Study on atmospheric pressure plasma processing in contact mode

N. Li, B. Wang*, H.L. Jin
School of Mechanical Engineering, Harbin Institute of Technology, China
bradywang@hit.edu.cn

Abstract

The previous designed plasma jet has an obvious drawback of low material removal efficiency during the atmospheric pressure plasma processing (APPP). To solve this problem, a plasma generator which can work in both contact mode and remote mode is developed. And the influences of both modes on the fused silica material processing are investigated. The experiment results show that under the same conditions, the material removal efficiency in contact mode is approximately 1～3 times higher than that in remote mode. This is mainly attributed to the more adequate chemical reaction between the excited atoms and workpiece surface in contact mode.

1 Introduction

In order to solve the low efficiency and the subsurface damaged layer problem in ultra-precision optics fabrication, the APPP technology is developed. It works on the basis of the chemical reaction between active particles excited by plasma and workpiece surface atoms at atmospheric pressure. Thus, it can avoid the subsurface damage caused by mechanical stress and allows, in principle, high-speed removal equivalent to chemical polishing [1].

Previously, plasma jet generators working in the remote mode were designed [2, 3]. The plasma which leaves the nozzle for the workpiece is already away from the electric field. This is not beneficial to maintain the activity of reactive radicals, thus the removal rate will be lowered. To solve this problem, a plasma torch which can work in contact mode is developed. In this mode, since the workpiece is located within the electric field filled with excited plasma, the reactive atoms will be adequately in contact with the surface to produce high removal efficiency. In order to prove that the contact mode is helpful to improving the removal efficiency, the processing effect of contact mode is studied through drawing a comparison between the removal rate in contact mode and that in remote mode.

2 Experimental set-up

In this paper, a plasma chemical machining head which can work in both remote mode and contact mode is developed. In the remote mode, as shown in Fig 1(a), the HF power is applied to the two co-axial electrodes. While in the contact mode, as shown in Fig 1(b), the central aluminium electrode is provided with HF power to perform as anode, the worktable is regarded as cathode, and the fused silica substrate itself is used as dielectric barrier layer.

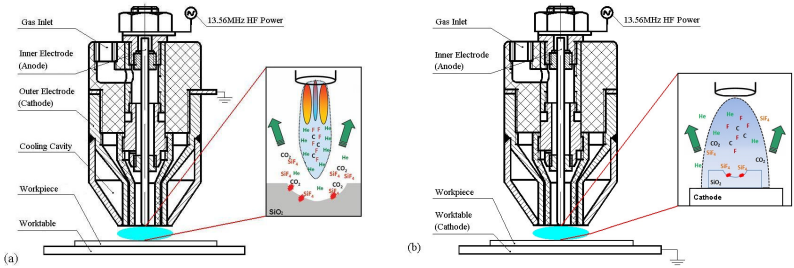

Figure 1: Remote mode(a) and contact mode(b) of plasma chemical machining head.

Fused silica substrates are processed by APPP under various conditions in both modes. The experiment parameters are shown in Table1. Single factor method is adopted in the experiments, and the key parameters of APPP including the flow rate of CF_4 (1), the flow rate of O_2 (2), the input power (3) and the processing time (4) are considered as the unique variable separately.

Table1: experiment parameters

Experiment No.	(1)	(2)	(3)	(4)
He (l/min)	2	2	2	2
CF_4 (ml/min)	10, 20, …, 100	30	30	30
O_2 (ml/min)	10	0, 3, 6, 10	5	5
Distance (mm)	2	2	2	2
Power (W)	260	260	220, 240, 260, 280	250
Time (min)	2	2	2	1, 3, 5, 7

3 Results and discussion

The plasma spectral intensities are monitored real-timely using the spectrometer. And the corresponding removal depths after processing are all measured by the profilometer. The experiment results are shown in Fig 2～ Fig 5.

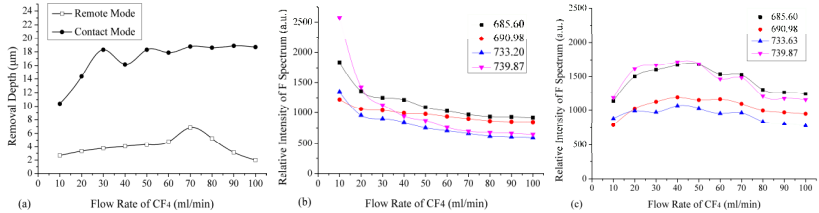

Figure 2: Effects on removal depth in both modes(a), F spectrum intensity in remote mode(b), F spectrum intensity in contact mode(c) by the flow rate of CF_4.

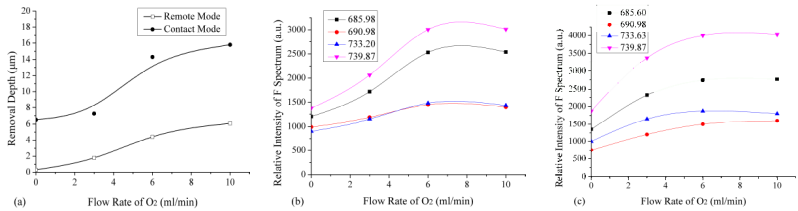

Figure 3: Effects on removal depth in both modes(a), F spectrum intensity in remote mode(b), F spectrum intensity in contact mode(c) by the flow rate of O_2.

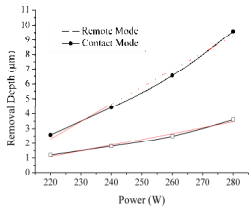

Figure 4: Effects on removal depth by the input power.

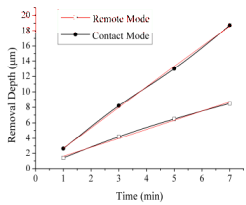

Figure 5: Effects on removal depth by the processing time.

As shown in Fig 2(a), in the remote mode, the removal depth firstly rises with the increase of CF_4 to reach a peak value at 6.85μm (when the flow rate of CF_4 is

70ml/min) and then goes down. Contrastively, in the contact mode, it keeps nearly stable at about 18μm after reaching the peak. However, in Figure 2(b), the change trend of F spectrum intensity does not accord with the removal depth in the remote mode. This is mainly because the "Self-absorption Phenomenon" has happened during this processing. And In Fig 2(c), we can see that in the contact mode, the variation trend of F spectrum intensity roughly goes with the removal depth.

As can be seen in Fig 3, the influence laws on the removal depth and the F spectrum intensity by the flow rate of O_2 are similar in both modes. In a certain range, the addition of O_2 can improve the removal depth. This is because the intermediate products CF_3, CF_2 and etc. ionized from CF_4 can easily react with O_2 to produce COF_2, CO or CO_2. This process will prevent the active particles in plasma from recombination. Then, more active F atoms can be utilized in the chemical reaction.

As shown in Fig 4, the removal depth increases almost linearly with the input power. However, it does not mean that the power can be raised infinitely. When the power is higher than a certain value, the plasma discharge will change to be unstable, and even the arcing phenomenon will occur.

In Fig 5, we can see that the removal depth is more or less constant with the processing time in both modes.

4 Conclusion

Since the removal depth is linear with the processing time, the removal efficency can be simply got by dividing the processing time into the removal depth. As can be seen in Fig 2(a), Fig 3(a), Fig 4 and Fig 5, the material removal efficiency in contact mode is approximately 1～3 times higher than that in remote mode. Therefore, it is proved that the contact mode of APPP is helpful to improving the removal efficiency.

References:

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