Advanced Conditioning Techniques for Fixed Abrasive Lapping Films Using Ceramic Rings

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ABSTRACT

In the highly competitive manufacturing industry, achieving superior product quality while maximizing efficiency is essential for sustaining industry leadership. Polishing or lapping using a diamond film plays a critical role in maintaining consistent material removal rates.

This study introduces an effective method to improve the performance of the lapping or polishing process by applying a new geometry during the conditioning of diamond lapping films. With this new approach, variation in diamond size is reduced and a more uniform path density is achieved, ensuring consistent exposure of embedded diamond particles.

As a result, material removal becomes more efficient, and removal rate shows a 150% improvement reaching approximately 1.0 µm per minute compared to 0.40 µm per minute with traditional conditioning. It also increases production capacity by 67% and reduces quarterly material usage by 39%, leading to cost savings.

In summary, this geometry offers an effective approach to enhancing the performance of diamond lapping films, with significant improvements in removal rate. Additionally, it boosts productivity while maintaining quality, offering a promising direction for advanced precision manufacturing.

1. 0 INTRODUCTION

Diamond lapping films play a crucial role in the polishing or lapping process, helping achieve smooth surfaces and precise thickness in manufacturing.

During the initial stage of use, conditioning is a standard practice to prepare the diamond lapping film, and Altic material has traditionally been used for this purpose, as illustrated in Figure 1.

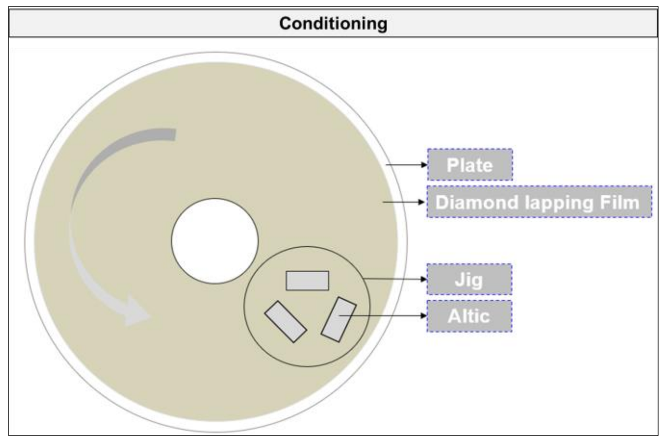


Fig. 1. Illustration of conditioning method using altic material.

But one main problem with using traditional conditioning is that it causes uneven material removal especially when the diamond lapping film is first used after conditioning.

This makes the process less efficient, reduces productivity, makes it harder to achieve accuracy, and increases the chance of defects. Figure 2 illustrates the behavior of diamond lapping films conditioned with traditional method.

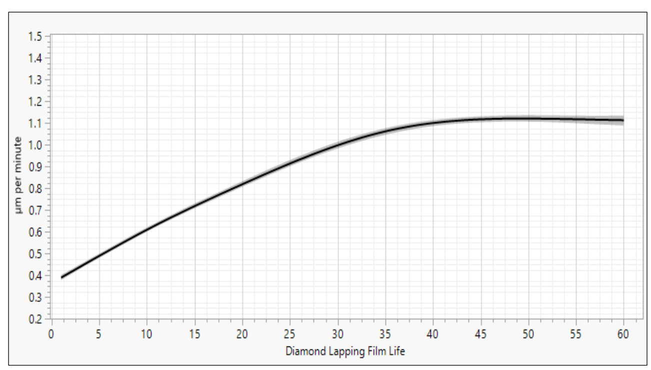


Fig. 2. Removal rate performance of diamond lapping film after conditioning traditional method.

2. 0 REVIEW OF RELATED WORK

Not Applicable.

3.0 METHODOLOGY

The experiment was conducted using the process flow as shown in Figure 3.

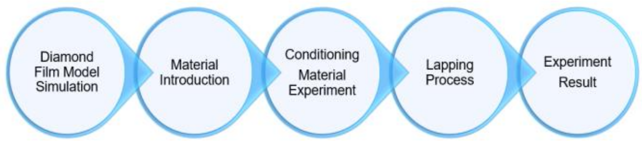


Fig. 3. Experiment Process Flow

3.1 Diamond Film Model Simulation

Using the formula below, Figure 4 shows the current simulated path density model of the diamond lapping film after it has undergone traditional conditioning with the Altic material.

Model simulation formula:

$$x = \big(d \times \cos(\alpha + \omega_p \times t)\big) + (r \times \cos(\beta + \omega_R \times t))$$

$$y = \big(d \times \sin(\alpha + \omega_p \times t)\big) + (r \times \sin(\beta + \omega_R \times t))$$

$Where:$

$\alpha = Ring\ position$

$\omega_p = Plate\ Speed$

$\omega_R = Ring\ Speed$

$d = Ring\ distance\ from\ plate\ center$

$r = Ring\ Radius$

$t = time$

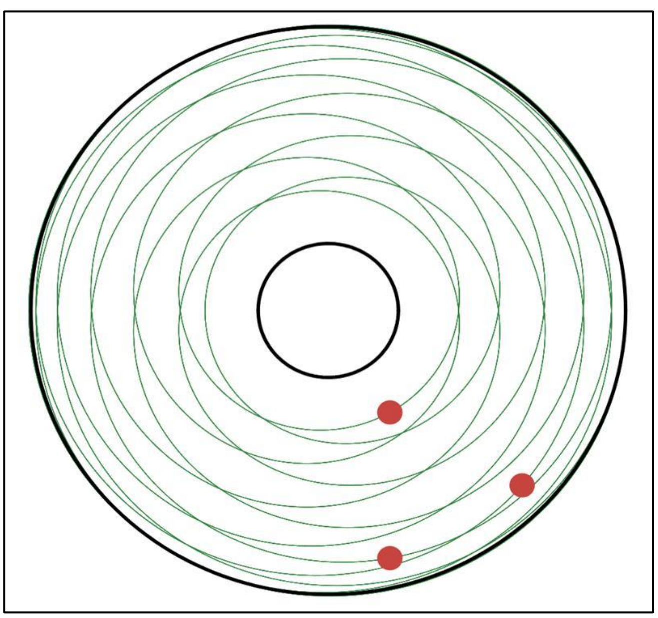


Fig. 4. Diamond lapping film simulated path density model using altic material in conditioning.

Using higher magnification metrology, Figure 5 shows the actual grain height of the diamond after conditioning using altic material.

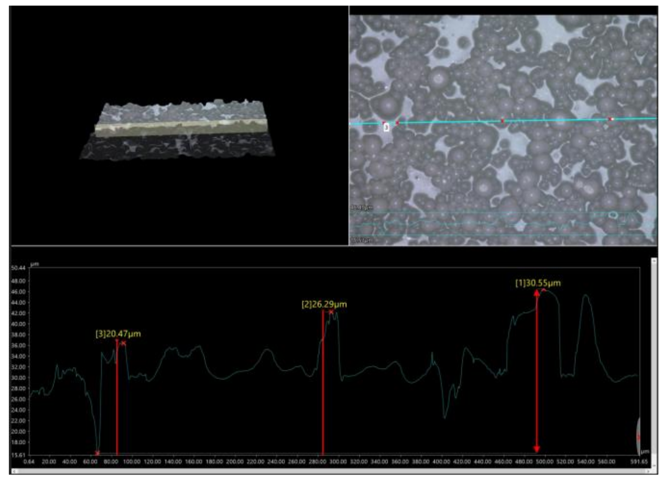


Fig. 5. Diamond height embedded in the lapping film post conditioning using altic material.

3.2 Material Introduction

Based on the simulation model and actual grain height validation, conditioning using Altic material remains insufficient to fully unlock the potential of the diamond lapping film. Therefore, it is recommended to explore a new, harder material that can further enhance the utilization of the diamond lapping film.

Ceramic materials are among the most widely recommended alternatives in the semiconductor and electronics industries, as they offer exceptional thermal stability, electrical insulation, and resistance to wear and corrosion.

When comparing the two, Altic a composite of alumina and titanium carbide exhibits a Vickers hardness in the range of approximately 1200–1400 HV. In contrast, advanced ceramic materials such as silicon carbide and boron carbide demonstrate significantly higher hardness values, often exceeding 2500 HV.

This superior hardness indicates that ceramic materials may provide improved wear resistance and performance in critical semiconductor applications.

3.3 Conditioning Method Experiment

To evaluate the effect of the new material, Table 1 summarizes the conditions to be used in the experiment.

Table 1. Summary of Experimental Combinations

Plate	Method	Conditioning Material	Plate Type
Plate A	Traditional	Altic	0.25 µm
Plate B	New	Ceramic	0.25 µm

3.4 Lapping Process

Lapping process was conducted by using fixed plate rotational speed (RPM), fixed chemical flow rate and fixed air pressure (psi), this is to avoid any additional factors affecting the lapping process.

Lapping rate was calculated by measuring the total removal divided by lapping time.

$$Lapping\ Rate = \frac{Removal}{Lapping\ time} = \frac{\mu m}{m}$$

4.0 RESULTS AND DISCUSSION

4.1 Result of Ceramic material in diamond lapping film

Figure 6 illustrates how the ceramic material used as a conditioning material in the diamond lapping film.

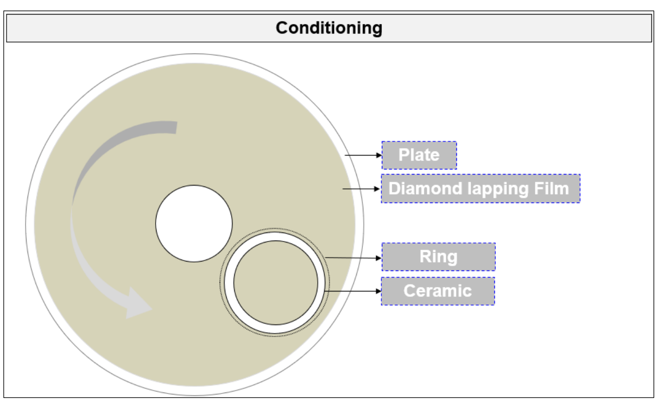


Fig. 6. Illustration of conditioning using ceramic material.

Using the same approach and formula, Figure 7 shows the simulated path density model of the diamond lapping film conditioned with new method and ceramic material.

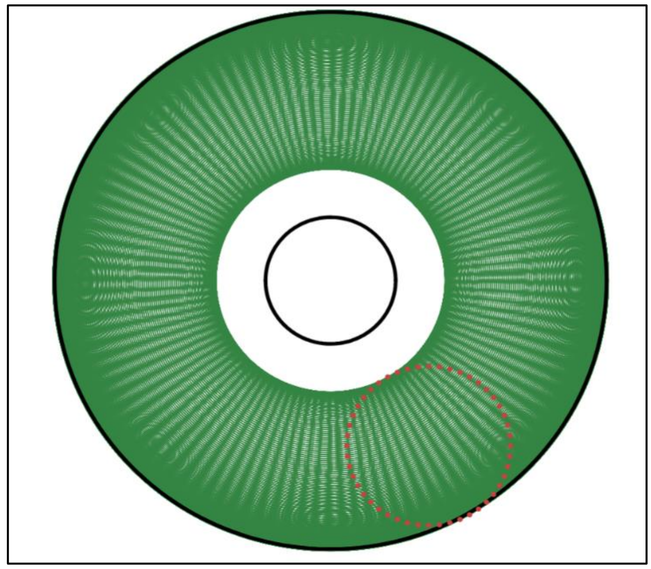


Fig. 7. Diamond lapping film simulated model path density using new method with ceramic material in conditioning.

New conditioning method with ceramic material produces a better path density compared to the diamond lapping film conditioned with Altic material as previously shown in Figure 4 and to validate the simulated model, Figure 8 presents the actual grain height of the diamond after conditioning with ceramic material.

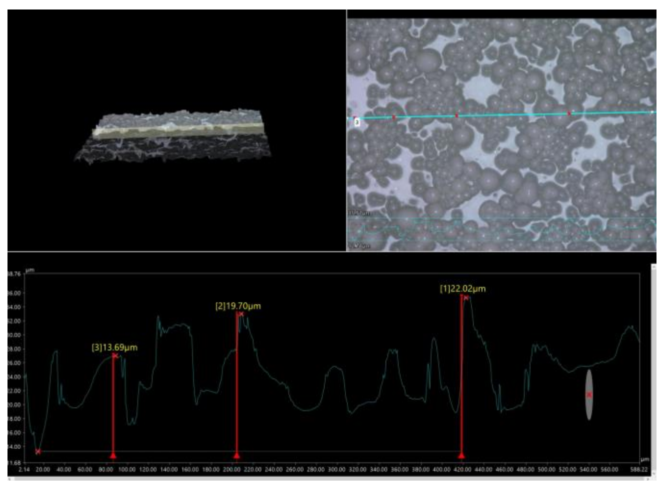


Fig. 8. Diamond height embedded in the lapping film post conditioning with ceramic material.

To further validate the results, both experimental diamond lapping films underwent grain height sampling measurements at the inner, middle, and outer regions, as illustrated in Figure 9. Refer to Figure 10 for the collected data and to Figure 11 for the summarized measurement comparison.

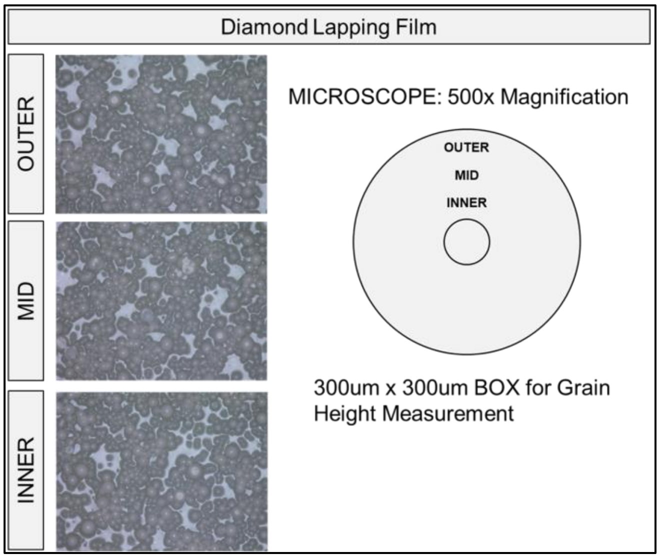
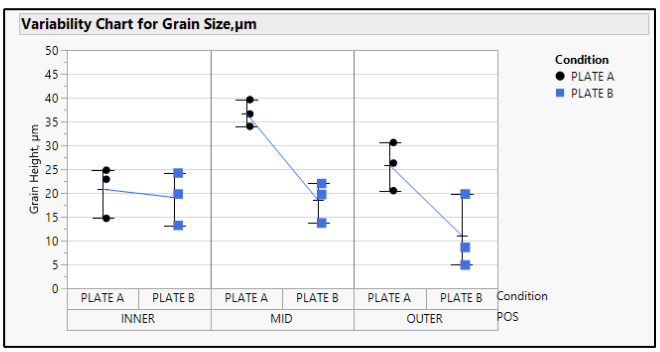


Fig. 9. Grain height measurement using 500x magnification and 300 µm x 300 µm area.



	Grain Height ,µm			
	Condition			
	PLATE A		PLATE B	
Position	Mean	Std Dev	Mean	Std Dev
INNER	20.80	5.37	19.07	5.54
MID	36.73	2.80	18.47	4.29
OUTER	25.80	5.07	11.10	7.76

Fig. 10. Grain size height data collection

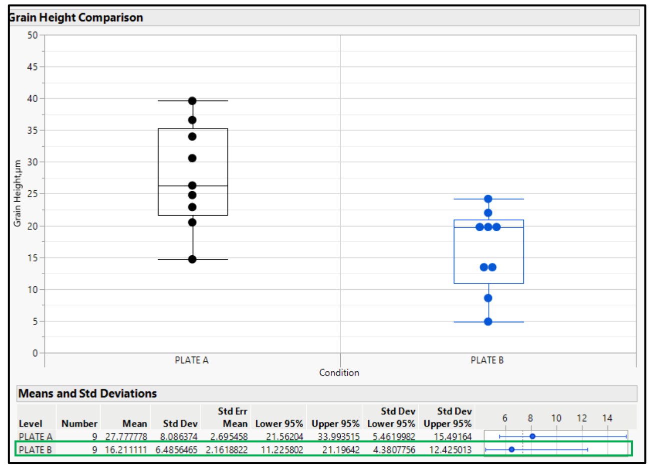


Fig. 11. Grain size height comparison

The change in grain height and minimized the variation are the keys observations on the diamond lapping film conditioned with new method and ceramic material.

Additionally, the path density based on the simulation exhibits better uniformity, as shown in Figure 12, and lastly the embedded diamond particles, previously covered by resin are more effectively exposed compared to those in the film conditioned using traditional with Altic material, as shown in Figure 13.

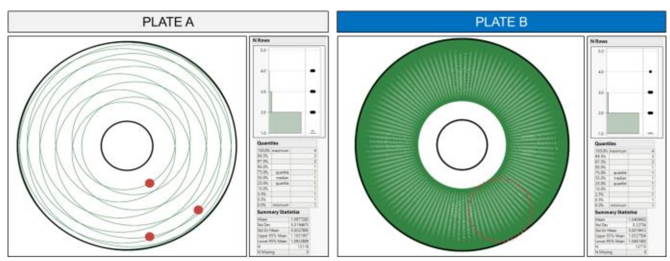


Fig. 12. Path density count improves variation from 0.31 to 0.22.

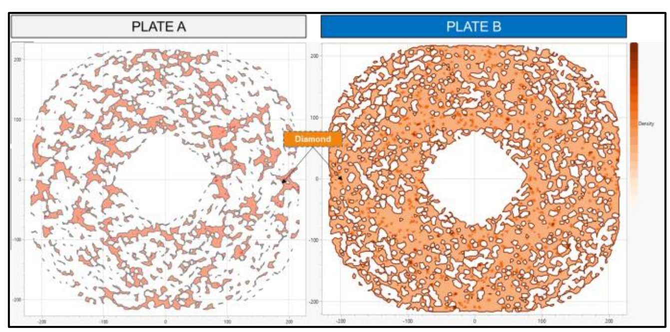


Fig. 13. Effect of the conditioning using ceramic material.

4.2 Effect in manufacturing

Further exploring the results, new conditioning method with ceramic material in conditioning shows 0.60 µm/min, approximately a 150% improvement over Plate A, particularly during the initial stage. This method also provides leverage to extend the lifespan of the diamond lapping film from 60 runs to 100 runs as shown in Figure 11.

Additional benefits related to manufacturing capacity are illustrated in Figure 12, where machine output increased from 10,000 to 16,700 units, equivalent to a 67% improvement due to the enhanced performance of the diamond lapping film.

Furthermore, the extended lifespan has reduced quarterly consumption from 177 pieces to 108 pieces, an improvement of approximately 39%, as shown in Figure 13.

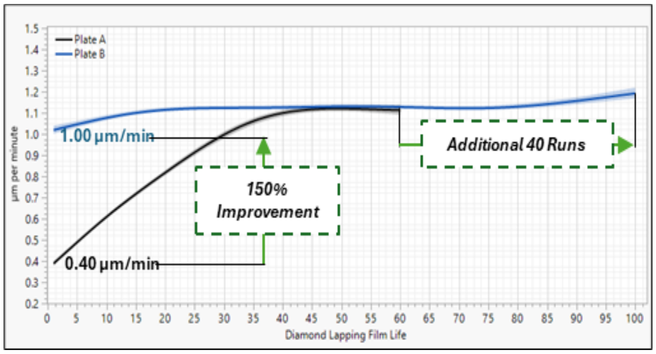


Fig. 11. The diamond lapping film performance increased from 0.4 to 1.0 microns per minute, representing a 150% gain in deposition rate specifically at the beginning of the run, and the lifespan extended from 60 runs to 100 runs.

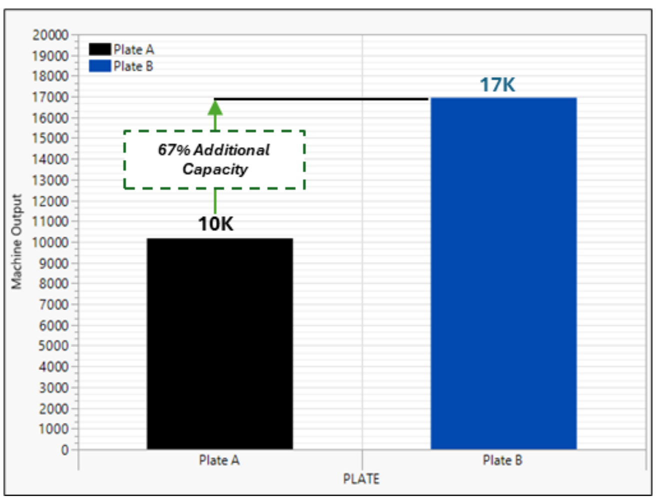


Fig. 12. An expected 67% increase in operational output, from 10,000 to 17,000 units per day. Indicates significant enhancements in manufacturing efficiency and capacity utilization.

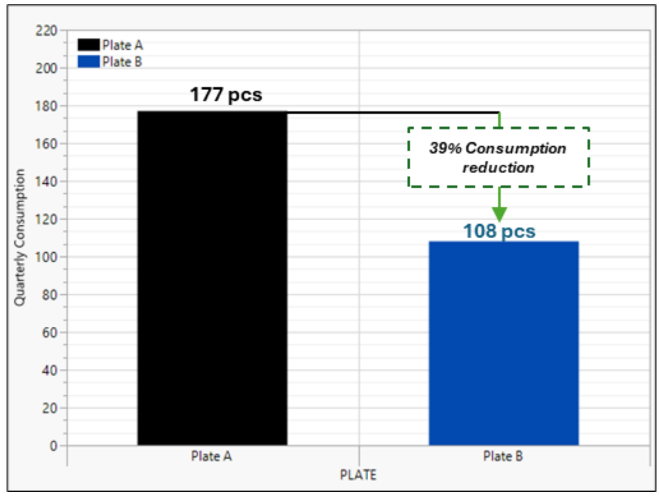


Fig. 13. An expected 39% reduction in consumption, from 177 pieces to 108 pieces per quarter and lead to quarterly cost savings.

5.0 CONCLUSION

The results of the new conditioning configuration demonstrate a reliable solution for maximizing the effectiveness of diamond lapping films, based on the experimental data. This geometry helps minimize grain height variation in the diamond lapping film and ensures uniform exposure of the embedded diamond particles. Therefore, adopting this approach can enhance polishing process stability, improve operational efficiency, and deliver quarterly cost saving

6.0 RECOMMENDATIONS

Based on the findings of this new geometry, minimizing grain height variation is essential for unlocking the full functional performance of the diamond lapping film, particularly in terms of consistency and wear characteristics. To further enhance material quality and process stability, future experiments should assess the feasibility of reducing grain height variation at the supplier level.

7.0 ACKNOWLEDGMENT

We sincerely express our gratitude to everyone who played a role in the successful completion of this project. Your dedication, expertise, and unwavering support have been invaluable throughout this journey. We extend special appreciation to the manufacturing operations team for good execution of the experiment and their hard work, commitment to excellence, and contributions that have significantly impacted the project's success. Your efforts are deeply valued and greatly appreciated

8.0 REFERENCES

Not Applicable.

9.0 ABOUT THE AUTHORS

Patrick Recella has 13 years of experience at Western Digital Corporation and currently holds the position of Senior Manufacturing Engineer. He has expertise in slider fabrication, specifically in the key process of backside lapping within the field of Process Engineering.

Roger Pabuaya has 6 years of experience at Western Digital Corporation and currently holds the position of Senior Manufacturing Engineer. He specializes in slider fabrication with a focus on Material Science.

Michelle Mendoza has 15 years of experience at Western Digital Corporation and currently holds the position of Senior Manufacturing Technician. He has expertise in slider fabrication, specifically in the key process of backside lapping within the field of Process Engineering

10.0 APPENDIX

Lap – is defined as to dress, smooth, or polish (something such as a metal surface) to a high degree of refinement or accuracy.

Polish – is defined as to make (something) smooth and shiny by rubbing it.

AlTiC – Aluminum Titanium Carbon Alloy Rod

Ceramic – is broadly defined as inorganic, nonmetallic materials that exhibit such useful properties as high strength and hardness, high melting temperatures, chemical inertness, and low thermal and electrical conductivity but that also display brittleness and sensitivity to flaws.

Conditioning – is a behavioral process whereby a response becomes more frequent or more predictable in each environment because of reinforcement, with reinforcement typically being a stimulus or reward for a desired response.

Diamond Lapping Film – is for single side flat lapping of row bars. These films use a thicker diamond coating with a higher diamond concentration and a tougher resin for an increased cut rate and longer life.

Grain height – is the diameter of individual particles in a granular material like sediment, soil, or clastic rocks. It's a key factor in geology, soil science, and materials engineering because it influences properties like porosity, permeability, and strength

Path Density – refers to how densely the tool paths (or conditioning traces) are distributed across the surface of the film. It's a measure of how uniformly the conditioning tool covers the surface during its motion.