METHOD FOR CONTROLLING THE CIRCULAR TYPE MICRO HOLE SIZE ON STAINLESS STEEL THIN FILM BY PHOTORESIST ETCHING

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Abstract - Fast development of wafer level packing (WLP) in recent years is mainly owing to the advances in integrated circuit fabrication process and the market demands for devices with high electrical performance, small form factor, low cost etc. Evaporating and electroplating are the two wafer solder bump processes in production today. Evaporating is high cost, and can not produce eutectic solder bumps due to the Sn and Pb vapor pressure difference. Electroplating is a relatively low cost option, but it requires photoresists steps that add to the cost and plated bump composition is not easy to control due to differences in Sn and Pb electrochemical behavior. Stencil print technology is a well established process used in surface mount board assembly. Technology advances in solder paste, stencil fabrication, and printing equipment make it possible to print Sn/Pb solder paste onto wafer to form bumps. Nowadays, there are three types of stencils available, chemical etching, laser cut and electroformed. Chemical etch stencils are cheap, but has the dimension and accuracy limitation. In this study, for improving the dimension and accuracy of stencil hole size, the etching conditions and methods for controlling the circular type micro hole size on 50µm thickness stainless steel has been investigated. For controlling the machined hole size with etching method, the relationship between dry film photoresist coating size after exposure and development and machined hole size has been compared. And also, the hole size machining limitation of etching method has been confirmed.

Keywords - Stencil Printing, Stencil Mask, Stainless Steel Thin Film, Etching

I. INTRODUCTION

Miniaturization and high performance demand more and more flip chip and chip scale packages in consumer products. High cost bumps for high end applications are not suitable and cost effective for these products. Developing a low cost bump technology is essential for low cost flip chip based CSP packages [1-2].

Evaporating and electroplating are the two wafer solder bump processes in production today. Evaporating is high cost, and cannot produce eutectic solder bumps due to the Sn and Pb vapor pressure difference [3]. Electroplating is a relatively low cost option, but it requires photoresist steps that add to the cost, and plated bump composition is not easy to control due to differences in Sn and Pb electrochemical behavior. Nowadays, technology advances in solder paste, stencil fabrication and printing equipment make it possible to print solder paste onto wafers to form bumps.

Stencil print technology is a well established process used in surface mount board assembly. Solder paste is deposited on the printed circuit board, and the pick and place machine places the component leads on the paste pads. Solder joints are formed after reflow. The print process control is an important segment in board assembly. The normal package lead pitch is larger than 400µm. To use this traditional technology to print on wafers, the main challenge is the reduced print pitch of the die I/O pads, which is normally less than 300µm, and becomes finer as the number of I/O increases. The process development is focused on the solder paste material selection, stencil design, and print process optimization to achieve the print pitch down to 200µm and less.

Nowadays, there are three types of stainless steel stencils available, chemical etching, laser cut and electroformed. Laser cut stencils are accurate, but the sequential processing can make costs prohibitive for wafer applications. And electroformed stencils provide fine pitch accuracy, but it needs final flatness improvement process after machining. Chemical etch stencils are cheap, but has the dimension and accuracy limitations [4].

Therefore, in this study, for improving the dimension and accuracy of chemical etched stencil hole size, the etching conditions and methods for controlling the circular type micro hole size has been investigated. For controlling the machined hole size with etching method, the relationship between dry film photoresist coating size after exposure and development and machined hole size has been compared. And also, the hole size machining limitation of etching method has been confirmed.

II. EXPERIMENTAL DETAILS

A. Photolithography on Stainless Steel Thin Film

To fabricate the stencil mask, 50µm stainless steel 304 thin film was applied. The coating process was conducted to prepare the micro-sized hole array on stainless steel surface. The photoresist is the negative type and the thickness of the DFR film (Hitachi. Ltd)

29µm. And the lamination has been carried out. The DFR roll temperature is 110℃, the roll speed is 3m/min and the roll pressure is 0.4Mpa. After the lamination, the sample has been held for 20min in 20℃ temperature. The mask used in the exposure is Cr glass mask which has different size circular type as shown in Fig. 1. The patterned hole sizes are 80µm, 100µm, 120µm, 150µm and 180µm.

Fig. 2 shows the process of making a pattern on stainless steel thin film using dry film photoresist. The dry film photoresist is negative type, therefore in the patterned portion of the glass mask, UV light is not received during exposure, and the dry film is not cured and could be peeled by developing solution. The exposure energy is 100mJ/cm^2 and the developing solution is 1 wt% Na_2CO_3 aqueous and the temperature is 25℃. Dipping type development has been applied and the development time is 50 seconds. After development the water spray has been carried out and nitrogen gas gun has been used for drying the stainless steel thin film. Fig. 3 shows the stainless steel thin film after dry film photoresist lithography process and the detailed spec.

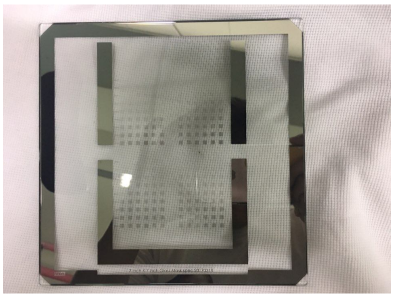

Fig. 1 Cr Glass Mask with Different Micro- Hole Array

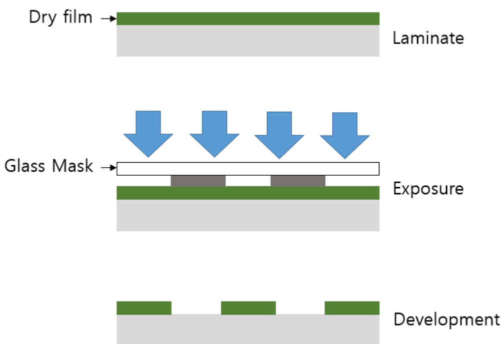

Fig. 2 Dry Film Photolithography Process

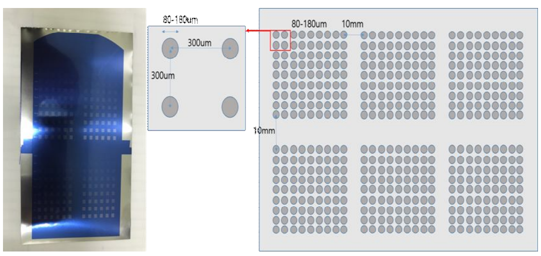

Fig. 3 Stainless Steel Thin Film after Dry Film Photoresist Lithography process

B. Wet Etching and Wet Etching System

Etching has been applied to fabricate stencil mask in industry. The etching properties of stainless steel sheet have been studied to make high quality products. The characteristics in spray type etching have also been studied, and the etching rate depends on the viscosity of the spray.

However, several problems occur in the manufacturing of stencil mask using wet etching method. First, the stainless steel contains impurities, so some areas could not be etched. In addition, with the pattern size decreased, the etchant could not penetrate properly, therefore, non-etched regions could be occurred. And etching has an undercutting phenomenon, which means that it could be difficult to get an vertical micro-size hole section.

Fe, Cr and Ni constituting the stainless steel 304 and can be machined by etching reaction with aqueous solution of ferric chloride ($FeCl_3$). The Fe^{3+} ions contained in the aqueous solution and can diffusing the metal from the surface. After the reaction, the ions desorbed from the metal surface are released. Micro-hole machining of stencil mask is performed as these chemical reactions repeatedly performed [5].

Experimental work was performed using a home built spray type wet etching system. Fig. 4 shows the spray type wet etching system and Fig. 4 shows schematic layout of wet etching system. The jig which can fix sample using taping method with polyimide tape which can oscillate. In this experiment, the spray pressure has been fixed as 0.08Mpa, etchant is 30wt% $FeCl_3$ solution and oscillation speed is 0.5Hz. And also the etchant temperature has been fixed as 30℃ as shown in table 1. After etching process, the stainless steel sample has been washed using DI water with ultrasonic vibration. And the dry film photoresist on the stainless steel has been removed using 10wt% NaOH solution.

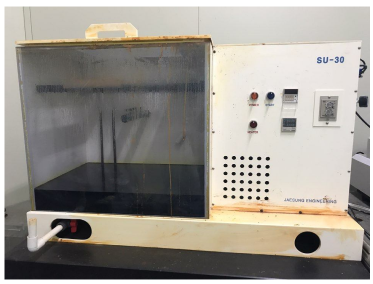

Fig. 4 Spray Type Wet Etching System

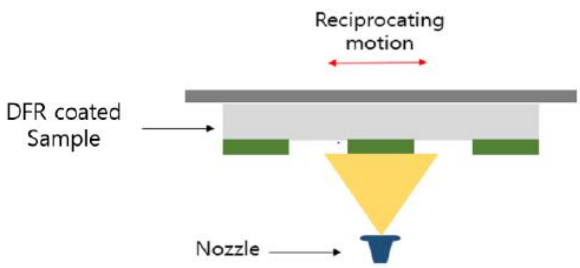

Fig. 5 Schematic Layout of Wet Etching System

Conditions	Values
Etchant	30wt% $FeCl_3$
Spray Pressure	0.08MPa
Temperature	30℃
Oscillation Speed	0.5Hz
Machining Time	300s – 600s

Table 1 Spray Type Wet Etching Conditions

III. EXPERIMENTAL RESULTS

A. Dry Film Photoresist Wet Etching with Different Patterned Micro Hole Size

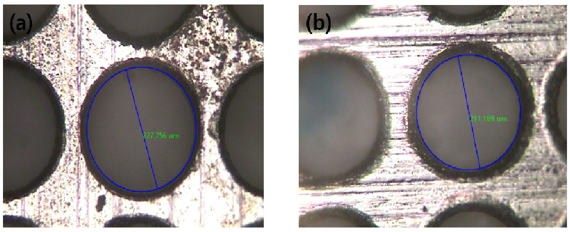

Fig. 6 Optical microscope images of machined stencil mask after 360s (a) 180μm and (b) 150μm dry film photoresist pattern

Dry film photoresist wet etching test with different patterned micro hole size have been applied. Fig. 6(a) shows 180μm patterned micro hole after wet etching. The diameter hole machined hole is about 227μm, which means that the diameter has been increased about 50μm. And Fig. 6(b) shows 150μm patterned micro hole after wet etching. The machined hole diameter is about 210μm and increased about 60μm after wet etching. This is because of that, when the machined hole diameter increase, the removed material will be increased in square, therefore, the machined hole size will increase slowly when the patterned dry film size increase.

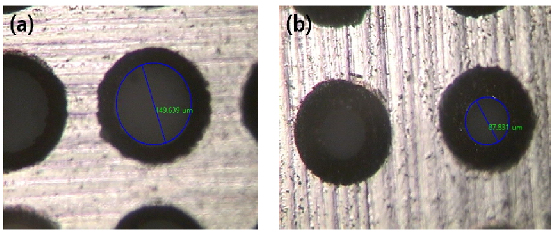

Fig. 7 Optical microscope images of machined stencil mask after 360s (a) 120μm and (b) 100um dry film photoresist pattern

Fig. 7 (a) and (b) show 120μm and 100μm dry film photoresist patterned stencil mask after wet etching for 360s. The machined hole size of 120μm patterned mask is about 150μm and 100μm patterned mask is 87μm. In this experiment, we can see that the machined hole size could be smaller than dry film photoresist patterned size. When the exposed stainless steel surface decreased, the surface area which can progress etching reaction decreased in square, too. However, the undercutting phenomenon will be occurred largely, with the machined hole size decreased.

So, this is important to find the proper dry film photoresist patterned size and wet etching process time for obtaining small machined stencil micro hole size.

B. Dry Film Photoresist Wet Etching with Different Machining Time

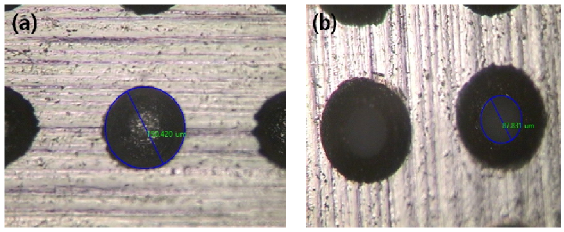

Fig. 8 Optical microscope images of machined stencil mask with 100μm dry film photoresist patterned after (a) 300s and (b) 360s wet etching process

For obtaining proper conditions to get smaller micro hole array with small undercutting, dry film photoresist wet etching with different process time have been applied. Fig. 8(a) shows 100μm patterned hole array after 300s wet etching process. The stainless steel thin film has not through machining, and 150μm size dimple array has been obtained. And after 60s more wet etching process, the thin film has been obtained hole array with about 90μm diameters.

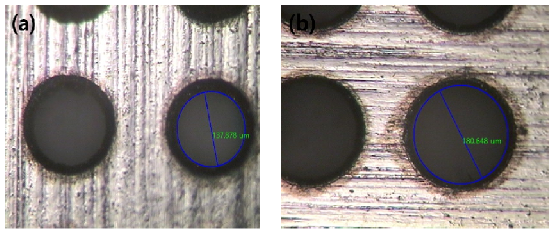

Fig. 9 Optical microscope images of machined stencil mask with 100μm dry film photoresist patterned after (a) 420s and (b) 480s wet etching process

Fig. 9(a) and (b) show machined hole arrays after 420s and 480s wet etching process. The 135μm level machined hole array has been obtained after 420s, and it continues to increase with the process time and gets 180μm level after 480s etching process.

And we found that with the hole size increases the undercutting phenomenon will be decreased, which is very important for stencil mask specification. The experimental results show that the machined hole array size could be decreased under 135μm diameter size only if the dry film photoresist size decreases.

C. Dry Film Photoresist Micro-Hole Wet Etching Size Limitation

In order to obtain micro hole array under 135μm diameter, wet etching process with 80μm dry film photoresist has been applied. During the experiment, we found that with the decrease of patterned dry film photoresist size, the hole wet etching process time will be increases due to decrease of etchant contact area.

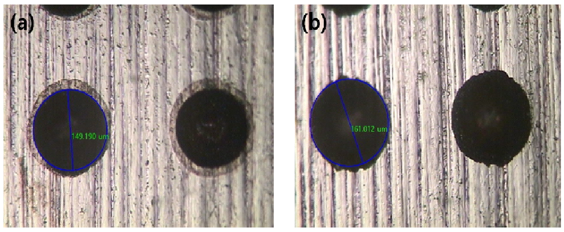

Fig. 10 Optical microscope images of machined stencil mask with 80µm dry film photoresist patterned after (a) 360s and (b) 420s wet etching process

Fig. 10 (a) and (b) shows dimple array after 360s and 420s wet etching using 80µm dry film photoresist pattern. Compared to 100µm dry film photoresist patterned film, it does not obtained machined hole after 420s etching process. And even after 60s wet etching it does not get hole array as shown in Fig. 11(a). After 540s wet etching process using 80µm dry film photoresist patterned film, we could get 130µm hole array with high uniformity and small undercutting phenomenon. Experimental results show that the machined hole array diameter could be decreased with the dry film photoresist patterned size. However, the etching process time will be increased for getting through hole array. And with the increase of hole size the undercutting phenomenon will be reduced, and also the uniformity of hole array will be increased. This type spray wet photoresist etching method is appropriate for obtaining 130 to 150 µm stencil mask fabrication. However, with the decrease of stencil mask hole size, both side dry film photoresist and bot side spray type wet etching will be demanded.

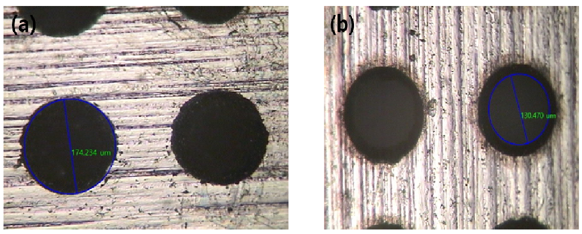

Fig. 11 Optical microscope images of machined stencil mask with 80µm dry film photoresist patterned after (a) 480s and (b) 540s wet etching process

CONCLUSION

In this study, for improving the dimension and accuracy of stencil hole size, the etching conditions and methods for controlling the circular type micro hole size on 50µm thickness stainless steel has been investigated.

Experimental results show that the machined hole array diameter could be decreased with the dry film photoresist patterned size. However, the etching process time will be increased for getting through hole array.

With the increase of machined micro hole size, the undercutting phenomenon will be reduced, and also the uniformity of hole array will be increased.

This type spray wet photoresist etching method is appropriate for obtaining 130 to 150 µm stencil mask fabrication. However, with the decrease of stencil mask hole size, both side dry film photoresist and bot side spray type wet etching will be demanded.

ACKNOWLEDGEMENT

This research was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2015R1A2A1A15054116).

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