Critical Feature Size of Polishing Pad and Its Performance

Mary McGahay[1], Gooyoun Kim[1], Sunghoon Lee[1], Hanchul Cho[2], and Hyongjae Kim[2]
[1] SMART Pad, Clifton Park, NY, USA
[2] KITECH, Dongnam Division, Precision Mechanical Process and Control R&D group, Principal Researcher, Busan, Republic of Korea

INTRODUCTION

As the critical dimension in semiconductor chips continues to decrease, more precise planarization in chemical-mechanical planarization (CMP) is required. At the same time, post-CMP scratch level, within-chip uniformity, and within-wafer uniformity must not be sacrificed. In addition, due to the recent shortage of chips, the high demand on chips, and increased number of CMP processes per chip, there are massive opportunities for CMP consumables. To meet the needs of advancing technology, SMART Pad has developed a novel conditioning-free polishing pad patterned with micro-features. While the primary mode of contact for conventional pads is point contact, meaning that the real contact area is about 1% and the real contact pressure is 100 times higher than the recipe, SMART Pad employs surface area contact between the micro-features and the wafer. This increase in real contact area results in a decrease in real contact pressure at the pad-wafer interface, leading to an increase in removal rate, a decrease in slurry consumption, an increase in planarization, and a decrease in scratch defects. In this work, the contact area and contact length of pad design and their effects on polishing rate are examined for features of various shapes. It is found that with increasing real contact area and real contact length, the removal rate increases.

BACKGROUND

The CMP process has long been an essential part of ultra large scale integration (ULSI) manufacturing. However, one reoccurring challenge in CMP processes is sustaining a stable polishing pad surface. The polishing rate is proportional to the surface roughness of the pad. While conventional pads are often resurfaced using a diamond conditioner, numerous factors such as the size and distribution of the diamond particles, pressure, conditioning method, and the stability of the conditioning tool govern the conditioning results, make it difficult to consistently maintain the roughness of the polishing pad. Variation in surface roughness may cause scratch defects and deteriorate uniformity.

SMART Pad has been working on an alternative polishing pad surface technology. Instead of a random, porous surface typically found on a conventional pad that requires conditioning to maintain the surface roughness, these novel, conditioning-free polishing pads employ a micro-feature design. This comparison is shown in Figure 1. The patterned surface changes the pad-wafer contact from point contact to surface area contact, reducing the pressure at the pad-wafer interface.

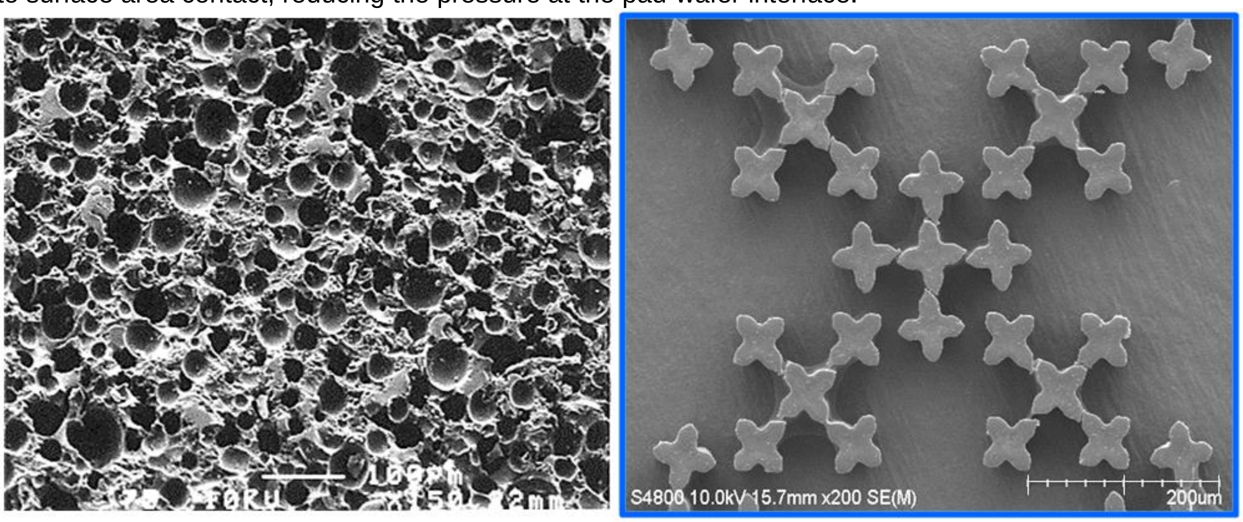

Figure 1: Conventional polishing pad surface (left) and SMART Pad surface (right)

In order to better understand how these features affect polishing performance, several patterns were designed with various shapes and sizes. Two key characteristics examined were the real contact area (RCA) and the real contact length (RCL). The RCA is defined as the ratio between feature area and total area. For example, using the exemplary pattern in Figure 2, the RCA would be S_1^2/S_2^2. It is predicted that with increasing RCA, the removal rate would decrease because of a decrease in pressure and the pad-wafer interface. However, this increase in RCA (and decrease in pressure) would also lead to a decrease in scratch defects and increase in planarization and wafer-level uniformity. RCL is the perimeter divided by the total area. Using Figure 2 once again, the RCL is $4S_1/S_2^2$. With higher RCL, it is believed that the removal rate will also increase because the probability of the slurry moving through the wafer and pad features increases, also increasing the amount of active slurry particles.

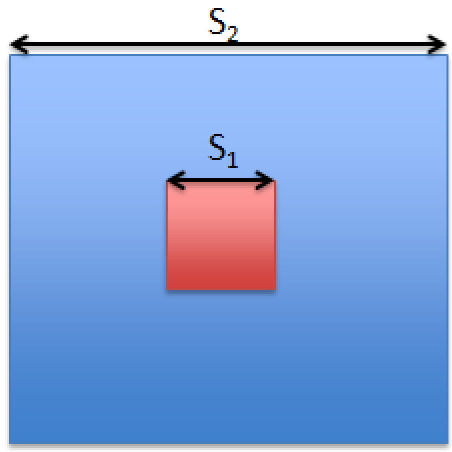

Figure 2: Example of microfeature pattern to demonstrate RCA and RCL

While the feature size can be adjusted to change the values of RCA and RCL, these parameters are also impacted by array distance. This is demonstrated in Figure 3. While the feature size remains the same for both patterns, the pattern on the right has a higher RCA and RCL because the array distance is shorter than the pattern on the left.

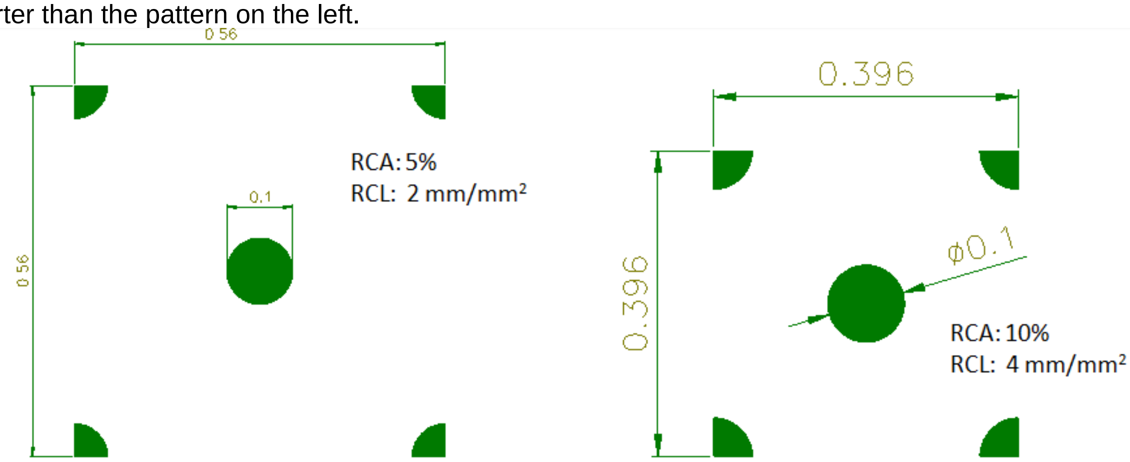

Figure 3: Different values of RCA and RCL for same feature size

EXPERIMENTAL

Micro-feature patterns of various sizes were created. The shapes used were circle, square, square-circle, triangle, and ellipses. Examples of these shape patterns are shown in Figure 4. The patterns are ranging in dimension, RCA, and RCL. A summary of the samples is listed in the table in Figure 5. For these tests, 8-inch blanket TEOS wafers were used. Polishing was done using a G & P Poli 500 machine with TSO-12 (Fumed Silica) slurry at a flow of 200 ml/min. The pressure during polishing was either 150 or 300 g/cm^2 and the velocity was 61 rpm.

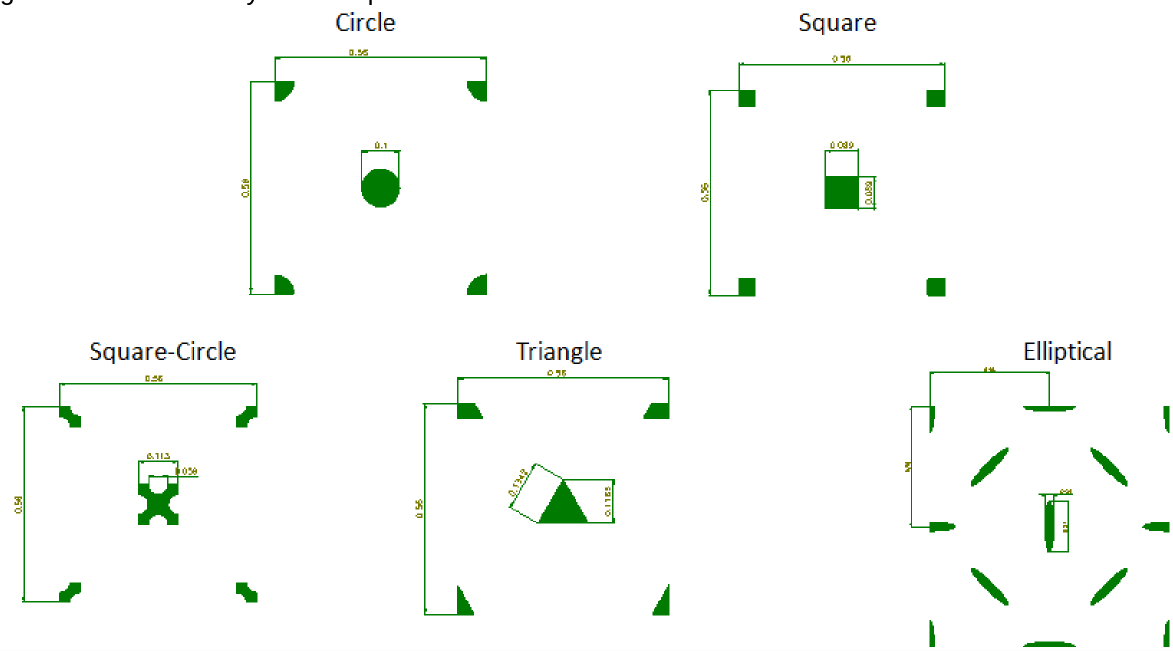

Figure 4: Example micro-feature patterns for the different shapes used in the designs

	RCA(%)	RCL(mm/mm^2)
0.95x0.05 rectangle	2.28	0.96
0.95x0.05 rectangle	10.96	4.24
0.02x0.02x5 square	2.89	5.79
100μm circle 5%	5.01	2
100μm circle 10%	10.02	4
100μm ellipse 5%	4.81	3.38
100μm ellipse 10%	9.62	6.32
100μm sq-cir 5%	5	3.7
100μm sq-cir 10%	10	7.4
50 μm circle 10%	10	8
50 μm circle 30%	30	24
100μm circle 10%	10	4
100μm circle 30%	30	12

Figure 5: Summary of micro-feature designs

DISCUSSION

Figure 6 shows the measure removal rate versus RCA for differently shaped micro-feature patterns. The dimension of the shape was kept constant for each shape. All patterns show an increase in removal rate with increasing RCA. Originally, it was thought that since increasing the contact area decreases the pressure, the removal rate would decrease.

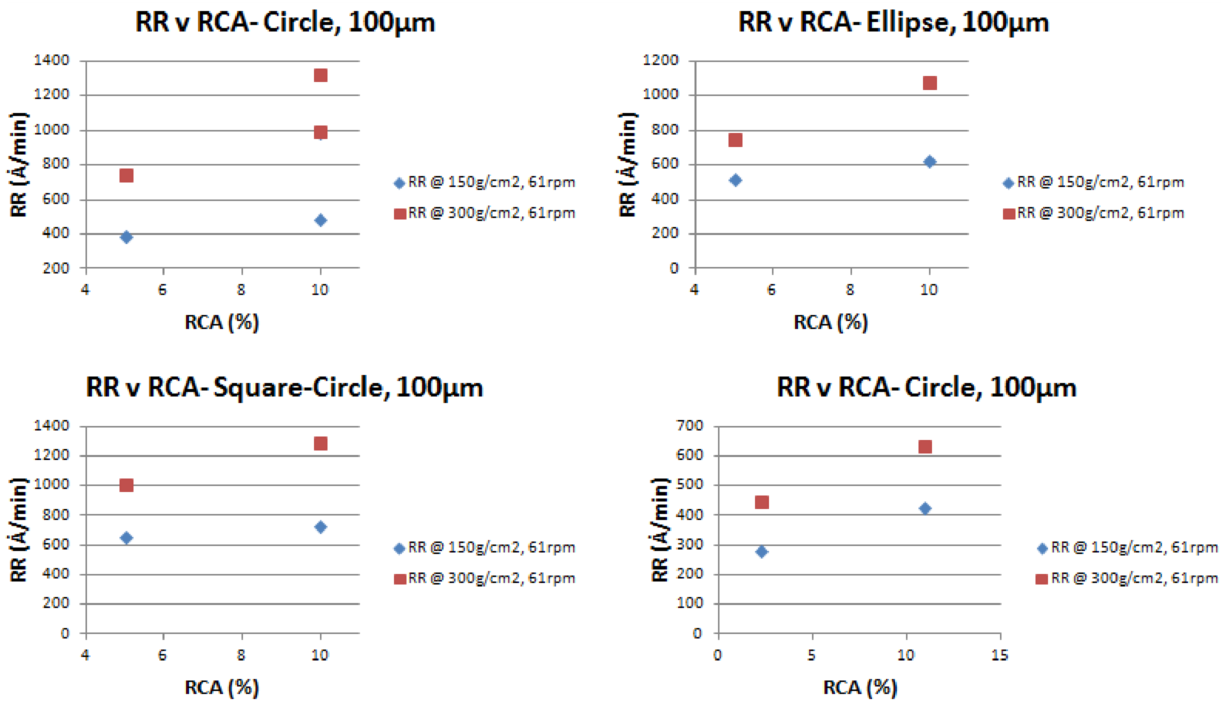

Figure 6: Removal Rate vs Real Contact Area for different micro-feature patterns

Figure 7 is the data shown previously in Figure 6 but replotted to be the removal rate versus RCL for all 5% RCA and 10% RCA patterns. An increase in RCL results in an increase in removal rate for both sets of patterns. This data also demonstrates that the increase in removal rate is not dependent on micro-feature shape.

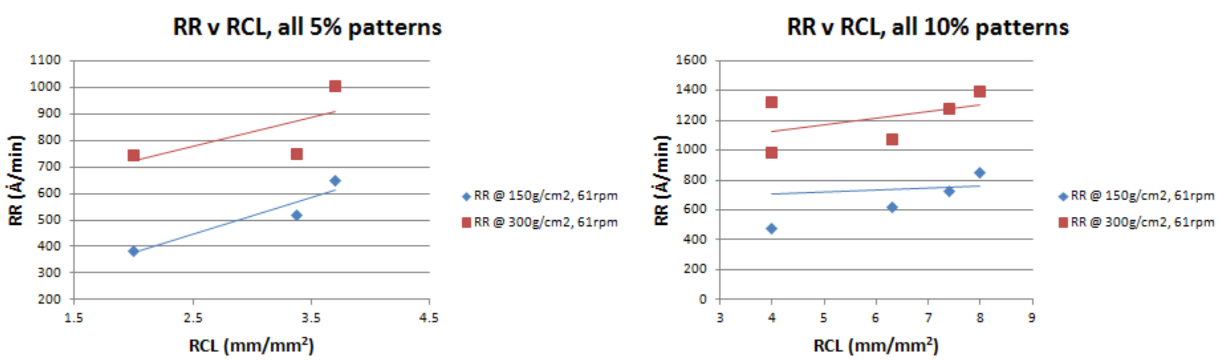

Figure 7: Removal rate versus Real Contact Area for all 5% RCA patterns (left) and all 10% RCA patterns (right)

The above results motivated an examination of how removal rate is dependent on RCL across all patterns. This is plotted in Figure 8. A clear logarithmic increase in removal rate with increasing RCL is established. This confirms that the increase in removal rate is independent of pattern shape and RCA. The increase in removal rate may be attributed to an increase in active slurry particles due to an increase in slurry movement.

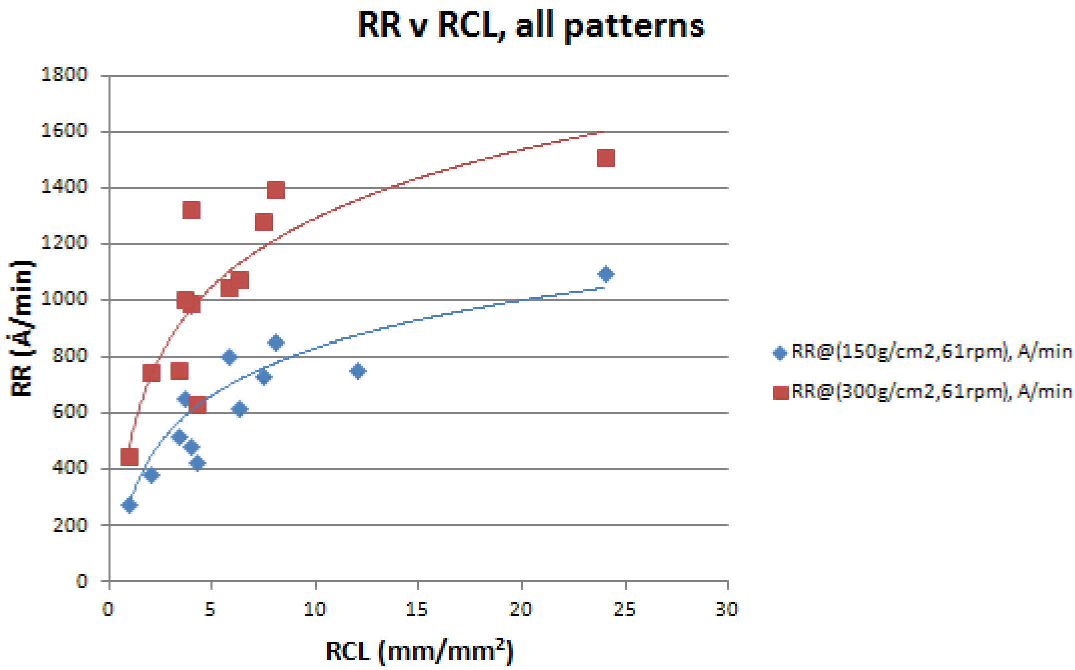

Figure 8: Removal Rate vs Real Contact Length for all patterns

CONCLUSIONS

A novel polishing pad developed by SMART Pad promises higher removal rate, fewer scratch defects, and improvements in planarization and wafer-level uniformity. The technology behind this pad is using surface contact via the fabrication of micro-features instead of the point contact typically found on conventional polishing pads. To understand how feature size affects polishing performance, pads with several types of micro-features with varying sizes were manufactured and tested with silica slurry. Results showed an increase in removal rates with an increase in real contact area and real contact length for all shapes. However, it was shown that real contact length is the dominant factor when considering micro-feature design and removal rate. This shows the promise of SMART Pad polishing pad in Oxide Silica base slurry CMP process such as Inter Layer Dielectric (ILD) CMP.

Corresponding Author:
Sunghoon Lee
Tel: +1-503-509-8009
E-mail: Sunghoon.Lee@SmartPadForCMP.com
SMART Pad
Clifton Park, NY 12148