Fundamental Characterizations of Diamond Disc, Pad, and Retaining Ring Wear in Chemical Mechanical Planarization Processes

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Outline

Introduction

Diamond disc wear characterization
  ➢ Active diamond characterization
  ➢ Aggressive diamond characterization
  ➢ Diamond wear characterization

Pad wear characterization
  ➢ Pad macro wear characterization
  ➢ Pad surface micro wear characterization

Retaining ring wear characterization

Summary
During pad conditioning, the interactions between the pad and diamond disc result in not only pad wear but also diamond disc wear.

During wafer polishing, the interactions between the pad and retaining ring result in not only pad wear but also retaining ring wear.
Diamond Disc Wear Characterization

- Active diamond characterization
- Aggressive diamond characterization
- Diamond wear characterization
Identify Active Diamonds - Short Draw Test


Conditioner is pulled only about ¼”.

Scratch origins are marked.
• Faint scratches
• Partial scratches

MMC TRD 100 grit
8.0 lbf
109 active diamonds
Identify Aggressive Diamonds - Long Draw Test

Polycarbonate surface is profiled

Conditioner is pulled more than one diameter.

Sometimes color is used for contrast
The ten most aggressive diamonds account for more than 50% of pad cut rate during conditioning.
Locate Aggressive Diamonds
Diamond Wear

New aggressive diamond

Same diamond after wear test

Normally there is no bulk wear on the diamond and micro wear occurs on the cutting edges of the diamond.
Pad Wear Characterization

- Pad macro wear characterization
- Pad surface micro wear characterization
Optimization of the pad conditioning sweep schedule on a rotary polishing tool can significantly improve the pad macro wear uniformity.
Pad Surface Interferometry Analysis

Profilometry analysis: surface roughness (top pad asperities to pad valleys), no consistent correlation with material removal rates.

Interferometry analysis: surface abruptness (top 20 - 30 µm pad asperities), closely correlated with material removal rates.
**Effect of Pad Conditioning**

Conditioned by Disc A

Conditioned by Disc B

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Disc A &gt; Disc B</th>
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<tbody>
<tr>
<td>Disc aggressiveness</td>
<td>A &gt; B</td>
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<tr>
<td>Coefficient of friction</td>
<td>A &gt; B</td>
</tr>
<tr>
<td>Variance of shear force</td>
<td>A &gt; B</td>
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<tr>
<td>Pad surface abruptness</td>
<td>A &gt; B</td>
</tr>
<tr>
<td>ILD removal rate</td>
<td>A &gt; B</td>
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</tbody>
</table>
Pad Surface Contact Area Measurement

Laser Confocal Microscopy

Zeiss LSM 510 Meta NLO
Plan-Neoflaur 10x/0.3 objective
488 nm wavelength laser
Pad Surface Contact Area Image
Pad Surface Contact Area Analysis

Pad contact area histogram

Pad contact area vs. Pressure
Effect of Pad Conditioning

The ratio of the contacting summit density to the contact area fraction is more important than either measured separately since the ratio determines the mean real contact pressure.
Retaining Ring Wear Characterization

Conventional methods:

- **Micrometry**
  - Long wear time
  - May introduce gross measurement error

- **Weight Loss**
  - Long wear time
  - May introduce gross measurement error
  - Cannot provide local wear rate

Advanced method:

- **Interferometry**
  - Short wear time
  - Provide accurate local wear rate
Retaining Ring Design and Wear Characterization

Several shallow trenches (1.5 mm in diameter and 0.2 mm in depth) were precision-machined into the land areas of each ring.

Design – 1  Design – 2

Trench interferometry image before wear test  Trench interferometry image after 4-hour wear test
Retaining Ring Wear Rate

Pre and post interferometry results from the micro-machined trenches indicate the following wear rates:

- PPS - 1 ring: 28.2 µm/hour
- PEEK - 1 ring: 24.0 µm/hour
- PEEK - 2 ring: 23.5 µm/hour

This indicates that the retaining ring material, not design, is the main factor influencing the wear rate.

Micrometry results (taken from areas adjacent to the micro-machined trenches) indicate a difference of ±13 percent compared to interferometry results.
COF and Pad Temperature

The PEEK rings achieve better lubricity and COF stability than the PPS ring.

Higher temperatures associated with the PPS ring can cause higher material removal rates, thus indicating that thermal effects need to be taken into account when qualifying rings made of new materials.
The PEEK – 2 ring achieves a narrower pad surface height distribution than the PPS – 1 and PEEK – 1 rings, suggesting that the slot design and or the edge rounding plays significant roles in shaping the pad micro texture.
Summary

The method for active and aggressive diamond characterization is introduced. Normally there is no bulk wear on diamonds and wear mainly occurs on the cutting edges of the active diamonds.

An optimized conditioning sweep schedule can generate a much more uniform pad thickness profile.

For pad surface micro wear characterization, confocal microscopy analysis is used to analyze pad surface contact area. Interferometry analysis is used to establish pad surface height probability density functions and extract pad surface abruptness.

Interferometry analysis is used to characterize retaining ring wear, which not only allows retaining rings to be subjected to significantly shorter than usual wear time, but also provides more accurate estimate of local wear rates than conventional micrometry or weight loss measurements.