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A new method for edge collapse prevention in fixed-abrasive lapping

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Abstract
The flatness affects the performance of the key parts in precision optics processing and Integrated Circuit (IC) manufacturing. Normally, the lapping and polishing process are always employed to achieve the high flatness. However, the edge effect cannot be avoided in lapping and polishing due to the process characteristics. Some methods are proposed to decrease the edge effect, but the current prevention methods are limited by many aspects. In this paper, a new method to prevent the edge collapse by protecting the edge is proposed. In this method, the edge collapse is prevented by enlarging the whole structure, and the edge is transferred to the sacrificial loop. In addition, the sacrificial loop is attached to the workpiece, which makes it become a whole structure. A series experiments are conducted to verify the prevention efficiency. The results show that the depth and width of the edge collapse have been reduced by about 80% and 55% respectively by this method. Hence, this method can achieve the effective prevention of edge collapse.

Keywords: Edge collapse, contact pressure, sacrificial, protection

1. Introduction

Continuous efforts have been made to produce high-precision components in IC manufacturing and precision optics processing by lapping and polishing. Lapping and polishing are ultra-precision manufacturing techniques in which the material is removed mainly by the grids scratching on the surface. However, due to the motion feature of the processes, edge collapse cannot be avoided on the finished surfaces. Edge collapse affects the performance of the key parts in the following two major applications. Firstly, in manufacturing large scale chips, the edge collapse will cause severe altitude gaps at the wafer boundary patterns distortion, and it will affect the performance of the IC chips. Moreover, the edge collapse will reduce the number of chips cut from a single wafer, which will increase the manufacturing cost. In addition, to make the magnetic disk smaller with higher storage capacity, the disk needs high flatness without edge collapse. Secondly, in optical machining, the edge effect will cause a decrease of damage resistance threshold value and the increase of scattering loss. The performances of optical segments are dominated by the edge effect greatly. Therefore, edge collapse is banned in the IC manufacturing, precision optics processing and so on.

There are several methods for preventing the edge collapse in previous research, which can be mainly classified into two kinds. On one hand, double-layered pads were invented to decrease edge collapse during substrate polishing [1]. But the newly developed pads could only suit specific types of materials. On the other hand, polishing path optimization was conducted to weaken the edge effect [2, 3]. Besides, the polishing head was designed to prevent the edge effect [4]. Nevertheless, it can only be used in sub-aperture polishing [5]. Particularly, the existing methods are not suitable for double-sided lapping process. Hence, a new method that can avoid the edge effect is needed to be explored urgently to prevent the edge collapse on full aperture lapping.

In this paper, a new method by protecting the edge with a sacrificial loop was proposed to prevent the edge collapse in double-sided lapping and polishing. Finally, the experimental validation was conducted on a double-sided lapping machine.

2. A new method to prevent edge collapse

The edge collapse can hardly be avoided by the optimization of process parameters. The edge protection method is a new approach for preventing the edge collapse. Basically, it prevents the edge collapse by enlarging the workpiece, because the edge collapse mainly caused by contact pressure increasing at the edge.

The edge protection structure shown in Figure 1 contains two loops: 1. sacrificial loop, which is the same material with the workpiece, is selected to enlarge the structure; 2. filler loop which is filled with different material, is analyzed entirely.

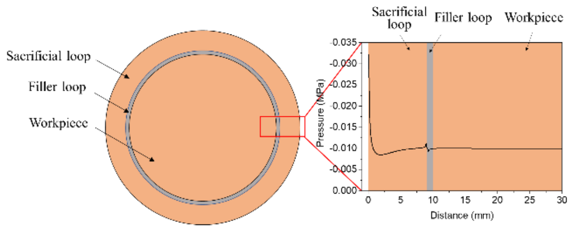
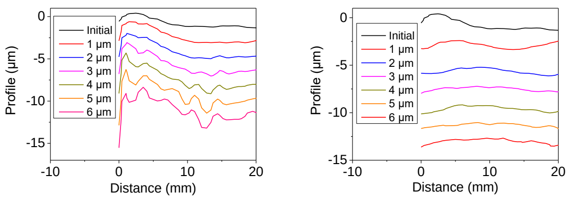


Figure 1. The schematic of edge protection strategy

3. Simulation

Simulation was conducted on the thin copper substrate, and the edge profile evolution was simulated with and without protection. The results shown in Figure 2 revealed that the edge collapse developed seriously without the protection method, and the edge collapse became stable because of the pressure distribution changing with the edge collapse. The pressure at the edge lowered and it tended to be the same to the centre area with the edge collapse development. With the protection method, the edge collapse tended to be lowered because of the pressure distribution. Thus, the method is effective on preventing the edge effect.

From the results, the width and depth of edge collapse have been decreased respectively by edge protection. It is mainly because that the contact stress tends to be the same on the whole surface. The dramatic increase of pressure has been transferred to the sacrificial loop, and the edge of the workpiece has been protected sufficiently. However, the protection effect is not the same with different parameters. From the experimental results, the edge collapse can be modified because of the contact pressure distribution on the surface. With the edge collapse on initial workpiece, the pressure at the edge becomes lower by edge protection method. The material removal at the edge tends to be slower than that at the central area which causes the edge collapse being weakened.



(a) (b)

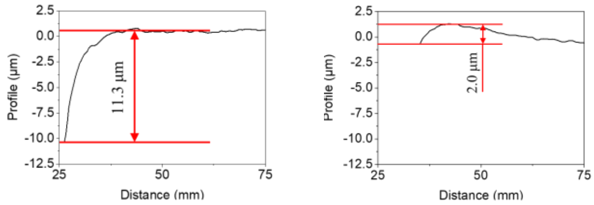
Figure 2. The profiles evolution (a) without protection (b) with protection

4. Experimental validation

Double-sided lapping with fixed abrasive pad was selected to verify the edge collapse and the effect of edge protection. The samples are thin copper substrates and the size is Φ 80×2.5 mm. The material of the sacrificial loop is copper, while the filler loop is pyrosol. The surfaces of samples and a sacrificial loop was pre-machined via turning which does not have obvious edge collapse, as measured using a flatness measuring instrument (FlatMaster 200 by Corning Incorporated, New York, USA) with the deviation 50 nm.

Double-sided lapping machine (YJ-6B5LA & YJ-6B5LC by Yujing Machinery Co., Ltd., Hunan, China) used in the previous research [6] is equipped with lapping plates sized Φ380 mm. The fixed abrasive pads with grooves, and the diamond particles sized 15-25 μm were used in this work. Before the experiments, the workpiece and sacrificial loop were fabricated together by double-sided lapping to obtain the same thickness. Then, filler was used to stick the workpiece and sacrificial loop together. To guarantee the protection effect, the filler loop was higher than the workpiece. The whole structure was processed by double-sided lapping in the experiments. Deionized water was used as coolant during lapping.

In verification experiments, the profiles were measured by the FlatMaster 200, and the profiles near the edge area were acquired to analyse the edge effect. The results with each parameter are compared to the initial profile, and it shows that the edge collapse is lowered by different scale. Because with the sacrificial loop attached on the substrate, the substrate is enlarged on the diameter and the initial edge becomes an inner point. The contact pressure decreased dramatically at the initial edge. Thus, the edge collapse can be improved by edge protection method. The experiments are conducted to compare the effect on edge protection. It is obvious from the comparison of the profiles in Figure 2 that the prevention of edge collapse achieves the best effectiveness with the prevention method. The edge collapse is improved eventually.



(a) (b)

Figure 3. The profiles (a) without protection (b) with protection

5. Conclusion

In this study, the edge collapse protection in double-sided lapping process with fixed abrasive pad is investigated. According to the formation mechanism, a new method by protecting the edge with sacrificial loop is proposed to prevent the edge collapse. The method is verified by experiments. The major conclusions are drawn as follows:

1. An edge protection method is proposed to prevent the edge collapse, and it was verified by the experiments.

2. With the method, the depth and width of the edge collapse have been reduced by about 80% and 55% respectively.

In summary, the proposed work can promote the comprehensive understanding of a meaningful solution for preventing the edge collapse. Future work will be focused on the exploration edge collapse in double-sided polishing with loose abrasives.

Acknowledgments

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References

[1] Enomoto T, Satake U, Miyake T, Tabata N 2011 A newly developed polishing pad for achieving high surface flatness without edge roll off. *CIRP. Ann-Manuf. Techn.* **60** 371-4

[2] Fu G 2002 A model for wafer scale variation of material removal rate in chemical mechanical polishing based on viscoelastic pad deformation. *J. Electron. Mater*. **31** 1066-73

[3] Tam H-y, Cheng H 2010 An investigation of the effects of the tool path on the removal of material in polishing. *J. Mater. Process. Tech.* **210** 807-18

[4] Chen KW, Wang YL, Chang L, Liu CW, Lin YK, Wang TC, Chang ST, Lo K 2001 Novel strategies of FSG-CMP for within-wafer uniformity improvement and wafer edge yield enhancement beyond 0.18 micro technologies *IEEE International Semiconductor Manufacturing Symposium*

[5] Zhou W, Zhang L, Fan C, Gu T, Zhao J 2015 Investigation into material removal influenced by edge effect in polishing. *P. I. Mech. Eng. B-J. Eng.* **231** 1409-22

[6] Pan B, Kang R, Guo J, Fu H, Du D, Kong J 2019 Precision fabrication of thin copper substrate by double-sided lapping and chemical mechanical polishing J. Manuf. Process. **44** 47-54