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Study on Undercut Characteristics of Die Steel in Spray Etching

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Abstract. The NAK80 die steel was processed in spray etching with mask preprocessing.The effect of the mask gap width and etching depth on the undercut ratio was investigated . The result shows that with the increase of the mask gap width the effect of the etching depth on the undercut ratio increases. Based on the experiment, the relation of the mask gap width, the etching depth and the undercut ratio is obtained.

Introduction

Chemical-etching, for its simple operation, high precision and low cost, is widely used in the printing of PCB board, metal precision machining, microelectromechanical system(MEMS) manufacturing and other fields[1,2]. The etching result is affected by the mask gap width, etching depth, undercut and other factors[3]. Since the corrosion of the majority material is isotropic, the etching was processing in the vertical direction, as well as in the width direction.And that results in undercut[4]. Undercut, caused by non-locality erosion on the metal, contributes to deviation of the etching size and deterioration of the dimensional accuracy. The convex graphic lines or outlets become thinner and smaller while the concave graphic lines or outlets become thicker and larger. These limit the accuracy of the etching processing[5]. It is necessary to study the relevant parameters that have impact on undercut. It will be a significance guiding to control the undercut amount and to improve the quality of the etching processing. In this paper, the NAK80 die steel is processed by spray etching. By changing the mask gap width ,the influence on the undercut ratio is observed.

Experimental section

A spray etching machine with hydraulic circulation system is used in these experiments. The spray pressure of the etching solution can be adjusted through the relief valve. The rotal workbench is applied to guarantee the uniformity of the etching. The experimental material is round lump NAK80 die steel with roughness less than Ra1.6. One-side of the sample is masked with degreasing and drying pretreatment. The mask material is photosensitive blue oil whose main component is resin-based ink. After the photo-curing and heat-curing, the mask has a strong acid resistance and a good adhesion to the sample. These characteristics can meet the requirements of the spray etching. The mask pattern size is 450×450μm with no missing spots, no dead pixels and uniform thickness. $FeCl_3$ is chosen as a main etching solution component. The spray pressure is set 0.6psi in the text. Stripping is needed after etching. Surface rust treatment should be done in order to ensure the effect of the subsequent process. Processing experimental flow chart is shown in Fig.1.

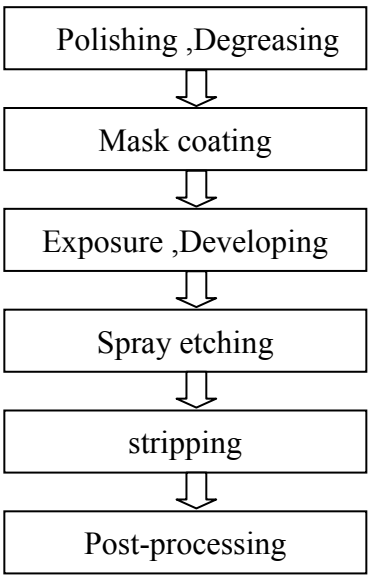

Fig.1.Etching process flow chart

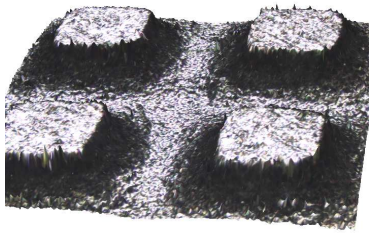

Fig.2.Micro-etching effect on die steel

The surface of the etching sample is convex-concave rolling microstructure. After process, it is found that the morphology structure is uniform with small size deviation. The partial microstructure of the etching sample is shown in Fig.2.

It can be observed that protrusions at the top surface is less than that at the bottom.The main factor of it is undercut.The cross section of a microstructure model is shown in Fig3.The laser scanning confocal microscope OLY4000 is used to measure the size .The undercut amount a and the undercut ratio k are calculated through the Eq. 1, Eq. 2:

$$c=a-b \quad (1)$$

$$k=c/d \quad (2)$$

Where, a *is* the upper line width.b *is* the lower line width. h *is* the etching depth.d *is* the mask gap width .

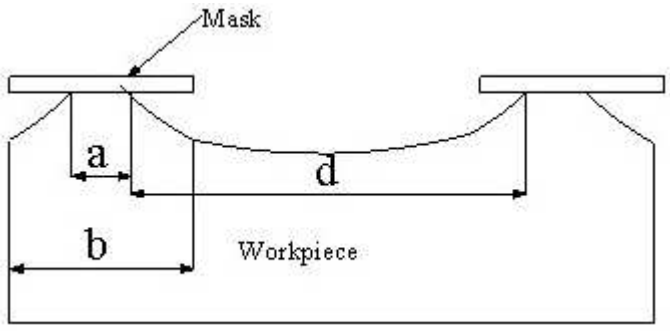

Fig.3. The schematic diagram of etching

Experimental results and discussion

In order to analyse the influence of the mask gap width and etching depth on the undercut,several experiments are carried out. All samples are carefully measured, especially the etching depth , the upper and lower line width of the convex. Fig. 4 to Fig.7 illustrate the relationship between etching

depth and undercut ratio with the mask gap width,respectively 100um, 150um, 200um, 250um. Fitting correlation is analyzed in origin software and the following parameters are obtained: R_{100}^2=0.9956，R_{150}^2=0.99534，R_{200}^2=0.98349, R_{250}^2=0.99228.

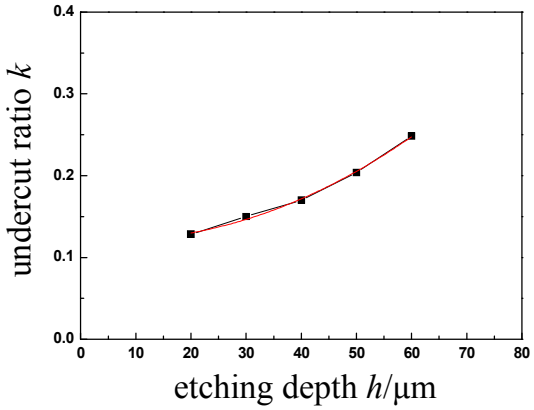

Fig.4.The relation of undercut ratio and etching depth in width of 100μm

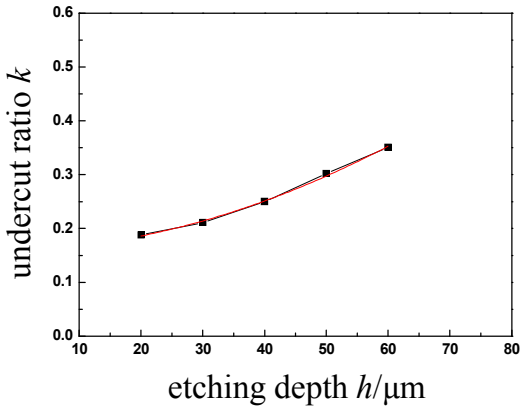

Fig.5.The relation of undercut ratio and etching depth in width of 150μm

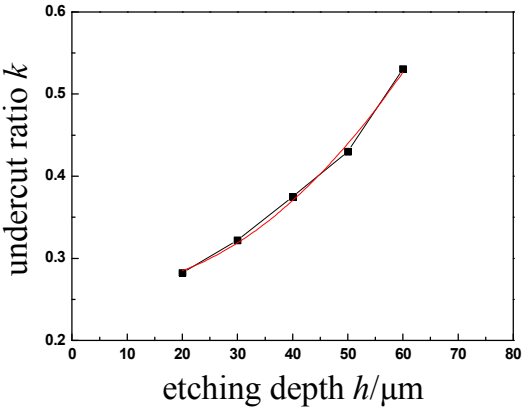

Fig.6.The relation of undercut ratio and etching depth in width of 200μm

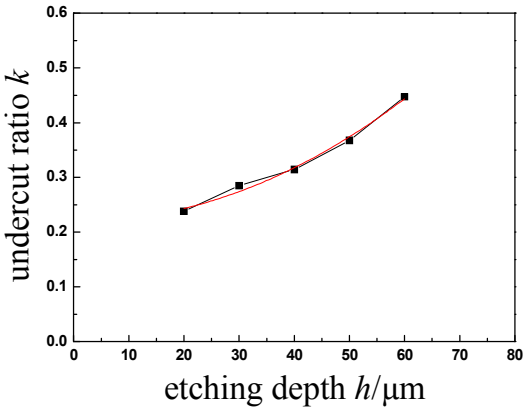

Fig.7.The relation of undercut ratio and etching depth in width of 250μm

As can be seen from these figures, etching depth and undercut ratio present a linear relationship in the same mask gap width. As the metal of the surface is removed to form pits ,new metal surface exposes around the pits. Etching continues to occur in the pits. The material removal in the vertical and the lateral direction are substantially the same since other processing conditions are the same. The conclusion is consistant to Ling Tian e.g.[6].The influence of the etching depth on the undercut ratio increases as the rise in the mask gap width. X. Zhu[7] found that the smaller size of the mask gap width, the more difficult to update the etching solution, so the erosion rate decreases. With the mask gap width increases, there are the less hindered for the etchant.

Once etching reacts fully, etching rate increases. The vertical and lateral erosion are enhanced, so does the affect of etching depth on the undercut ratio which leads to more undercut. Laermer[8] found that in order to obtain a certain depth while maintain a good dimensional accuracy, it needs to control the undercut. A higher etching rate and a suitable mask gap width should be taken. The etching depth should be controlled within a certain range.

M=dk/dh presents the impact factor of etching depth on the undercut ratio. From figure 4 to 7, M is calculated respectively:M_{100}=0.003, M_{150}=0.00407, M_{200}=0.00523, M_{250}=0.0062.Through data

analysis and linear fitting ,the relation between the mask gap width and the factor M is shown in Fig.8.The mask gap width and the undercut ratio present a linear relationship. The equation of the mask gap width and the factor M can be expressed as Eq. 3:

$$d=AM+B \tag{3}$$

Where, d is the mask gap width with unit of μm. M is the impact factor of etching depth on the undercut ratio. A and B are constant coefficients (relevant to etching condition parameters).

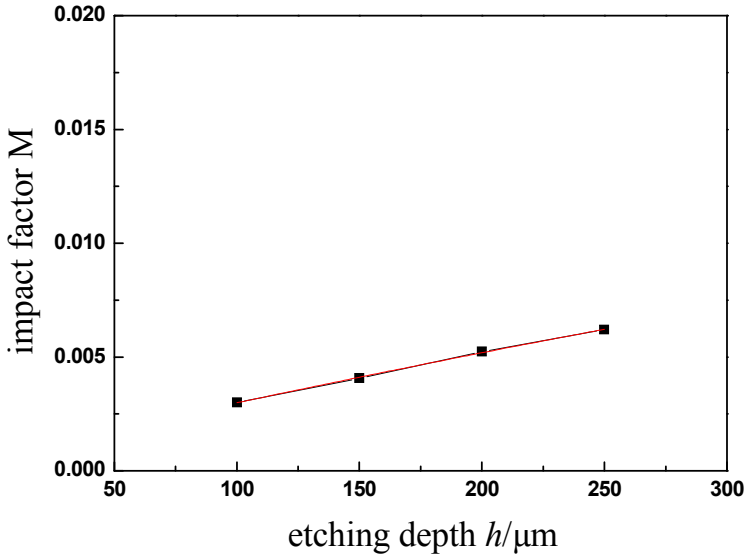

Fig.8. The relation of the mask gap width and the M value

Keeping other processing conditions unchanged, the efficient A and B can be calculated through the etching depth and the undercut ratio in etching processing.Accordingly ,it can be estimated the relationship between etching depth and undercut ratio of different mask gap width.Taking into account of the changes in etching depth and undercut helps to ensure the machining accuracy of the mask processing.

Conclusions

(1)The mask gap width and etching depth affect the undercut amount and undercut ratio. With the same mask gap width, the undercut ratio increases as the etching depth rises. Basically, both of them meet the direct proportion. And when the mask gap width increase, the effect of etching depth on the undercut ratio increases.

(2)Through numerical analyse, the relationship between the etching depth, the undercut ratio and the mask gap width is deduced. Based on these, estimate the undercut amount corresponding to different etching depth and different mask gap width. Controlling etching depth and undercut amount within a certain range helps to improve the dimensional accuracy of the etching process.

Acknowledgements

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References

[1]Piao Liu: J. Corrosion and Protection Vol.28 (2007), p. 238-241 (In Chinese)

[2]Yongsheng Chen, Jianhua Wang: J. Wuhan Institute of Chemical Technology Vol.24 (2003), p. 64-67 (In Chinese)

[3]Lingjun Sun, Junsheng Liang: J. Micro-mechanics and Micro-engineering Vol.19 (2009), p. 1-8

[4]Jingwei Liu, Gary K.Fedderl: Silicon Undercut Characterization in a CMOS-MENS Process (Transducers and Euroseasors'07, Lyon, France, Jun.2007) pp. 505-508.

[5]Chunpu Li: J. Screen Printing Industry Vol.8 (2007), p. 36-37 (In Chinese)

[6]Ling Tian, Zhidong Li: J. Printed Circuit Information Vol.12 (2007), p.55-56(In Chinese）

[7]X. Zhu,:PhD thesis, CMU J. Materials processing technology Vol.99 (2008), p.337-340

[8]Laermer F, Schilp A, Funk K,et al:Bosch Deep Silicon Etching Improving Uniformity and Etch Rate for Advanced MEMS Applications, 12th IEEE Int Conf on Micro Electro Mechanical Systems,Orlando ,FL ,USA , Jun.17-21, 1999, pp.211-216