Preparation and Evaluation of Hydrophilic Fixed Abrasive Pad

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\textbf{Abstract.} The swelling ratio and the pencil hardness of pad were introduced to evaluate the properties of hydrophilic fixed abrasive (FA) pad. The effect of pad composition on its swelling ratio and pencil hardness was studied. Results show that the swelling ratio increases with the rise of content of Trimethylopropane Triacrylate (TMPTA) and Urethane Acrylate (PUA) and the pad gets harder while there is more TMPTA and less PUA. Results also show that a low swelling ratio corresponds to a high material removal rate (MRR), and a low wet pencil hardness to a low surface roughness in each group.

\textbf{Introduction}

The bonding strength between the upper layer and the matrix of hydrophilic fixed abrasive (FA) pad becomes weaker as a result of its swelling in the process of polishing. It is easily removed during the relative movement between pad and work-piece, which enable the pad to own the self-conditioning characteristics. Hydrophilic bonders were adopted to prepare a FA Pad by J.Y. Choi [1]. And a very smooth surface with an average surface roughness of several nanometers was obtained when it was used to polish an injecting plastics mould. A long run stable polishing was reached by H. Kim using hydrophilic FA Pad containing alumina abrasives [2]. It was found that MRR was sensitive to the wafer’s profile rather than the material itself by a joint research of 3M and Applied Materials [3]. Such defects as dishing and erosion dropped a lot.

When FA pad applied to copper chemical mechanical polishing (CMP), the step height was reduced to 20nm [4]. The dishing happening in conventional CMP with silica slurry was solved by J. Gagliardi and A. Romer by using FA pad [5]. A comparison between polishing with an FA Pad and a high selective slurry was conducted by Rodel [6].

A mold for manufacturing FA pad was fabricated by C.R. Keppeler [7]. Reference 1 also introduced a new method to prepare FA pads. Material removal mechanisms with FA CMP were presented by B. Lee and C.P. Sukam [8, 9].

The aims of this work are to analyze the effect of pad composition on its properties and the relationship between pad properties and its polishing behavior.

\textbf{Experimental}

The preparation flow of FA pad was illustrated in Fig 1. Diamond powders with an average size of 5 microns were chosen as the abrasives. An orthogonal design table L\textsubscript{16} (4\textsuperscript{5}) was employed to study the influence of pad composition on its swelling ratio and pencil hardness. TMPTA and PUA were chosen as the influencing factors and table 1 listed the levels of tested factors. Polyethylene Glycol Diacrylate (PEGDA) and Ethoxylated Trimethylopropane Triacrylate (EO15-TMPTA) constituted the left content. A mixed photo initiator was added to initiate the polymerization reaction. UV curing of the printed pad was conducted on F600S (Fusion UV System, Inc). The swelling ratio was calculated from the difference of pad mass between before and after swelling in a DI water for 30 Mins, while the pencil hardness was marked from -6 (the softest) to 6 (the hardest). All K9 optical glasses were lapped on a lapping machine PHL-350 for 10 Mins. The ADE MicroXAM 3D profiler was used to measure the surface roughness of polished glasses.
Results and Discussion

Effect of Pad Content on Its Properties. Usually, the polymer network expands because of the permeation of water when the pad contacts with water, which causes the decrease of bonding strength between the surface and the subsurface layers of the pad and the pencil hardness. The swelling ratio of pad decreases slightly with the increase of the content of PUA (see Fig.2). Both the dry pencil hardness and the wet one also decrease. There are three active functional groups for TMPTA. The density of functional groups and the crosslink density improve while more TMPTA added. Fig.3 exhibits that the swelling ratio dropped more sharply compared with PUA. The curve of pencil hardness vs. content of TMPTA rises, while that of PUA drops.

![Fig.2 Effect of Content of PUA on pad swelling ratio (a) and pad pencil hardness (b)](image-url)
Polishing Characteristics of FA Pad. Eight formulas were chosen and divided into three groups (listed in Table 2). The swelling ratio is almost the same and the wet pencil hardness changes a lot in each group.

Table 2  Groups of pad

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pad No.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Swelling ratio /%</td>
<td>2.10</td>
<td>2.13</td>
<td>2.48</td>
<td>2.67</td>
<td>2.58</td>
<td>3.27</td>
<td>3.26</td>
<td>3.34</td>
</tr>
<tr>
<td>Wet pencil hardness</td>
<td>-2</td>
<td>-5</td>
<td>-2</td>
<td>-3</td>
<td>-5</td>
<td>-3</td>
<td>-4</td>
<td>-6</td>
</tr>
</tbody>
</table>

An abrasive-free slurry containing some surfactants which were helpful to the wetting of the pad was adopted as a lubricant. The MRR and the surface roughness of polished glasses are exhibited in Fig.4 and 5. Generally, the MRR decreases obviously with the increase of the swelling ratio. There is only a little difference in the swelling ratio among formulas in each group. Maybe the error gives rise to the abnormal change in group 2. The relationship between MRR and wet pencil hardness is more complicated. There isn’t a general rule. But in each group, it is found that the MRR increases with the wet pencil hardness.

Fig.3 Effect of Content of TMPTA on pad swelling ratio (a) and pad pencil hardness (b)

Fig.4 Material removal rate vs. pad swelling ratio (a) and pad wet pencil hardness (b)

The rule of average roughness (Sa) of polished glasses is much more complicated. A higher swelling ratio leads to a quicker removal of the upper layer of pad during polishing and a lower protrusion height in pad. So, a lower Sa is obtained in group 1 and group 3. With the increase of wet pencil hardness, a pad owns better capability to support diamond abrasives, which results in a rougher surface. Owing to a short polishing time and a rough initial surface, a higher MRR is critical to lower its surface roughness. Pad 2 and pad 5 share the same wet pencil hardness, but the former has a higher RR. As a result, the glass polished with pad 2 has a lower surface roughness (Sa 124nm), while the one polished with pad 5 has a higher surface roughness (Sa 360nm).
Fig.5 Average roughness of polished glasses vs. pad swelling ratio (a) and pad wet pencil hardness (b)

Conclusions

1. The rise of content of TMPTA leads to the drop of swelling ratio and the increase of the pencil hardness, while the rise of content of PUA results in the drop of both swelling ratio and pencil hardness.

2. The pad swelling ratio and wet pencil hardness exert a great influence on the MRR and the surface roughness of polished glasses. A low swelling ratio is helpful to improve MRR, and a low wet pencil hardness corresponds to a low surface roughness.

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References


