Honeywell

WAFER THINNING MATERIALS WHITE PAPER

# Honeywell Silicon Polish Etchant II

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## OVERVIEW

Honeywell Electronic Materials has added Silicon Polish Etchant I, for polishing the backside of a wafer, to its extensive semiconductor processing product portfolio. Honeywell's world-class production facilities and techniques produce an etchant with excellent batch-to-batch product uniformity. This product uniformity results in consistent drum-to-drum and bottle-to-bottle wafer polishing and etching characteristics such as surface roughness, etch rate, and etch uniformity.

A stable etcher as well as a consistent etchant is needed to ensure a stable wafer backside etching process. Honeywell Electronic Materials, in collaboration with SEZ America, Inc., has completed designed experiments to investigate the effects of equipment parameters on wafer polishing and etching performance. The effects of process temperature, chuck rotational speed, etchant flow rate, as well as dispense profile on the silicon surface roughness, etch rate, and etch non-uniformity are presented. A SEZ 200mm Model 203 Spin-Processor etcher located at the SEZ America, Inc. research lab in Phoenix, AZ was employed for this study.

## DESIGNED EXPERIMENT

A reduced four-factor, three-level, Box-Behnken response surface employing 20 runs (and 20 wafers) was used. The etcher parameters (factors) and their settings are presented in Table I. Column one contains the etcher parameters that were varied. Columns two through four contain the high, middle, and low values respectively of the etcher parameter settings.

Table 1. Etcher Parameters and Their Settings

| | SETTING | | |
|---|---|---|---|
| ETCHER PARAMETER | High | Middle | Low |
| Temperature (ºC) | 28 | 25 | 22 |
| Chuck Speed (RPM) | 800 | 600 | 400 |
| Flow Rate (L/min.) | 2.0 | 1.8 | 1.6 |
| Dispense Profile (mm) | 80 | 75 | 70 |

The SEZ single-wafer spin-processor dispenses chemistry on to the surface of a wafer, which is rotating on a process chuck. Chuck rotation speed, chemical flow rate, temperature, and dispense profile (track of the chemical dispense nozzle relative to the speed of the track across the wafer) are all highly controlled parameters throughout processing to achieve specific etch characteristics on the wafer. A combination of these parameters dictates etch characteristics, such as etch rate, uniformity, and wrap-around on the bevel edge to the wafer front side.

The average silicon loss, ($\Delta$d), was determined by averaging the difference in wafer thickness at 29 locations on each 200mm wafer prior to and after etching. The silicon etch rate was calculated by dividing the average silicon loss by the etch time. The percent silicon etch non-uniformity, N%, was calculated by employing equation (1)

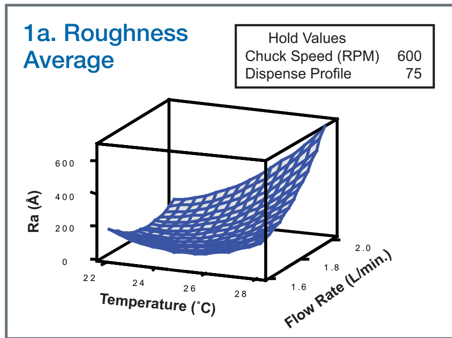
$$N\% = +/- 100\sigma/\Delta d \qquad (1)$$

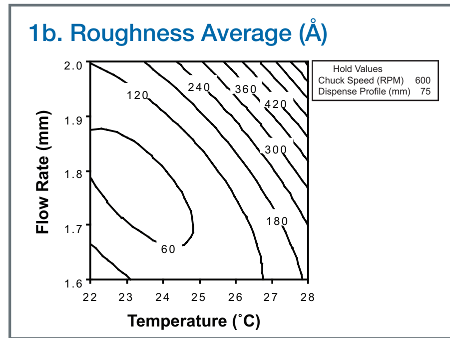
where $\sigma$ is the standard deviation of the etch measurements. If the wafer center etched faster than the wafer edge, N was assigned a positive value. If the wafer center etched slower than the wafer edge, N was assigned a negative value. The post-etch surface roughness average, Ra, of a wafer was determined by measuring the center of that wafer after etch using a KLA-Tencor P2 profilometer.

## POST ETCH SURFACE ROUGHNESS AVERAGE

Surface and contour plots of the post etch surface roughness average, Ra, of the Honeywell Silicon Polish Etchant II as a function of flow rate and temperature when the settings of the other tool parameters (chuck speed and dispense profile) are held at their middle settings are presented in figures 1a and 1b respectively (see page 2). A calculated minimum Ra of 50Å occurs at a temperature of 23.5ºC and a flow rate of 1.75 L/minute. Changing either the temperature or flow rate settings will increase the surface roughness. At low temperature, the surface roughness is low and the flow rate has little effect on the surface roughness. At high temperature surface roughness increases with increasing flow rate. For example, Ra increases from 190 to 660Å as the flow rate increases from 1.6 to 2.0 L/minute while the temperature is held constant at 28ºC. At high flow rates, Ra dramatically increases with increasing temperature. For example, Ra increases from approximately 120 to 660Å as the temperature increases from 22 to 28ºC while the flow rate is held constant at 2.0 L/minute. A high flow rate coupled with a high temperature will produce the roughest surface (i.e. highest Ra value).

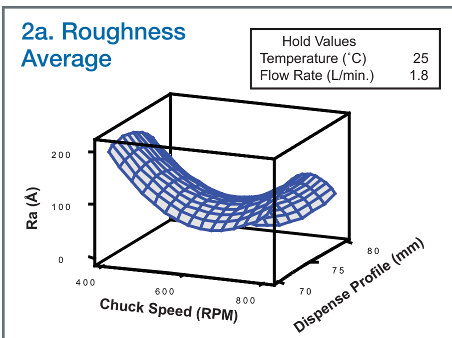
The chuck speed and dispense profile have a small effect on Ra. Surface and contour plots of Ra as a function of chuck speed and dispense profile when the settings of the other tool parameters (flow rate and temperature) are held at their middle settings are presented in figures 2a and 2b respectively (see page 2).

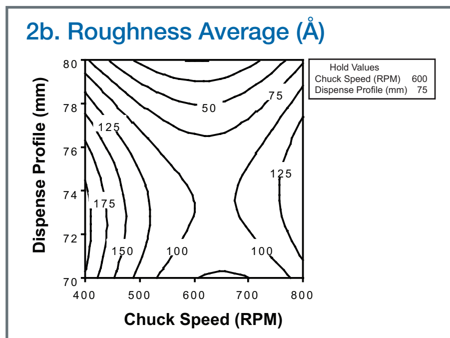



**Figures 1a and 1b.**

**Surface (1a) and contour (1b) plots of the post etch surface roughness average, Ra, of the Honeywell Silicon Polish Etchant II as a function of flow rate and temperature when the settings of the other tool parameters (chuck speed and dispense profile) are held at their middle settings.**




**Figures 2a and 2b.**

**Surface (2a) and contour (2b) plots of the post etch surface roughness average, Ra, of the Honeywell Silicon Polish Etchant II as a function of chuck speed and dispense profile when the settings of the other tool parameters (flow rate and temperature) are held at their middle settings.**

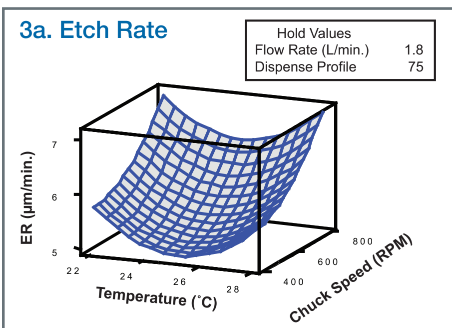
## Post Etch Surface Roughness Average, continued

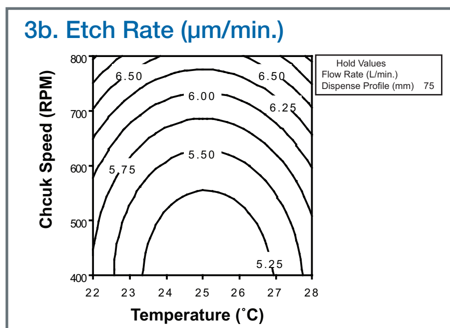
Ra approaches 0Å at a chuck speed of 600 RPM and a dispense profile of 80mm. Ra increases to 200Å as the chuck speed and dispense profile are lowered to 400 RPM and 70mm respectively.

## SILICON ETCH RATE

Surface and contour plots of the silicon etch rate of the Honeywell Silicon Polish Etchant II as a function of chuck speed and temperature when the settings of the other tool parameters (flow rate and dispense profile) are held at their middle settings are presented in figures 3a and 3b respectively. The silicon etch rate is primarily determined by the chuck rotational speed. The silicon etch rate, for example, increases from approximately 5.25 to 6.5 µm/minute as the chuck increases from 400 to 800 RPM while the temperature is held constant at 25ºC. The silicon etch rate is lowest at the middle temperature setting. The silicon etch rate, for example, decreases from 7.0 to 6.3 then increase again to 7.0 µm/minute as the temperature increases from 22 to 28ºC. while the chuck speed is held constant at 800 RPM.

The flow rate and dispense profile also have an effect on the silicon etch rate. Surface and contour plots of the silicon etch rate as a function of flow rate and dispense profile when the settings of the other tool parameters (chuck speed and temperature) are held at their middle settings are presented in figures 4a and 4b respectively (see page 3). A minimum value in the etch rate of 5.5 µm/minute occurs at a flow rate of 1.8 L/minute and a dispense profile of 75mm. Changing either the flow rate or dispense profile settings will increase the etch rate.




**Figures 3a and 3b.**

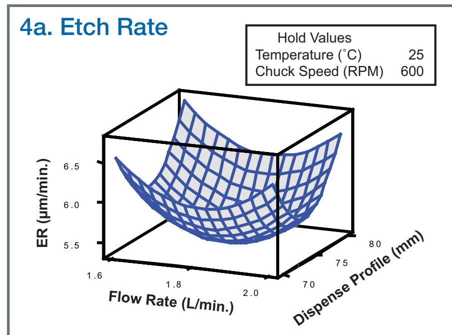
**Surface (3a) and contour (3b) plots of the silicon etch rate of the Honeywell Silicon Polish Etchant II as a function of chuck speed and temperature when the settings of the other tool parameters (flow rate and dispense profile) are held at their middle settings.**

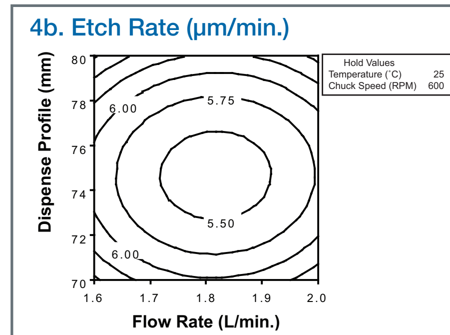
## SILICON ETCH NON-UNIFORMITY

Surface and contour plots of the silicon etch non-uniformity of the Honeywell Silicon Polish Etchant II as a function of chuck speed and flow rate when the settings of the other tool parameters (dispense profile and temperature) are held at their middle settings are presented in figures 5a and 5b respectively (see page 3). Low chuck speeds and high flow rates yield high non-uniformity values (i.e. an uneven etch). For example, a chuck speed of 400 RPM and a flow rate of 2.0 L/minute yield a non- uniformity of approximately 11 percent. On the other hand, high chuck speeds and low flow rates yield low non-uniformity values (i.e. an even etch). For example, a chuck speed of 800 RPM and a flow rate of 1.6 L/minute yield a non-uniformity of approximately 5.5 percent.

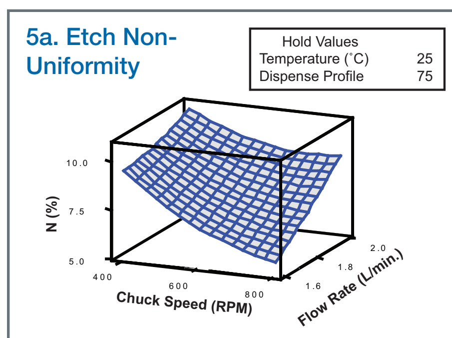
## Silicon Etch Non-Uniformity, continued

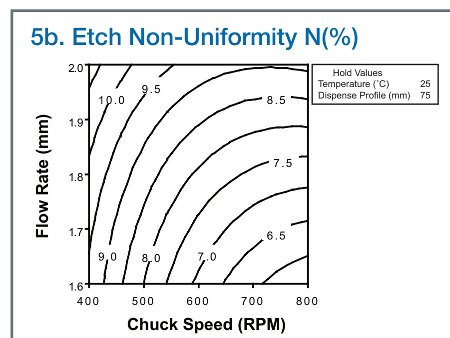
The dispense profile and temperature also have an effect on the silicon etch non-uniformity. Surface and contour plots of the etch non-uniformity as a function of dispense profile and temperature when the settings of the other tool parameters (chuck speed and flow rate) are held at their middle settings are presented in figures 6a and 6b respectively. A calculated maximum etch non-uniformity of 8.0 percent occurs at a temperature of 25.5ºC and a dispense profile of 74mm. Changing either the temperature or dispense profile settings will decrease the etch non-uniformity. A low temperature and large dispense profile will yield the lowest non-uniformity values (most uniform etch). For example a temperature of 22ºC and a dispense profile of 80mm results in an etch non-uniformity of 3.5 percent.



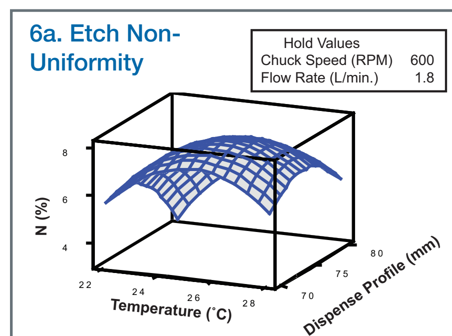



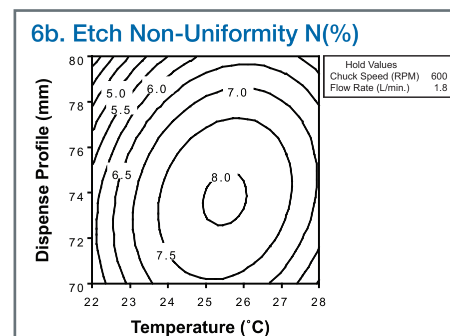

**Figures 4a and 4b.**
**Surface (4a) and contour (4b) plots of the silicon etch rate of the Honeywell Silicon Polish Etchant II as a function of flow rate and dispense profile when the settings of the other tool parameters (chuck speed and temperature) are held at their middle settings.**




**Figures 5a and 5b.**
**Surface (5a) and contour (5b) plots of the silicon etch non-uniformity of the Honeywell Silicon Polish Etchant II as a function of chuck speed and flow rate when the settings of the other tool parameters (dispense profile and temperature) are held at their middle settings.**




**Figures 6a and 6b.**
**Surface (6a) and contour (6b) plots of the silicon etch non-uniformity of the Honeywell Silicon Polish Etchant II as a function of dispense profile and temperature when the settings of the other tool parameters (chuck speed and flow rate) are held at their middle settings.**

## SUMMARY AND ACKNOWLEDGEMENTS

Honeywell is producing a Silicon Polish Etchant with excellent batch-to-batch product uniformity. A designed experiment study has been completed to investigate the effects of etcher parameters on wafer etching performance. This study has shown that the post etch surface roughness is a function primarily of the flow rate and temperature.

In addition, this study has shown that the silicon etch rate is a function primarily of the chuck rotational speed. The silicon etch rate increases with increasing chuck speed. The silicon etch non-uniformity is a function primarily of the chuck speed and flow rate. Increasing chuck speeds and decreasing flow rates yield decreasing etch non-uniformity (more uniform etches).

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