Honeywell

WAFER THINNING MATERIALS WHITE PAPER

# Honeywell Silicon Polish Etchant I

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## OVERVIEW

Honeywell Electronic Materials has added Silicon Polish Etchant I, for polishing the backside of a wafer, to its extensive semi-conductor 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)

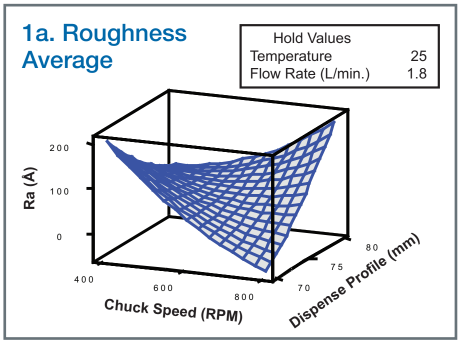
$$N\% = +/- 100\sigma/\Delta d \qquad (1)$$

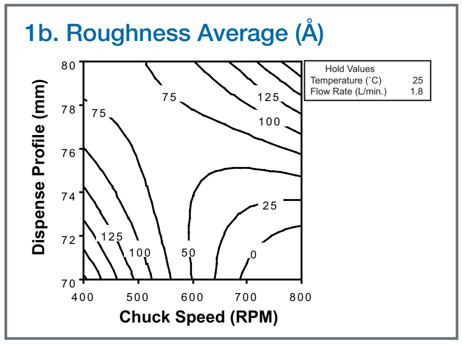
where $\sigma$ is the standard deviation of the etch measurements. If the wafer center etched faster than the wafer edge, N was assigned a positive value. If the wafer center etched slower than the wafer edge, N was assigned a negative value. The post-etch surface roughness average, Ra, of a wafer was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

## POST ETCH SURFACE ROUGHNESS AVERAGE

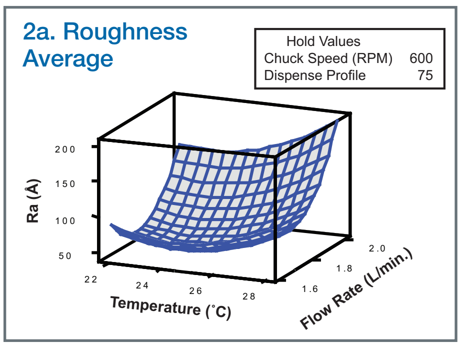
Surface and contour plots of the post etch surface roughness average, Ra, of the Honeywell Silicon Polish Etchant I as a function of chuck speed and dispense profile when the settings of the other tool parameters (flow rate and temperature) are held at their middle settings are presented in figures 1a and 1b respectively (see page 2). When the dispense profile is large, Ra increases with increasing chuck speed. For example, Ra increases from approximately 70 to 180Å as the chuck increases from 400 to 800 RPM while the dispense profile is held constant at 80mm. When the dispense profile is small, Ra decreases with increasing chuck rotational speed. Ra decreases from approximately 200 to 0Å as the chuck increases from 400 to 800 RPM while the dispense profile is held constant at 70mm. High chuck speed coupled with a small dispense profile will produce the smoothest surface (i.e. lowest Ra value). A high chuck speed coupled with a large dispense profile or a low chuck speed coupled with a small dispense profile will produce the roughest surface (i.e. highest Ra value).

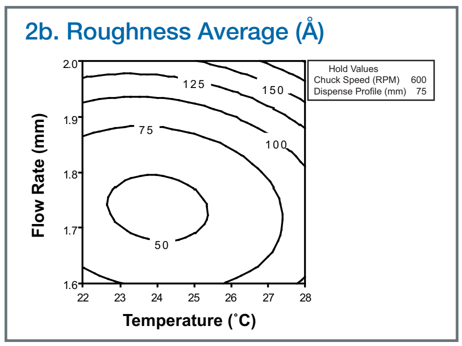
The flow rate and temperature also have an effect on Ra. Surface and contour plots of Ra as a function of flow rate and temperature when the settings of the other tool parameters (chuck speed and dispense profile) are held at their middle settings are presented in figures 2a and 2b respectively. A calculated minimum Ra of 50Å occurs at a temperature of 24ºC and a flow rate of 1.75 L/minute. Changing either the temperature or flow rate settings will increase the surface roughness.




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

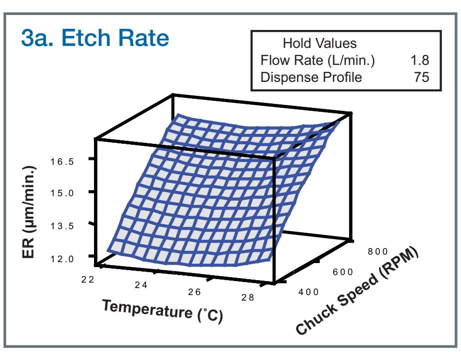


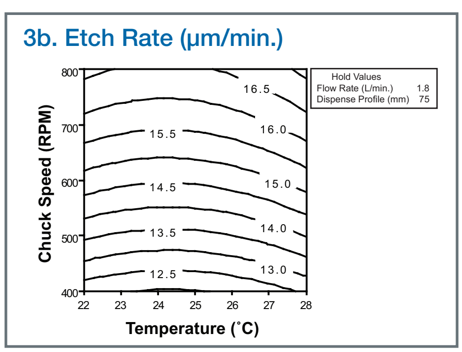




**Figures 2a and 2b.**
**Surface (2a) and contour (2b) plots of the post etch surface roughness average, Ra, of the Honeywell Silicon Polish Etchant I as a function of flow rate and temperature when the settings of the other tool parameters (chuck speed and dispense profile) are held at their middle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

## SILICON ETCH RATE

Surface and contour plots of the silicon etch rate of the Honeywell Silicon Polish Etchant I 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.




**Figures 3a and 3b.**
**Surface (3a) and contour (3b) plots of the silicon etch rate of the Honeywell Silicon Polish Etchant I 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.**

The silicon etch rate is primarily determined by the chuck rotational speed. The silicon etch rate, for example, increases from approximately 12 to 16.5 µm/minute as the chuck increases from 400 to 800 RPM while the temperature is held constant at 25ºC. The etchant temperature has less of an effect on the silicon etch rate. The silicon etch rate, for example, only increases from 16.5 to 17 µm/minute as the temperature increases from 22 to 28ºC. while the chuck speed is held constant at 800 RPM.

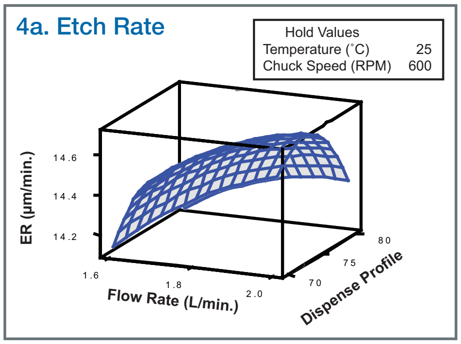
The flow rate and dispense profile have a small effect on the silicon etch rate. Surface and contour plots of the silicon etch rate as a function of flow rate and dispense profile when the settings of the other tool parameters (chuck speed and temperature) are held at their middle settings are presented in figures 4a and 4b respectively (see page 3). The etch rate, for example, increases from approximately 14.4 to 14.7 µm/minute as the flow rate increases from 1.6 to 2.0 L/minute while the dispense profile is held constant at 75mm. The etch rate barely changes from 14.4 to 14.3 µm/minute as the dispense profile increases from 70 to 80mm. while the flow rate is held constant at 1.8 L/minute.

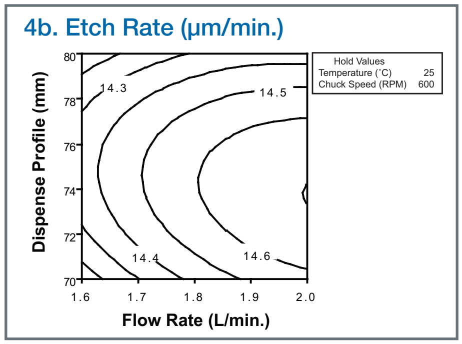
## SILICON ETCH NON-UNIFORMITY

Surface and contour plots of the silicon etch non-uniformity of the Honeywell Silicon Polish Etchant I 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 5a and 5b respectively. The silicon etch non-uniformity is primarily determined by the chuck rotational speed. The silicon etch non-uniformity, for example, decreases from approximately +8 (center fast) to +3 (center fast) percent as the chuck speed increases from 400 to 800 RPM while the dispense profile is held constant at 75mm. The dispense profile has little effect on the silicon etch non-uniformity. The silicon etch non-uniformity remains approximately constant at +4.5 (center fast) percent as

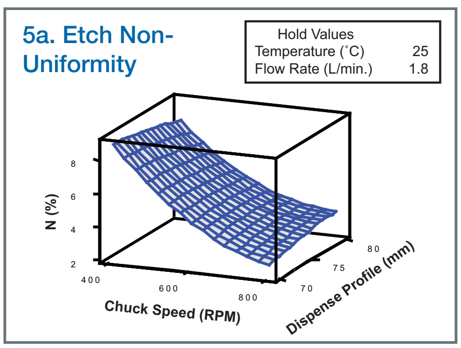
## Silicon Etch Non-Uniformity, continued

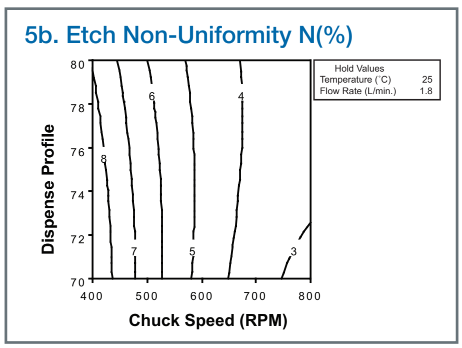
the dispense profile increases from 70 to 80mm. while the chuck speed is held constant at 600 RPM. The flow rate and temperature have a small effect on the silicon etch non-uniformity. Surface and contour plots of the etch non-uniformity as a function of flow rate and temperature when the settings of the other tool parameters (chuck speed and dispense profile) are held at their middle settings are presented in figures 6a and 6b respectively. A calculated minimum of 4.8% in the etch non-uniformity occurs at a temperature of 24.5ºC and a flow rate of 1.75 L/minute. Changing either the temperature or flow rate settings will increase the etch non-uniformity.



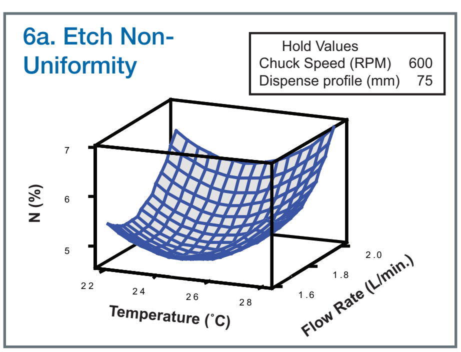



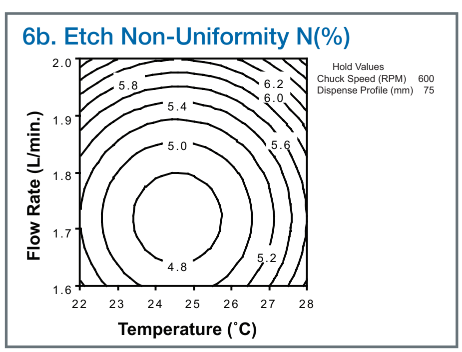

**Figures 4a and 4b.**
**Surface (4a) and contour (4b) plots of the silicon etch rate of the Honeywell Silicon Polish Etchant I as a function of flow rate and dispense profile when the settings of the other tool parameters (chuck speed and temperature) are held at their middle settings.**




**Figures 5a and 5b.**
**Surface (5a) and contour (5b) plots of the silicon etch non-uniformity of the Honeywell Silicon Polish Etchant I 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.**




**Figures 6a and 6b.**
**Surface (6a) and contour (6b) plots of the silicon etch non-uniformity of the Honeywell Silicon Polish Etchant I 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.**

## 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 chuck speed and dispense profile. When the dispense profile is small, surface roughness decreases with increasing chuck speed. When the dispense profile is large, surface roughness increase with increasing chuck speed.

In addition, this study has shown that the silicon etch rate as well as etch non-uniformity are functions primarily of the chuck rotational speed. The silicon etch rate increases and the etch non-uniformity decreases (i.e. the etch becomes more uniform) with increasing chuck speed.

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