Development of a polishing pressure control system for ultra-precision finishing

Jiang Guo[1], Masayuki Hara[1], Hirofumi Suzuki[2,3], Shin-ya Morita[3],Yutaka Yamagata[3] and Toshiro Higuchi[1]
[1]*Department of Precision Engineering, School of Engineering, The University of Tokyo, Japan*
[2]*Department of Mechanical Engineering, Chubu University, Japan*
[3]*RIKEN (The Institute of Physical and Chemical Research), Japan*

guojiang@aml.t.u-tokyo.ac.jp

Abstract

Polishing pressure control plays a key role in the ultra-precision finishing of micro structured molds because it strongly affects the polishing performance. In this paper, a real-time polishing pressure control system is proposed to improve the stability of polishing. The proposed pressure control system mainly consists of a load cell and a piezo-stage which is fixed on a stepper motor stage. The load cell is used to measure the force between the polisher and the workpiece, whereas the piezo-stage is applied to adjust the force with micro/nano positioning change. A PID controller is applied to calculate the command voltage for driving the piezo-stage based on the measured force. This method enables the polishing force to be controlled within a range of 0.2 mN to 200 mN with a resolution of 0.2 mN. Some fundamental polishing experiments have been conducted and the results demonstrate that the proposed method enables a stable polishing.

1 Introduction

Recently, the vibration assisted polishing (VAP) method has been applied to finish the micro structured molds which are highly required in new fields such as Micro channels, Fresnel lenses and Wafer Level Cameras (WLC), and several attractive results have been reported [1-3]. In this method, vibrators can be focused on polishing very small area with high removal efficiency and the scratches generated by cutting or grinding are removed, therefore better surface roughness is obtained. However, the polishing performance is usually unstable due to poor polishing pressure control. The polishing pressure which is the polishing load per unit area is

difficult to be controlled because the contact area between polisher and workpiece is quite small (under 0.2 mm^2) and it is easy to be influenced by many factors such as polishing tool movement and abrasive supply. In our previous research, a balance adjustment mechanism is used to control the polishing pressure with no force feedback; It has a very simple structure and the pressure load can be controlled within a range of 2 mN to 20 mN with a resolution of 2 mN [4]. But it is not stable enough due to the influence as mentioned above. To solve this problem, we propose a real-time polishing pressure control system. The paper begins with the development of the polishing pressure control system. Then through some fundamental experiments, the system performance has been evaluated.

2 Development of the real-time polishing pressure control system

The proposed polishing pressure control system mainly consists of a load cell, a piezo stage and a linear stage driven by a stepper motor. A schematic diagram of the system is illustrated in Figure 1 and the experiment system setup is shown in Figure 2.

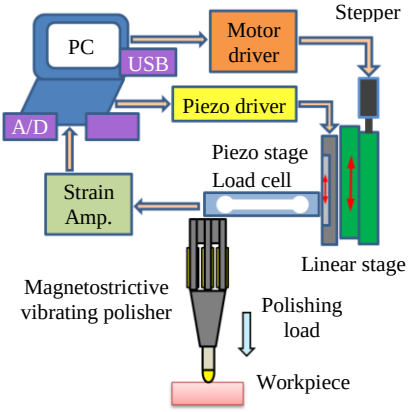

Figure 1: System schematic illustration

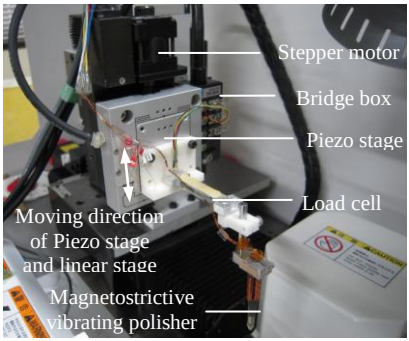

Figure 2: Experiment system setup

The load cell has a rated capacity of 1 N with a rated output of 1 mV/V and it is applied to measure the contact force between the polisher and the workpiece. The piezo stage is fixed on the linear stage and has a very quick response and a high positioning resolution of 5 nm with a travel range of 100 μm which is applied to adjust the contact force with nano/micro positioning change. The force measured by

the load cell is amplified and sent to PC via an A/D converter. A PID controller is applied to calculate the command voltage for driving the piezo stage based on the measured force. The linear stage is used to prevent the force change beyond the travel range of the piezo stage, which leads to the system out of control. It has a large travel range of 20 mm with a high positioning resolution of 0.5 μm and is controlled by PC through RS232 serial communication. If the command voltage exceeds a threshold which is configured in the control program, the linear stage will be driven to compensate the position change. The sampling time of the system is 1 ms. A flow chart of the pressure control is shown in Figure 3.

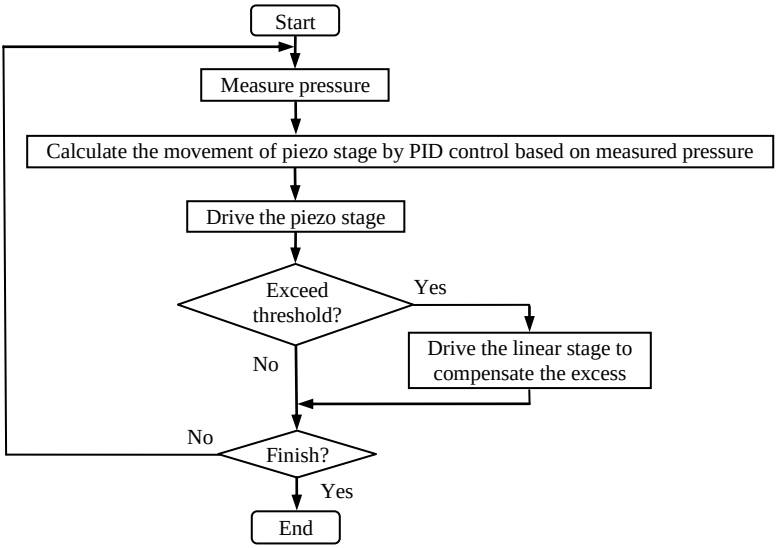

Figure 3: Flow chart of polishing pressure control system program

3 Performance evaluation

Two testing experiments were conducted to evaluate the newly developed polishing pressure control system. In one experiment, we examined the force feedback performance by increasing the desired force with 0.2 mN every second. As shown in Figure 4, the measurement result shows that the system has a high force control resolution with 0.2 mN. Then we compared the pressure change given to a flat workpiece during polishing under pressure control and no pressure control. The polishing tool scanned on the surface of the workpiece and the initial polishing load

was set as 2.5 mN. The scanning distance was 2 mm, and the scanning speed was fixed at 0.36 mm/s. The scanning was performed from 3s to 8s. As shown in Figure 5, the result under real-time pressure control shows a significant improvement in the polishing with constant pressure.

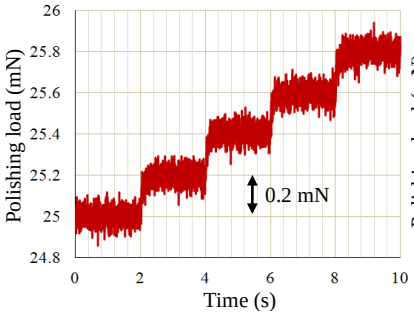

Figure 4: Resolution measurement

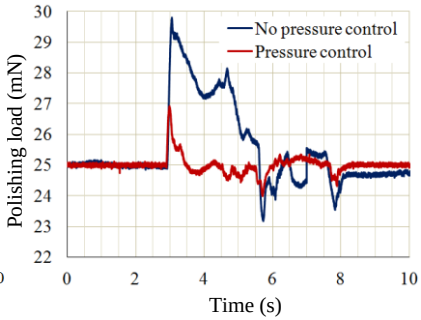

Figure 5: Comparison experiment results

4 Conclusion

The polishing pressure control system which can keep the polishing pressure constant in real-time is developed to improve the stability for ultra-precision polishing. Future investigations will focus on other testing experiments and improvement of this pressure control system to meet the reqiurements of different polishing experiments.

References:

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