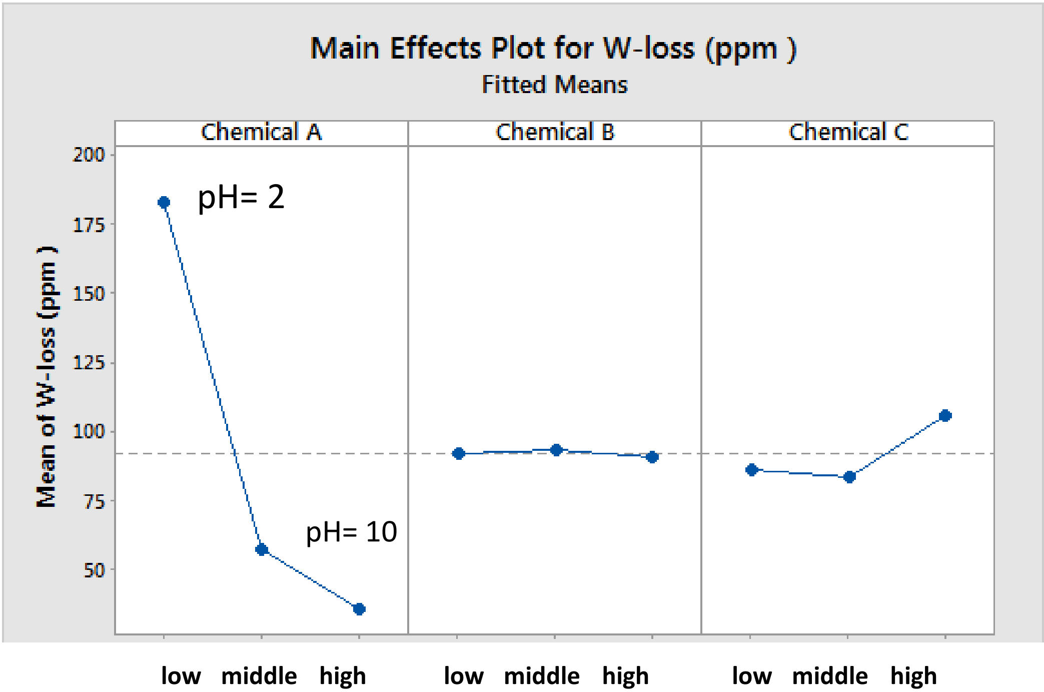






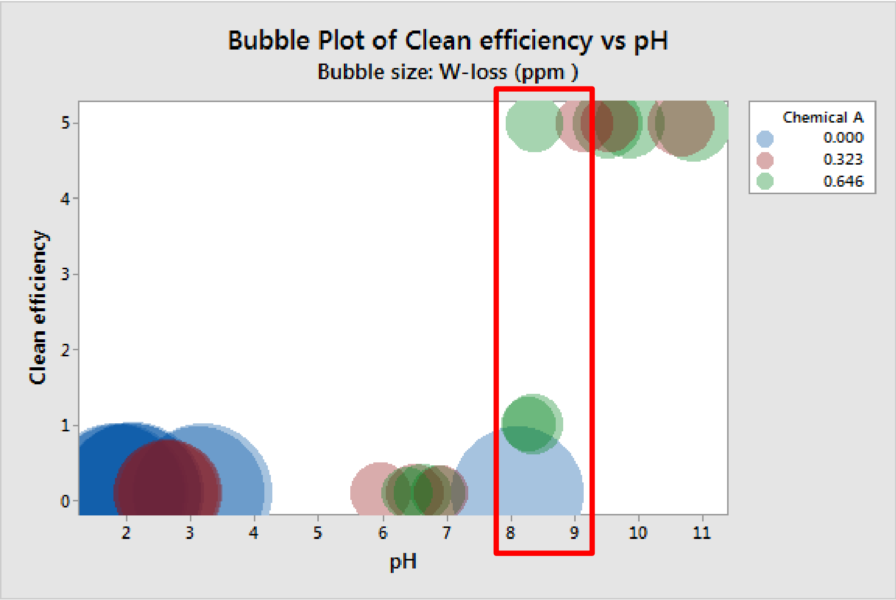
- From main effects plot, we found that increased amount of **Chemical A** would enhance clean efficiency but increased amount of **Chemical C** would decreased clean efficiency. The clean efficiency improvement came from pH effect or zeta potential effect because when we increased the amount of **Chemical A** the pH would increase at the same time.

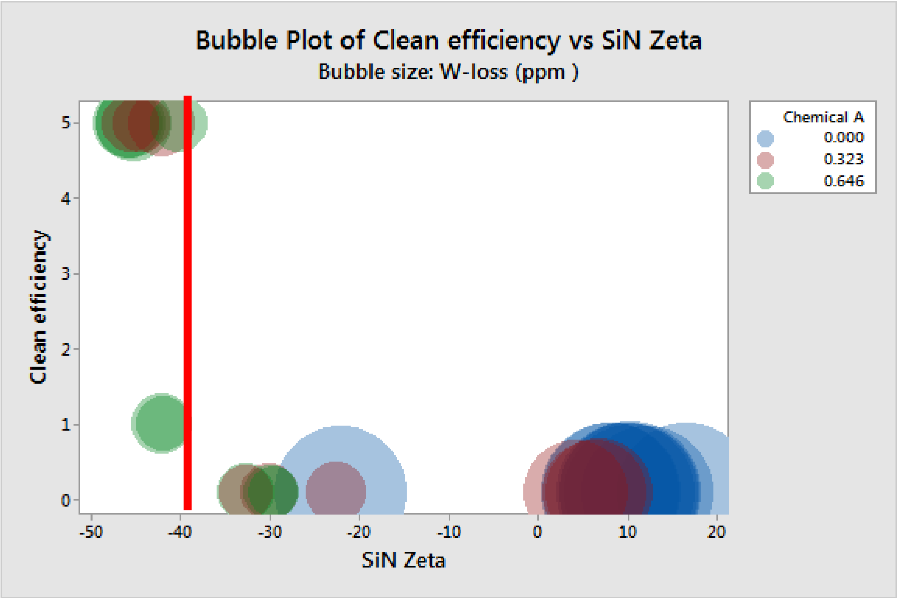
Tungsten compatibility improvement by added chemical A



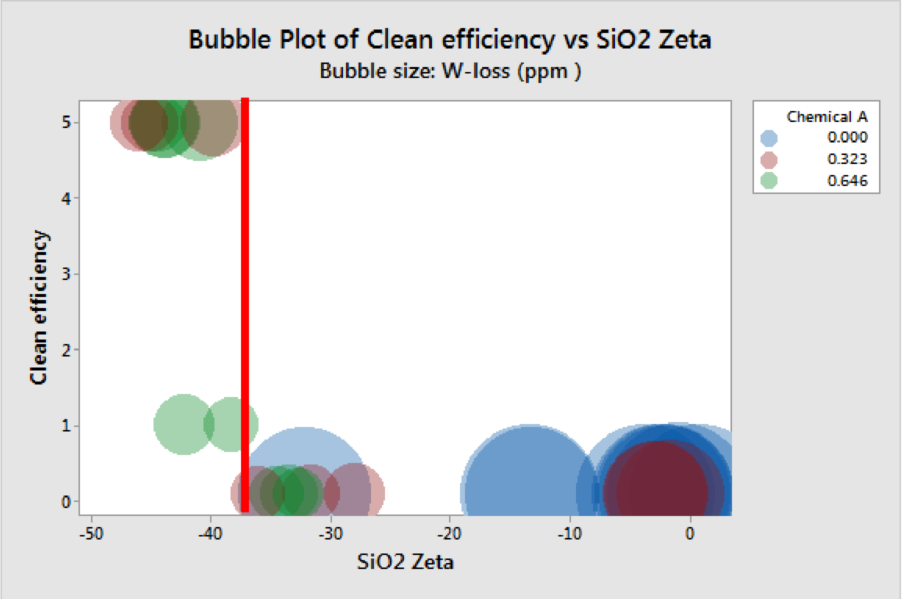
- Added **chemical A** could improve tungsten compatibility and reduce tungsten loss in the formulation. It is well known tungsten is easy to corrode in high pH region. However, **chemical A** showed good tungsten compatibility in the high pH region. When we added **chemical C** amount higher than middle level, it will increase tungsten loss.

Proposed clean mechanism on Si_3N_4





- We could find lower W-loss and better clean efficiency on pH 8 to 9. If zeta potential of SiN is less than -40 mV, it will showed better clean efficiency in the formulations. We also observe same trend on SiO_2 when zeta potential is less than -38 mV. Zeta potential effect maybe come from pH effect.



Summary

- In the high pH region, lower adhesion force between polystyrene and Si_3N_4 will result in better clean efficiency.
- **Chemical A** could show good tungsten compatibility in the high pH region.
- If the zeta potential of Si_3N_4 & SiO_2 is less than -40 mV, the formulations yielded better cleaning efficiency