LAPPING PLATE ALLOY: CHARACTERIZATION OF (Sn/Bi) RATIO

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ABSTRACT

Lapping is a key process for achieving precise dimensional control in nanometer-scale components, especially in the growing storage device industry. As demand increases, manufacturers face the challenge of improving material removal rates without compromising quality or process stability.

This study addresses the issue by introducing a harder lapping plate material (lower Sn/Bi ratio) and optimizing key input parameters using the DMAIC methodology. A 2k full factorial design was applied to analyze the effects and interactions of process variables on lapping performance.

Results showed a 47% increase in lapping rate with 60% lower decay rate. The high hardness of bismuth reduces diamond tip penetration, allowing more efficient and stable material removal.

This work demonstrates a practical and effective method to enhance lapping performance. The use of harder plate materials significantly improves removal rate and productivity while maintaining quality, offering a new direction for advanced precision manufacturing.

1. 0 INTRODUCTION

The HDD storage capacity demand is steadily increasing with around 25% annually. This huge increase in areal density demand drives to further reduce the Slider dimension thus increasing the total data recorded per disk. Going smaller dimension poses a lapping challenge to allow higher material removal without compromising the quality, productivity and process stability.

In related studies, H.Tanaka et.al concluded that decline in lapping rate is due to low initial cutting edge height or abrasive sinking[1]. In this context, cutting edge height is the height of the protruded diamond. In every lapping cycle diamond is slowly pushed into the plate which reduces the diamond height, hence a reduction in lapping rate. Additionally, lapping plate material is equally important in maintaining lapping rate[2]. A higher work hardening coefficient lapping plate is ideal to maintain and reduce abrasive sinking[1]. Overall, achieving a higher lapping rate, the diamond indentation and plate material work hardening coefficient must be evaluated; hence, this paper will explore these concepts further.

The high material removal demands to introduce higher lapping rate lapping process which based on the concepts discuss should both be able to maintain diamond height and lapping plate with higher work hardening coefficient. To address this, a harder plate was introduced, lower Sn/Bi ratio lapping plate is relatively harder compared to the reference lapping plate. Theoretically, the higher percentage of Bi increase the work hardening coefficient which will allow diamond to maintain its height. In addition, using harder plate, plate key input variables will also be optimize using 2k full factorial as part of the Analysis phase of the DMAIC.

2. 0 REVIEW OF RELATED WORK

See 1.0 INTRODUCTION

3.0 METHODOLOGY

The experiment was conducted using the process flow as shown in Fig.1. First lapping plates are created with varying KIV's. Plates parametric was measured to set the before and after lapping comparison. Plate Atomic force microscopy (AFM) was done to get the Grain density and Diamond height.

Fig. 1. Experiment Process Flow

3.1 Plates Preparation

Shown in the Table 1 the plate KIV's was varied during the lapping plate creation.

Table 1. List of Plate Parametric

Parameters	*Levels*	
Land width	Low	High
Groove Depth	Low	Low
Charging time	Low	High
Charging weights	Low	High

The 4 parameters as shown in table 1. are used to create 2k full factorial (2x2x2x2). Two response output variable was also defined, see equation 1 and 2.

$$[eq. 1] \quad Lapping\ Rate = \frac{Removal}{Lapping\ time} = \frac{nm}{s}$$

$$[eq. 2] \quad Removal\ per\ rev = \frac{Lapping\ rate}{RPM} = \frac{nm}{rev}$$

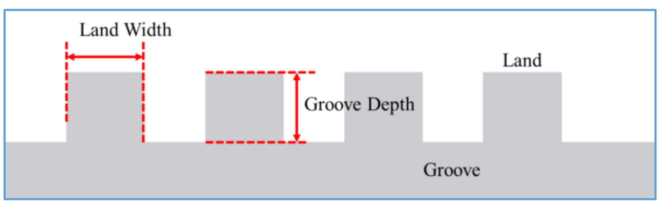

Fig. 2. Lapping plate Land width and Groove depth illustration

Plates preparation includes land and groove creation as shown in Fig. 2, during facing process. The plate land served as the area for diamond indentation via charging process while groove serve as the lubricant canals for proper flow of lube throughout lapping plate.

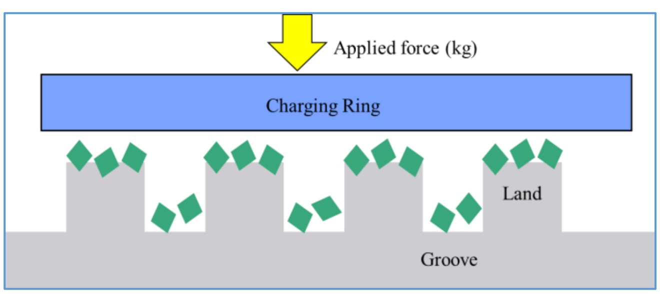

Fig. 3. Plate Charging illustration

Charging process is the procedure where diamond is indented into the lapping plate by applying force on top of the charging ring. In this process the applied force and charging time affects the charged diamond uniformity while land width dictates the effective charging surface then grove depth insures proper spread of diamond.

Overall, 4 parameters were varied to create 2x2x2x2 2k full factorial design of experiment (DOE) resulting to 16 combinations to understand and optimize the 2-responses, lapping rate and removal/rev.

3.2 Lapping Process

Lapping process was conducted by using fixed plate rotational speed (RPM), fixed workpiece oscillation speed and fixed lapping force, this is to avoid any additional factors affecting the lapping process.

Lapping rate was calculated by measuring the total removal divided by lapping time, and to normalize the lapping rate (eq. 1) and removal per revolution (eq. 2) was calculated.

3.3. Additional Measurements

On top of the plate and lapping parametric, Atomic Force Microscope (AFM) imaging was also done to measure the diamond grain density and diamond height. Diamond grain density is the total area with diamond over the workpiece area (5nm x 5nm). Diamond height is the total diamond height where zero reference is set on the plate surface. The addition of these measurements allows to directly compare the two different composition plate.

4.0 RESULTS AND DISCUSSION

The main advantage of using 2k full factorial DOE is that we can filter and understand the relationship of all the factor and optimize based on the factor contribution to the response.

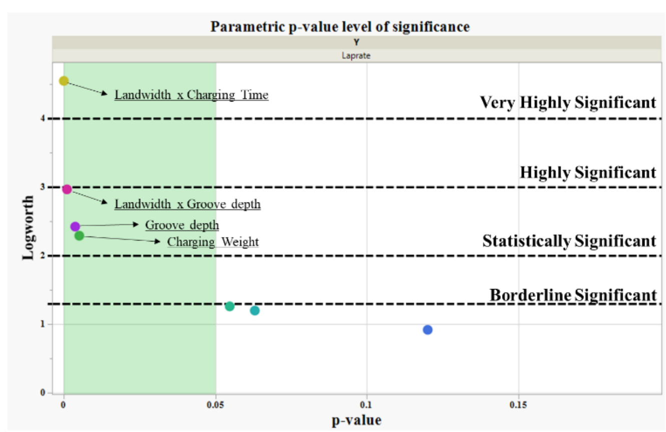

Fig. 4. Logworth over p-value parametric level of significance

Fig. 4. Shown the level of significance for the define parameters including the interaction. Land width by itself is not showing significance to lapping rate, but the interaction between charging time and groove depth are both above statistically significant.

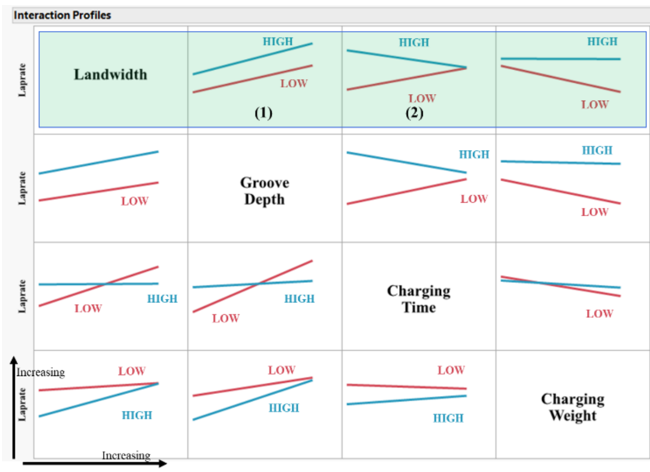

Fig. 5. Parametric interaction plot with high and low values, (1) land width x Groove depth and (2) land width x charging time.

Fig. 5. Box (2) is the interaction between land width and charging time (very high significant) showing that increasing charging time with high land width will yield to higher lapping rate but until to a certain point where in low and high land width values intersect. This implies that there as the land width widens the charging process becomes inefficient due to groove width shrinkage which will impact diamond slurry flow.

Additionally, the interaction of land width and groove depth is very straight forward (Fig. 5 box (1)) where increasing groove depth with high land width values will give higher lapping rate. Increasing groove depth allow better diamond slurry for which will aid to indent more diamond to the larger surface area due to high land width.

Putting this interaction into use, high lapping rate was demonstrated as shown in the Fig. 6 with ~47% laprate increase. The optimize plate has higher starting lapping rate and able to maintain high throughout the lapping cycle. Additionally, the optimize plate has slower lapping rate decay ~60% slower to the reference plate. To investigate further, diamond density and diamond dimension using AFM.

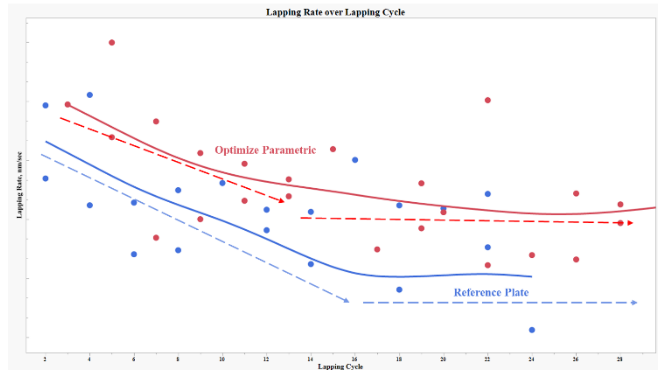

Fig. 6. Lapping rate over lapping cycle

Optimized plate condition has higher diamond density and is has lower sigma in comparison to the reference plate a shown in the Fig. 7.

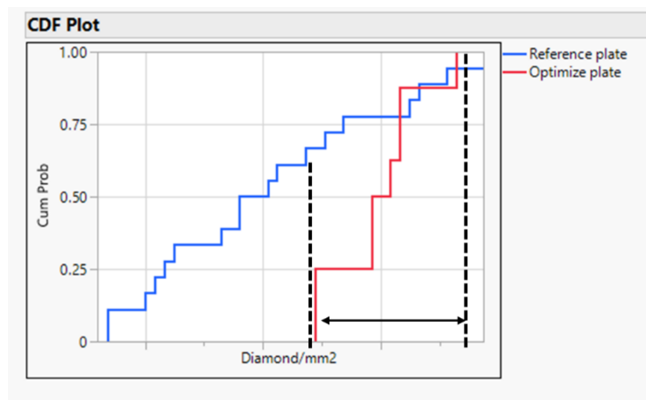

Fig. 7. Cumulative distribution function for diamond height. (measurement is before lapping process)

Furthermore, both optimized and reference plate is using the higher Sn/Bi ratio showing a unique behavior where lapping rate degrade faster at the start of the lapping cycle then hit a saturation point. This saturation point now has a stable lapping rate. This behavior is intrinsic to the plate material as shown in the Fig. 8.

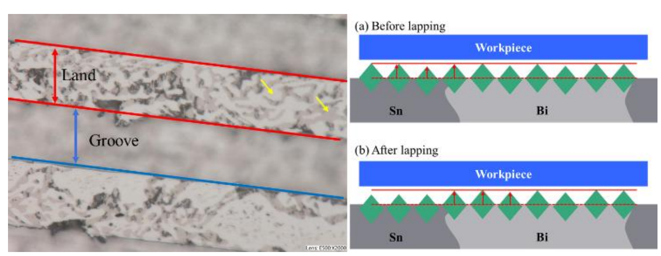

Fig. 8. Left image (plate surface image), right image (lapping cycle illustration)

The Sn and Bi distinct layer create different rates of diamond indentation. Since Sn is relatively softer than that of Bi, diamond indent faster in Sn layer creating the high decay at the start of the lapping cycle, this now create the plate saturation point where the diamond on the Bi layer is indent less compared to Sn layer as illustrated in the Fig. 8. Consequently, after the saturation point — lapping rate stabilizes improving lapping cycle as shown in Fig. 6.

5.0 CONCLUSION

This study successfully demonstrated that using harder plate material increases lapping rate to compensate with the increase in material removal demands of the product.

Additionally, by utilizing the 2k full factorial DOE — plate parameter relationship and interaction was realized hence further optimization into the plate condition. The interaction of land width into charging time and groove depth gives further understanding into the plate lapping mechanism.

The increase of lapping rate is due creation of diamond height difference at the saturation point during the lapping process, where the diamond sink slower in the Bismuth layer since it is relatively harder compared to Tin. At the saturation point the lower diamond height sigma allows more uniform applied force resulting to higher stock removal.

6.0 RECOMMENDATIONS

This study was able to demonstrate that using harder plate increases the lapping rate, but this also introduces manufacturing problems since the plate hardness imposed more accurate plate preparation facing process. Due to distinct Tin and Bismuth layer, High groove depth leads to low landwidth integrity resulting to broken lands. It is recommended to optimize facing condition to reduce the broken landwidth occurrence.

7.0 ACKNOWLEDGMENT

The authors would like to express a most profound gratitude to the following peoples:

Eduard Prudente, Geraldine Datuin, Marabini Coronado, Diana Rose Salazar, Erika Arriane Oliveros, Miriam Menamendaz, Manuel Villapando, Alex Maala and Michelle Mendoza for the execution and monitoring support. Byron Luna, Aileen Jara and John Herber for the review and guidance in the experiment and technical paper writing.

Western Digital Storage Technologies (Philippines) Corp. for giving the opportunity and environment to make the processing and evaluation possible.

8.0 REFERENCES

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9.0 ABOUT THE AUTHORS

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10.0 APPENDIX

Not Applicable.