# Improvement of the pad wear shape in fixed abrasive chemical-mechanical polishing for manufacturing optical components

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**Abstract:**

Fixed abrasive chemical mechanical polishing has some advantages in generating planarity surfaces of optical components. The surface after polishing has better uniformity, and the material removal rate is much more than the traditional chemical mechanical polishing. The pad wear shape has a significant effect on the uniformity of the surface in the chemical mechanical polishing process. The shape of the pad after wear is almost concave, and it has been challenging to create a flat surface. Therefore, there is a requirement for creating a better pad shape. The better the pad shape is, the more uniform the surface is. Kinematic analysis has been done to investigate the effect of the conditioning process on the pad shape. Some proposals are presented to create a better pad shape. In this paper, kinematic aspects of effects of the conditioner speed and the pad speed on the pad shape were investigated. In addition, a new model, including new designs of the conditioner and pad, is proposed. The conditioner in the new model is static instead of oscillation. The new model generates a better uniformity of the pad shape compared to the old model. The result was validated by an algorithm which was validated by the experiments reported in our previous paper.

## 1 Introduction

Chemical mechanical polishing (CMP) is a planarization process which creates a surface with high levels of planarity and low defectively. The work piece surface is held by a rotating carrier and faced against a rotating pad surface. The pad surface is refreshed by a rotating conditioner. This conditioner also oscillates in the pad radius direction. Both the conditioner and the work piece surface cause the pad surface wear with time. Many investigations have been showed that the conditioner effect is the most significant factor for the pad wear. The pad wear

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shape is very important to the flatness generation of the surface. Therefore, it is important to improve the conditioner to create a better pad wear shape as well as better work piece surfaces.

There are two types of pads used in the polishing: a soft pad with loose abrasives and a hard pad with abrasives embedded on the pad's surface, which is called the fixed abrasive pad [1].Many researchers have shown that the hard pad gives better uniformity but worse roughness surfaces comparing to the soft pad. In this study, the fixed abrasive pad conditioning is further investigated based on our previous work [2].

The pad wear rate could be affected by many factors [3, 4], such as a soaking time, a conditioning pressure, the pad's and conditioner's properties. However, the shape of the pad wear is almost concave which results in the non-uniformity of the polishing surface. It has been challenging to create a flat pad surface[5]. Many researchers have used kinematic analysis to investigate the conditioning process [2, 6-8]. However, almost all the above researches are about the soft pad, not the fixed abrasive pad. Feng [9] showed that when the dimension of the conditioner decreased, the uniformity of the pad wear shape increased. In addition, the pattern of the grain distribution on the conditioner surface had no effect on the pad wear shape generation. Baisie et al. [10] concluded that the sweeping profile of the conditioner affected the pad wear profile. Although many suggestions have been proposed to create a better uniformity of the pad wear, "there always exist some transition regions in the pad shape near the pad center and the pad periphery"[5].

In this paper, the effects of the conditioner process parameters on the pad wear shape are investigated. Based on that, a new model of the chemical mechanical polishing was proposed to get a better pad wear shape. This model was a combination of a new design of both the conditioner and the pad. A program in the previous research [2] was used to simulate the pad wear shape created by the new model.

## 2 Effects of conditioning process parameters

As reported in [2], the pad surface was divided into small areas. Based on the kinematic motions of the conditioner and the pad, trajectory paths of the conditioner abrasive grains were modeled. A program was built to count number of passes of the paths on the small areas. The number of passes was changed to negative value so that the more the number of passes was, the deeper the area was. The cross section of the pad was shown on the oscillation direction of the conditioner. The shape of the curve represented the form of the pad wear shape.

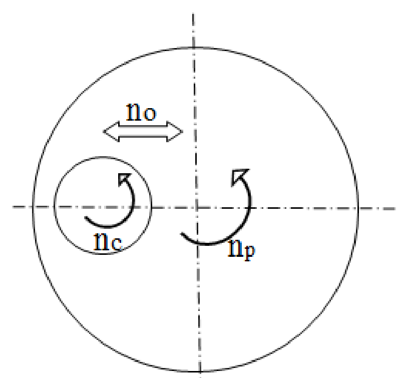



Fig. 1. Schematic representation of a conditioning process in polishing.

The conditioning process parameters, such as the speeds of the conditioner and the pad, the oscillation velocity of the conditioner, can affect the pad wear shape. By extending the model developed earlier[2], effects of those parameters were examined. The rotation speeds of the pad and the conditioner are $n_p$, and $n_c$ revolutions per minute (rpm), respectively. The oscillation speed of the conditioner is $n_o$ strokes per minute (strokes/min) as shown in Fig. 1. When the oscillation speed increases from 1 to 10 (strokes/min), the shapes of the pad wear are almost unchanged (Fig. 2). Similarly, the effect of the conditioner speed is small on the shape of the pad wear. When the conditioner speed increases from 1 to 100, the pad wear shapes are nearly the same. However, it is different from effects of the pad speed. When the pad speed is small, the change of the speed creates a significant changing in the pad wear shape. When the pad speed increases, the pad wear shape tends to be stable (Fig. 3).

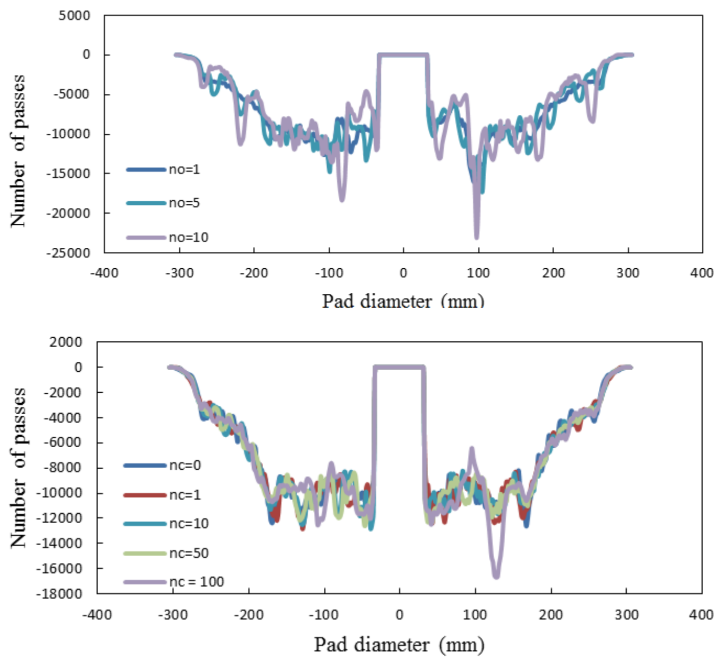
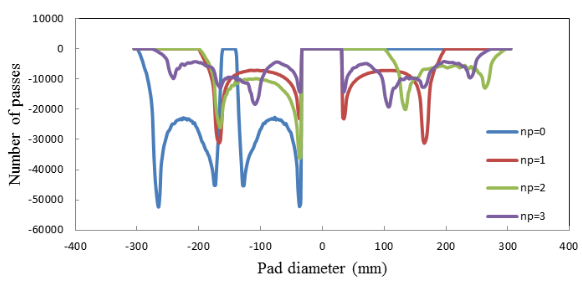



Fig. 2. Effect of the oscillation speed (strokes/min) and the rotational speed (rpm) of the conditioner on the pad wear shape.



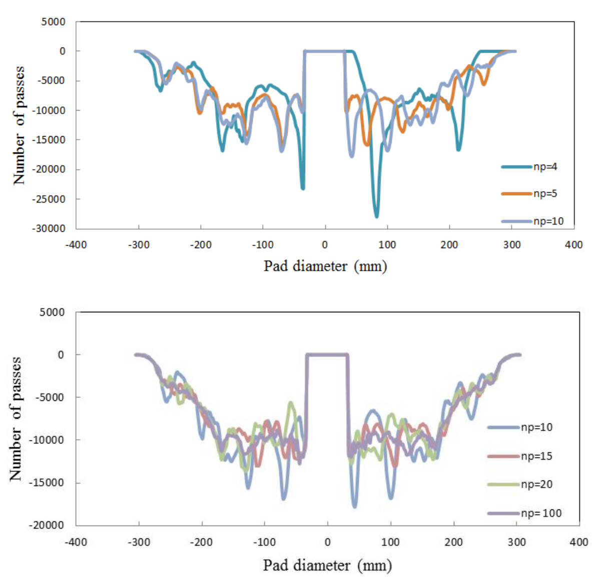




Fig. 3. Effect of the pad speed (rpm) on the pad wear shape.

It can be concluded that the pad speed is the most important factor affecting the uniformity of the pad wear shape. The more the speed of the pad is, the better the pad surface's roughness after the conditioning process is. However, there are not many differences in the pad wear shapes when the pad speed increases. In practice, the pad speed is usually between 10 rpm and 100 rpm. Therefore, in practice, the pad wear shape should not be influenced by the pad speed.

## 3 Improvement design & Discussion

As shown above, the conditioner process parameters do not change the concave of the pad wear shape. Therefore, the pad wear shape cannot be improved by investigating those parameters. On the other hand, the pad size and the conditioner size affect the uniformity of the pad wear shape. The distribution of the grains on the conditioner is also a problem. The pad wear shape depends on the cutting density and the time contact between the pad surface and the conditioner grains[2]. The distribution of the grains on the conditioner surface determines the cutting density on the pad surface. In addition, the pad shape also affects the pad wear shape[11]. Therefore, the best way to improve the pad wear shape is changing the conditioner and pad shapes.

A new model was proposed to get a better uniformity of the pad wear shape. The conditioner is a ring with a width of 15 mm and the inside radius of 290 mm as shown in Fig. 4. It is placed static, no oscillation, only rotation. The distance between its center and the pad center is 160 mm. The pad is modified by creating a hole with a diameter of 200 mm at the pad center. The rotation speeds of the conditioner and the pad can be any value above 10 rpm.

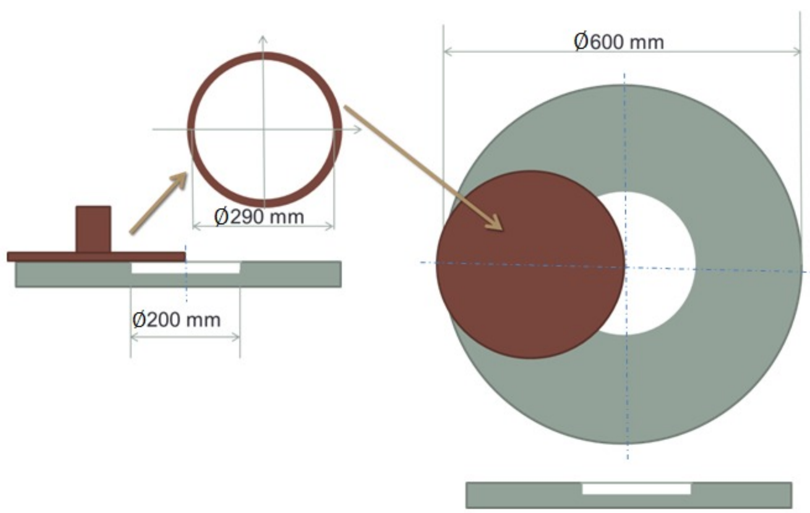



Fig.4. The new conditioner and pad in the new model.

The profile of the pad wear created by the new model is more uniform than that of the traditional model (Fig. 5). Instead of the concave shape, the new model created a slightly convex shape. Although the area of the pad surface in the new model is lesser than the old pad because of the hole at the new pad center, the uniformity of the new pad is much more improved. The flat part in the new pad wear shape is much more than the one in the concave shape. It promises a better uniformity of the wafer surface in the CMP process. In addition, the hole at the pad center can help to eliminate debris created on the pad surface. When debris created by the cutting actions of abrasive grains of the pad on the wafer surface and of the conditioner on the pad surface, it is flew away to the pad hole and out of the pad edge. The lesser the debris on the pad surface, the lesser defects appear on the work piece surface in the polishing process.

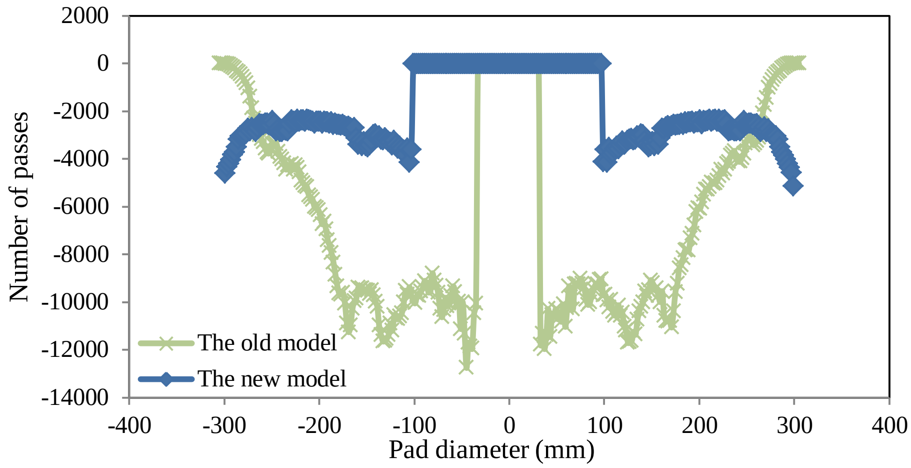



Fig.5. The pad wear shapes of the new model and the old model.

The pad wear shape which is created in the fixed abrasive CMP is similar with the one in the traditional CMP. They are both concave shapes. Therefore, based on kinematic analysis, the model in this research can be used to improve of the pad wear shape of the soft pad.

## 4 Summary

In this paper, the effects of different kinds of speeds, i.e. the rotation speeds of the conditioner and the pad, the oscillation speed of the conditioner, have been investigated, allowing a better understanding of the kinematic aspects of the conditioning process of the polishing with fixed abrasive pad. A new model for the fixed abrasive conditioning process, including a new pad and a new conditioner, was developed. This new model improved the wear shape of the pad caused by the conditioning process. According to the result of the new model, the pad shape after the conditioning process is more uniform than the old one conditioned by the old model.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