Chemical Mechanical Polishing(CMP) of High Thermally Conductive Interlayer Dielectrics (ILDs)

Harkishanbhai Jayantibhai Dobariya, Materials Science and Engineering
Mentor: Terry Alford, Associate Director and Professor
Ira A. Fulton Schools of Engineering

INTRODUCTION

Diamond wafers are ideal for high-power electronics due to their exceptional thermal, mechanical, and electrical properties. However, current CMP slurries struggle to balance surface smoothness and minimal damage. This project proposes a novel slurry using mixed oxidants and B_4C abrasives to improve wafer quality for advanced packaging applications.

Research Objectives

Achieving ultra-smooth, low-damage diamond surfaces can significantly advance high-tech applications like quantum computing, power devices, and detectors. Diamond's extreme properties support performance in harsh, high-temperature environments. Improved polishing boosts efficiency and reliability of these next-gen semiconductor components.

METHODS

CMP is used: initial mechanical polishing with diamond abrasives (10 µm to 0.5 µm) on a Scaife plate, followed by chemical polishing using mixed-oxidant slurries (K_2FeO_4, $KMnO_4$, CrO_3, KIO_4) and B_4C abrasives. Diamond films (1 inch diameter) were polished on a SiC pad with optimized pressure (266.7 kPa), speed (60 rpm), and slurry pH. Surface roughness was evaluated using a ZeScope optical profilometer. The role of oxidants in enhancing oxidation and material removal was analyzed using thermokinetic modeling and the Arrhenius

Slurry No.	Oxidant	Content	Additive	Content	De-ionized water	Abrasive 2 µm B_4C
1	K_2FeO_4	50g	84% phosphoric acid	10 ml	200 ml	30g
2	$KMnO_4$	20g	84% phosphoric acid	50 ml	150 ml	30g
3	CrO_3	30g	84% phosphoric acid	50 ml	150 ml	30g
4	KIO_4	30g	84% phosphoric acid	15 ml	200 ml	30g

Table 1 Slurry compound

Mechanics of the Process:

The surface carbon reacts to form CO_2:

$$C(s) + O_2(g) \rightarrow CO_2(g),\ \Delta G^\circ = -397.259\ \text{kJ/mol}$$

This synergy enables effective material removal and surface smoothing.

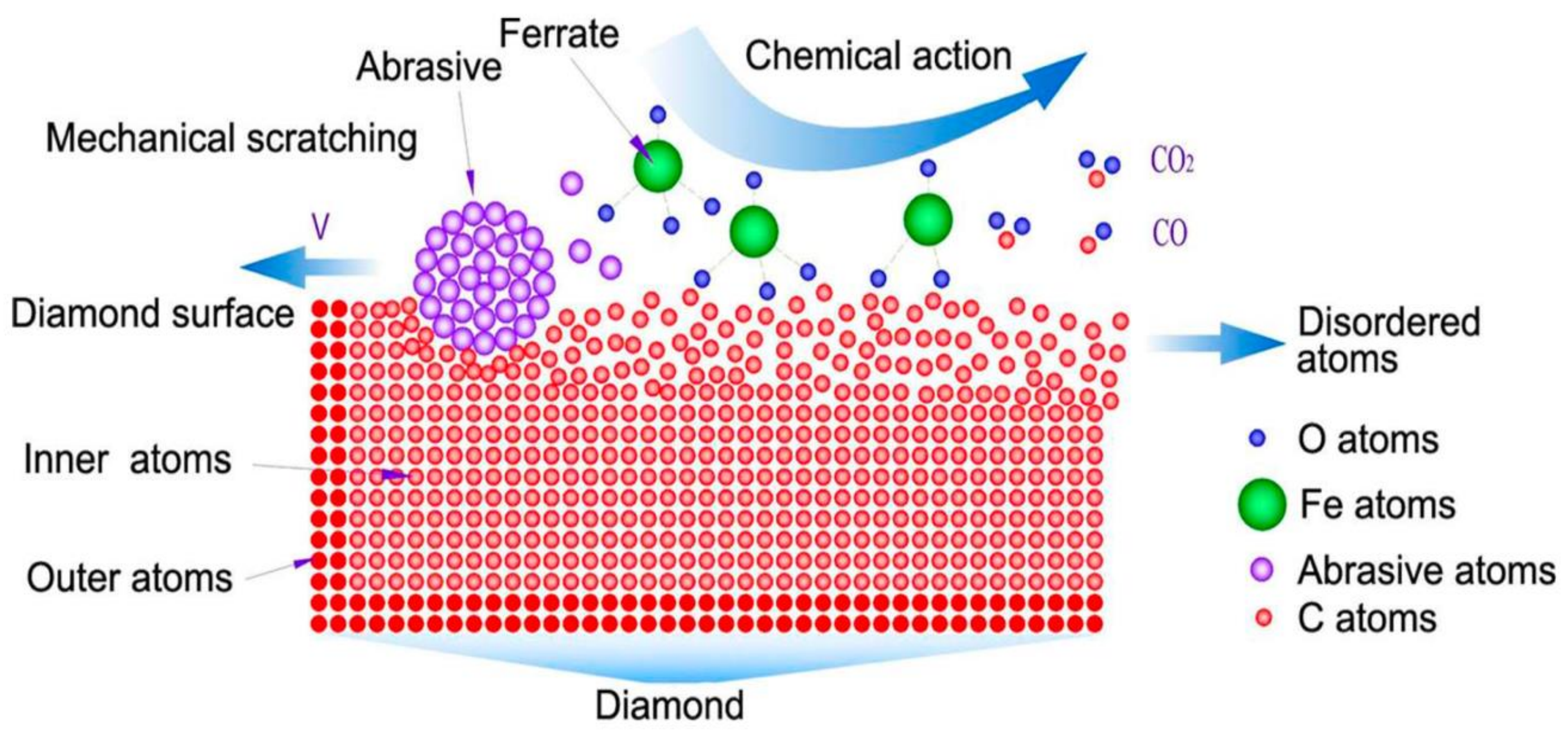

Fig 1. Schematic diagram of the chemical mechanical polishing process

CONCLUSIONS

This project will successfully develop an optimized CMP process for diamond wafers, achieving surface roughness below 10 nm with minimal damage layers. By using a novel slurry composition combining Potassium Ferrate and Boron Carbide abrasives, the process significantly improved surface quality. These advancements hold great potential for enhancing the performance of diamond-based components in high-power electronic applications. Further optimization of the process could lead to even better results for industrial applications.

NEXT STEPS

- Adjust CMP parameters to reduce surface roughness and enhance polishing results.
- Refine the process to improve wafer quality and overall performance.

ACKNOWLEDGMENTS

I sincerely thank Dr. Terry Alford for his mentorship, the Eyring Material Center for support with characterization, the Undergraduate Lab for facilitating experiments, and my project group for their collaboration.

REFERENCES

[1] Malshe, A. P., Park, B. S., Brown, W. D., and Naseem, H. A., "A Review of Techniques for Polishing and Planarizing Chemically Vapor-Deposited (CVD) Diamond Films and Substrates," Diamond and Related Materials, Vol. 8, pp. 1198–1213, **1999**.

[2] Coe, S. E., and Sussmann, R. S., "Optical, Thermal and Mechanical Properties of CVD Diamond," Diamond and Related Materials, Vol. 9, pp. 1726–1729, **2000**.

[3] Z. Yuan, Z. Jin, Y. Zhang, Q. Wen, "Chemical Mechanical Polishing Slurries for Chemically Vapor Deposited Diamond Films," Journal of Manufacturing Science and Engineering, Vol. 135, pp. 135-142, **2013**.