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An Experimental Study on the Improvement of Microscopic Machinability of Glass using the Discharging Peak Control Techniques in the Electrochemical Discharge Machining Technologies

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Electrochemical discharge machining is a very recent technique for non-conducting materials such as ceramics and glasses. ECDM is conducted in the *NaOH* solution and the cathode electrode is separated from the solution by H_2 gas bubble. Then the discharge is appeared and the non-conductive material is removed by spark and some chemical reactions. In the ECDM technology, the H_2 bubble control is the most important factor to stabilize the discharging condition. In this paper, we proposed the discharge peak monitoring/ discharging duty feedback algorithms for the discharge stabilization and the feasibility of this algorithm is verified by various pattern machining in the constant preload conditions for the cathode electrode..

Keywords : ECDM(electrochemical discharge machining), Glass machining, MEMS, micro-channel

1. INTRODUCTION

The glass, due to its transparency and its chemical resistance, is often used in MEMS technology in combination with silicon wafers that have integrated mechanics and electronics. ECDM is an alternative solution to the laser machining, the etching with HF or normal drilling and milling with special tools. The experimental results show that the proposed system gives uniform discharging condition that the shapes of the machined hole, channels and surfaces by ECDM are quite nice, under the constant preload condition for the tool without any feedback motion control in vertical direction.

2. THE PRINCIPLES OF ECDM FOR GLASS

When the voltage is applied in the machining glass material with ECDM technology, H_2 bubbles are generated at the cathode and O_2 at the anode. The two electrodes are separated from the solution by a gas film and sparks are generated through the bubbles around the cathode. The removal of glass takes place at the cathode, where discharges appear. The erosion of the glass is not only thermal, due to the spark generation, but also chemical due to the chemical attack of the glass by the alkali solution[6].

The etching reaction of the glass is:

$$2NaOH + SiO_2 \rightarrow Na_2SiO_3 + H_2O$$

Therefore, in order to machining the glass material in a micro-scale, the discharging voltage should be reduced to the critical voltage of 25V~30V that Gosh[4] and Langen[6] have proposed, to minimize the machining effect by the discharging spark and make the etching process by NaOH reaction into the major machining mechanism.

3. EXPERIMENTAL SET-UP

The title of the paper should appear in 12-point **bold** In order to maintain the uniform thickness of electrolyte film on the glass workpiece to stabilize the rate of bubble generation at the ECDM electrodes and to maintain the constant distance between the tool (cathode) and anode, the head block for electrodes is composed as shown in Fig. 1.

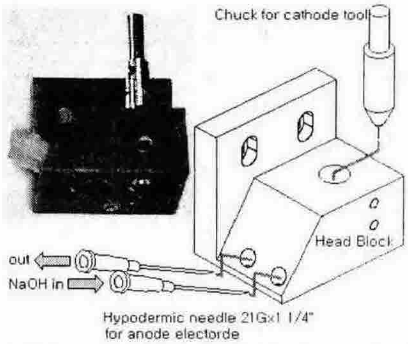

Fig. 1 Schematics of the head block and electrodes

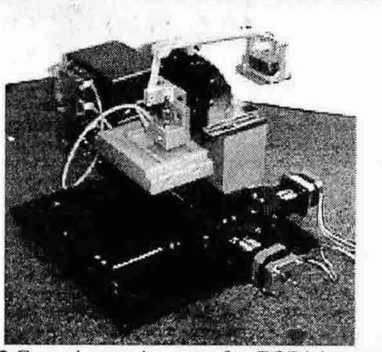
Fig. 2 Experimental set-up for ECDM patterning

The head block is attached to the linear motion table, which is guided by the cross roller bearings for vertical movement. In order to investigate the effect of the stabilization of discharge peak to the machinability of glass material, the lever mechanism, which is supported by the knife type edge, is attached to the table for vertical direction as shown in Fig. 2 and the ECDM is performed with the tool press the workpiece in a constant pressure. The X-Y table, which is driven by the stepping motors, moves the workpiece, but the tool gives the constant pressure only to the workpiece in vertical direction.

In order to generate the electrochemical discharge in the NaOH solution, the LC type discharging circuit, whose duty ratio of the power supplying time is controlled by the field effect transistor(FET), is composed as shown in Fig. 3. In the LC type discharging system, the supply voltage is the critical value of 30V to initiate the electrochemical discharge, the inductance is 4 mH, the capacitance is 156.7 μF and 15W% NaOH solution is used for the electrolyte. The LC type circuit for discharge generation is governed by the FET and its duty ratio is modulated by the microprocessor. In order to monitor the discharging intensity, the circuit for detecting the voltage variation of discharging peak is adopted as shown in Fig. 4. The voltage pickup location for discharging peak monitoring is the needle for anode, which supplies the electrolyte.

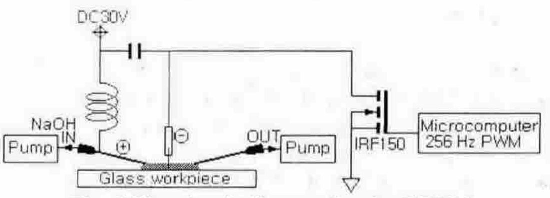

Fig. 3 The circuit diagram for the ECDM

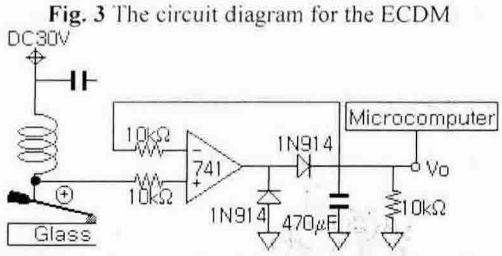

Fig. 4 Peak detector circuit for monitoring the voltage variations of the electrical discharge

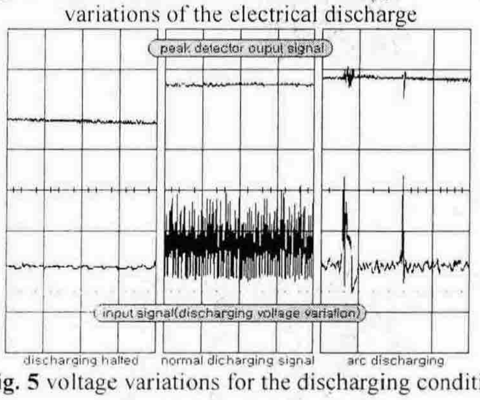

Fig. 5 voltage variations for the discharging conditions

The monitored results for the discharging voltage and its peak variations are shown in Fig. 5. The discharging is halted by the excessive NaOH solution of leak of hydrogen bubbles and the output voltage signal from the peak detection circuit is diminished. In order to re-initiate the discharge, the duty ratio of the PWM algorithm should be increased. On the contrary, the excessive hydrogen bubbles increase the erosion of electrodes and reduces the material removal rates. The experimental observation shows that the reduction of the duty ratio of the PWM algorithm makes the normal discharging conditions.

3. ECDM PATTERNING ON GLASS

The various patterns of line are machined using a discharging peak voltage variation monitoring and PWM feedback algorithm. The X-Y table, which is driven by the stepping motors of 10μm/pulse resolution and supported by linear guide systems, moves the workpiece and the feed rate is 10μm/2sec in each direction. The Fig. 8(a) and its magnified shapes of (b) are the case of 50 grams preload. In this case, the contact force between the tool and glass material is not enough during the ECDM procedure that the scallop appears to the machining direction. Increase the preload to 200 grams and the increase of the contact force improve the quality of the machined surface as shown in Fig. 8 (c) and (d).

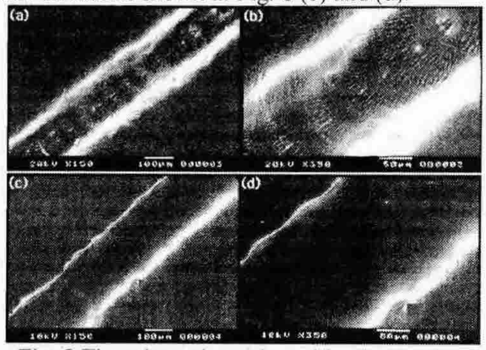

Fig. 8 The micro-channel machined on a glass

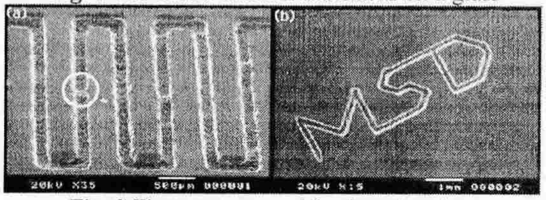

Fig. 9 The patterns machined on the glass

Fig. 9 shows the machined results for the 2-dimensional micro-channel patterns. In the circle of the Figure 9 (a), the discharging is interrupted for a moment during the ECDM procedures that the machining is not sufficient. The few more insufficiently machined places are found in the channel, but almost all the channel is machined very nice.

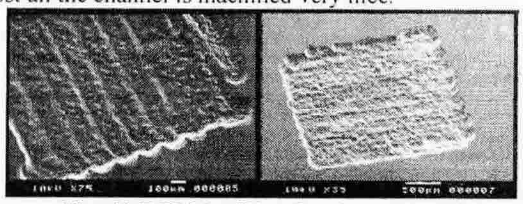

Fig. 10 ECDM milling for glass material

Fig. 10 shows the machined result for 2-dimensional milling with ECDM technology. The machining is performed for the 2000μm x 2000μm region by feeding speed of 10μm/pulse-2sec and 100 mm span. The machined surfaces are relatively rough because of the various reasons. But this machining is performed only with the preloaded conditions for vertical direction that if the active position control algorithm is adopted in vertical direction, it is possible to improve the surface roughness and the shape completeness.

4. REFERENCES

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