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A Study of Design Optimization Using Response Surface Analysis and Fabricaiton MEMS Probe Tip

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Abstract

In semiconductor manufacturing process, probe station that is testing equipment is important. Inspection step is for detecting defects on semiconductor before the packaging. Probe card is a part of probe station and contains probe tip that contacts to semiconductor. Through probe tip, it can inspect defects of semiconductor. In this paper, optimization method is used with response surface analysis to design MEMS type probe tip. And fabricating probe tip uses maskless lithography, electro-plating and lapping process.

Keywords

Probe Tip, Semiconductor, Maskless Lithography, Response Surface Analysis, Optimization

1. Introduction

Recently, semiconductor technology develops to highly integrate and compact. So testing process for semiconductor is also developed [1]. Probe station is test equipment for chips on wafer, using probe tip involved in probe card for testing [2]. Probe card can be classified into cantilever, vertical and MEMS (Micro Electro Mechanical System) types [3]. In this paper, we design MEMS type probe tip using optimization method with response surface analysis and fabricate probe tip through maskless lithography, electro plating and lapping process.

2. Probe Tip Design Optimization Using Response Surface Analysis

2.1. Probe Tip Design and Structure Analysis

For proper performance of probe tip, few conditions are needed. Not damage to semiconductor, enough displacement for contact with semiconductor, superb fatigability that is caused from repeat motion, and good electrical conductivity for transmit electrical ignal. Additional, probe tip is needed more than 2 gf contact force for stable contact with semiconductor [34].

In this paper, we fabricate probe tip as blade type that is used for FoC (Film on Chip). Set initial values using

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structure analysis for optimization with response surface analysis. We design probe tip as shown **Figure 1**. The basic size of probe tip are L = 2.0 mm, W = 0.2 mm, T = 0.045 mm and progress structure analysis. We fabricate probe tip using electro plating with Nickel, so properties of probe tip that we made are different from general Nickel materials. From this reason, we measured properties of Nickel that made from electro plating and use these data for analysis [5]. The value of electro plating Nickel is shown as **Table 1**.

Mesh and boundary condition of analysis is shown as **Figure 2**. Fixed points are part that adhere to interposer and vertical displacement point is bottom of cantilever beam that contact with semiconductor. Under these conditions, we confirm stress distribution of probe tip cause from vertical over drive. Structure analysis mesh is 50 um tetrahedrons mesh

Form the result of structure analysis, maximum stress occur at the point that is linked with main body of probe tip and maximum strength is 751.48 MPa. This value is under the yield strength of Nickel, so probe tip that we design is suitable. But we cannot assure this design is best, so progress optimization of probe tip using response surface analysis.

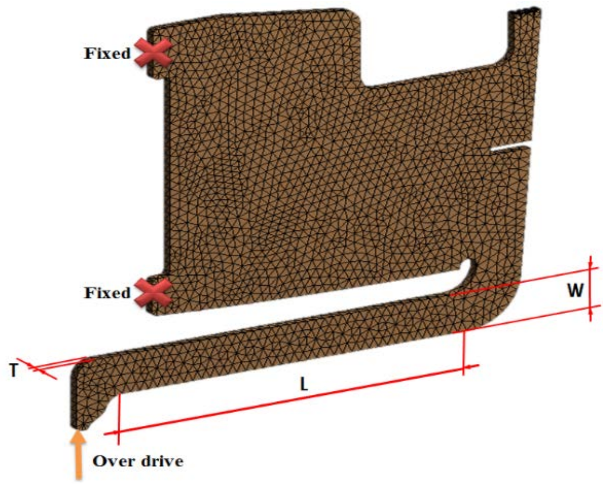


Figure 1. Figure and mesh of probe tip.

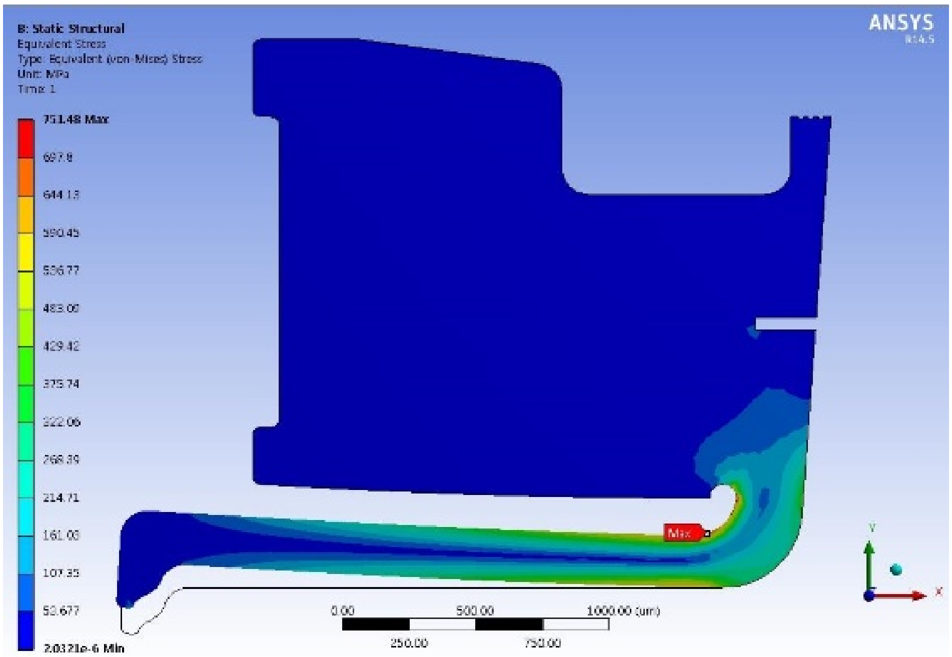


Figure 2. Result of equivalent stress of probe tip.

2.2. Design Optimization of Probe Tip

For design optimization use analysis software Ansys 14.5. Design variables range are length 2.0 - 2.5 mm, width 0.15 - 0.20 mm, thickness 0.045 - 0.050 mm, over drive 100 um displacement as shown in **Table 2**. Use two boundary conditions for optimization minimum contact force 2 gf and yield strength of nickel 860 Mpa.

Figure 3 are results of response surface analysis stress and contact force by length, width and thickness. First, in case of stress, as over drive increase, length, width and thickness are also increased (**Figure 4**). As length increase, stress is decreased and the width is boarder, the stress is bigger. But as thickness increase, stress is decreased till 0.0475 mm and after that point stress is increased.

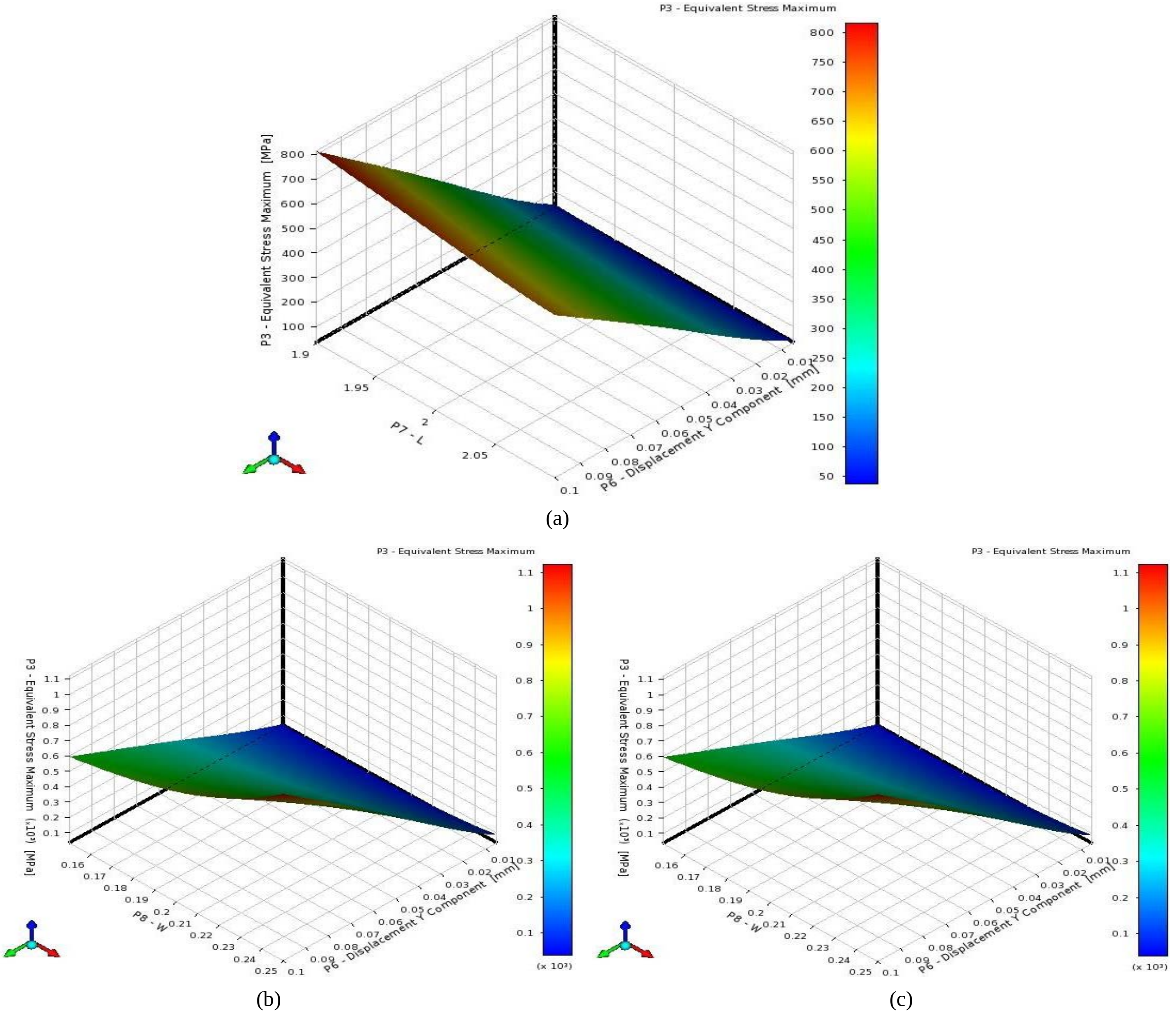


Figure 3. Results of equivalent stress of parameters. (a) Stress by length; (b) Stress by width; (c) Stress by thickness.

Table 1. Material properties of nickel.

Density	Modulus of Elasticity	Tensile Strength	Poisson's Ratio
8.90 g/cm^3	169 Gpa	882.7 Mpa	0.31

Table 2. Range of design parameters.

Length	Width	Thickness	Over Drive
2.0 - 2.5 mm	0.15 - 0.20 mm	0.045 - 0.055 mm	0.05 - 0.100 mm

Second, in case of contact force, over drive increase, length, width and thickness are also increased. In each case, contact force increase when length is shorter, width is boarder and thickness is thicker. **Figure 5** shows influence of each variables to stress and contact force and priority of influence of variables is over drive > width > length > thickness. This tendency is similar to case of cantilever beam in material mechanics.

Table 3 is 3 optimum condition cases that are drawn using response surface analysis and through this tendency, confirm fabrication possibility of probe tip.

3. Fabrication of Probe Tip

Probe tip fabrication process is as shown **Figure 6**. First, PR (Photo Resist, AZ4620) coating on Al plate with thickness 50 um and making a pattern that use maskless lithography system. Next, remove pattern that made by lithography with developing process and nickel plating on Al plate with the way of electro plating. After electro plating, lapping the nickel. Through this process thickness of nickel is 49 um. And using etching process to divide probe tip with Al plate.

Maskless lithography system that is used for fabricating probe tip is DMD type and exposure UV light source on pattern image. Image format is Bitmap Through this system, we fabricate blade probe tip type patterns.

Figure 7 is shown surface roughness of nickel before and after lapping. Surface roughness values at before lapping are Ra = 0.3915 um, Rt = 2.6409 um and at after lapping are Ra 0.0822 um, Rt = 0.6544. From these results, we can confirm improvement of surface roughness through lapping.

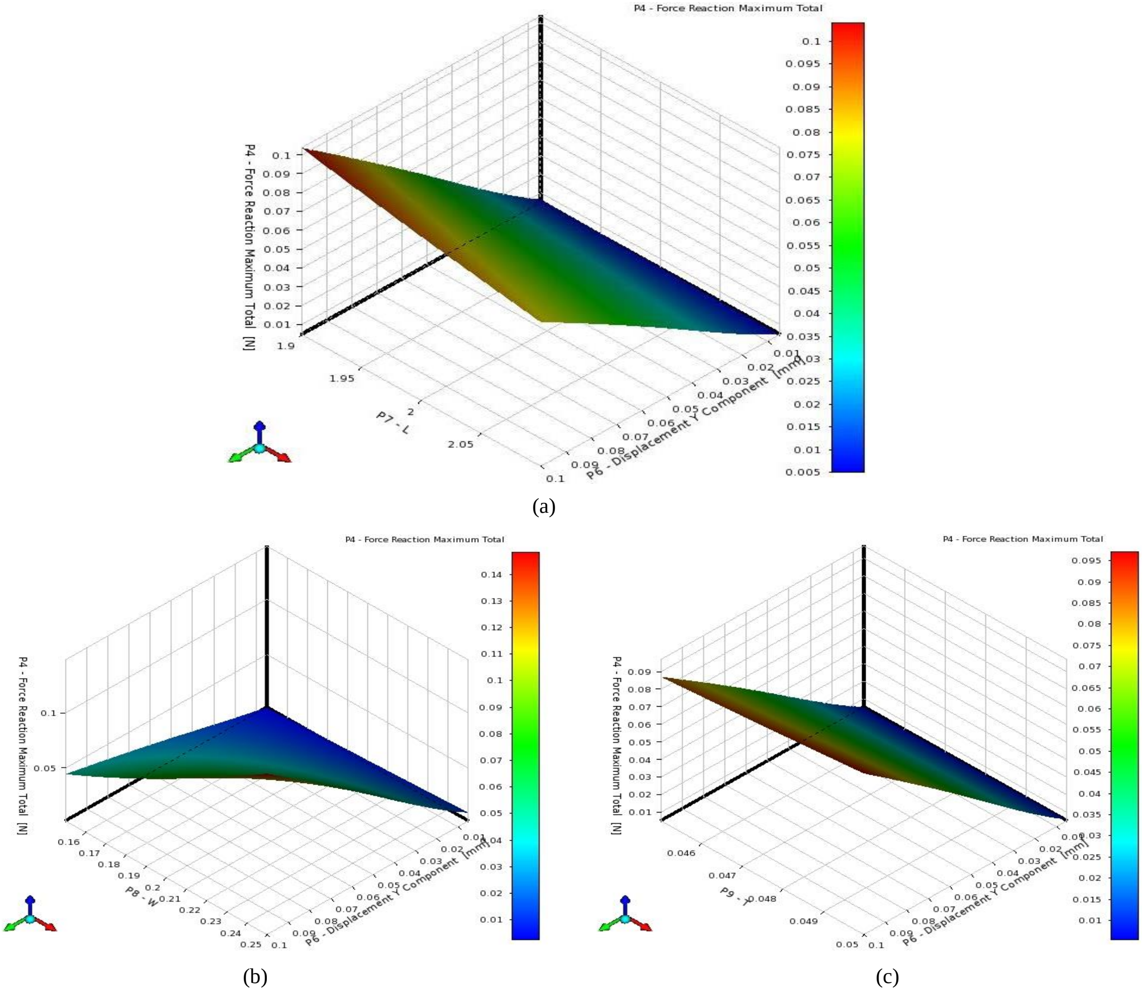


Figure 4. Results contact force of parameters. (a) Contact force by length; (b) Contact force by width; (c) Contact force by thickness.

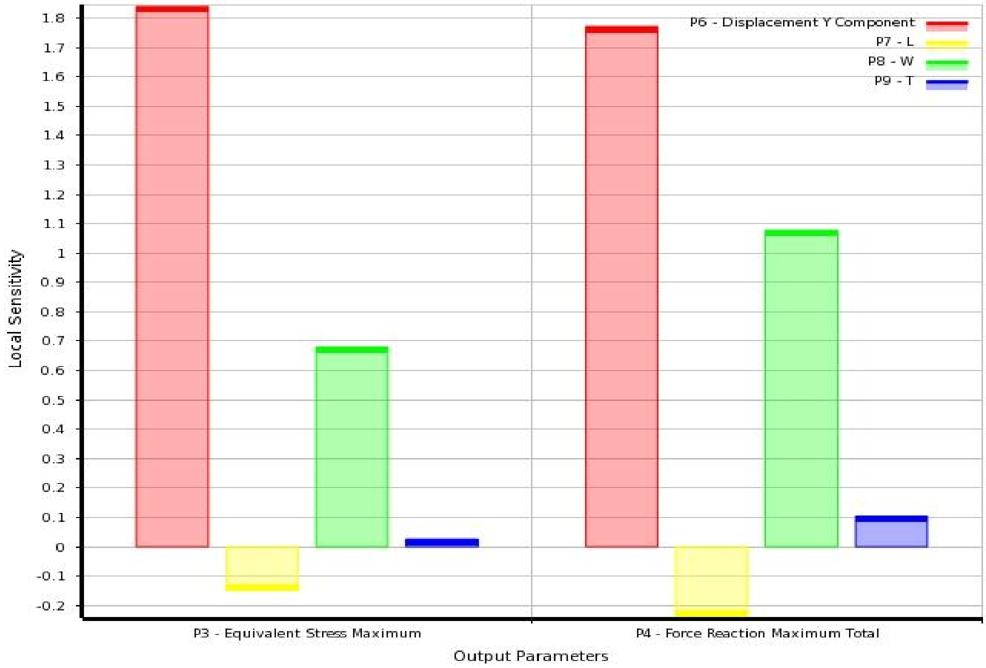


Figure 5. Influence of parameters to stress and contact force.

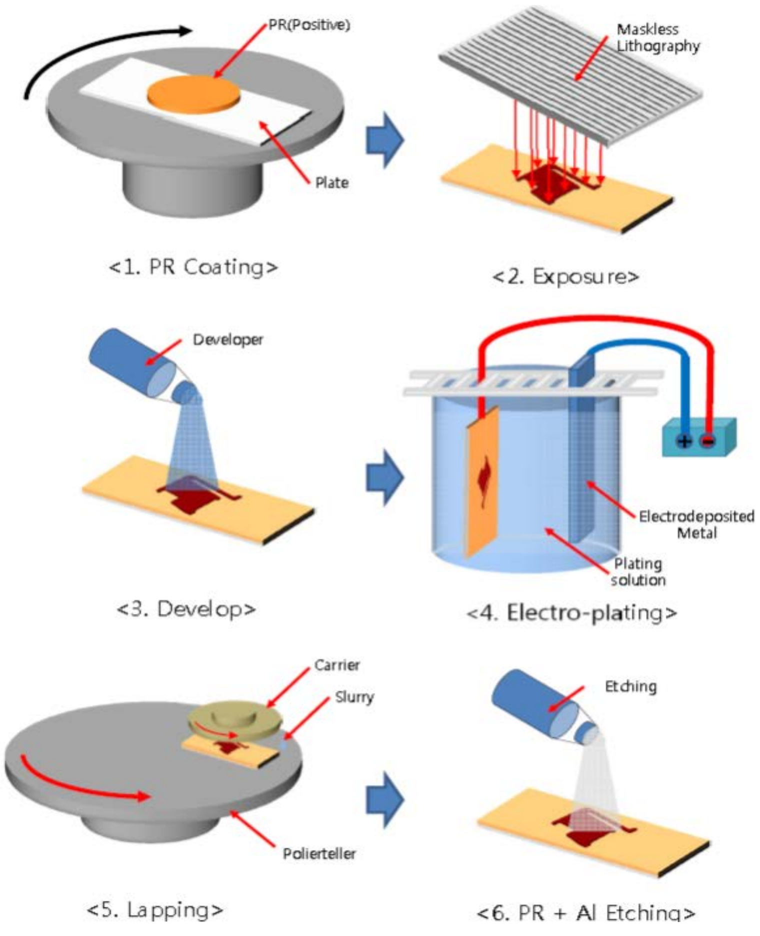
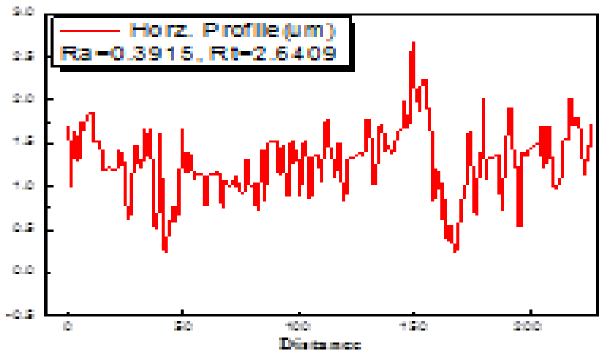
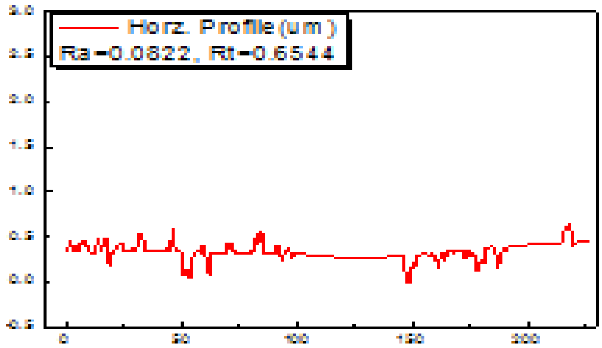


Figure 6. Fabrication process of probe tip.



(a)



(b)

Figure 7. Surface roughness on nickel.

Table 3. Case of optimization result.

	Over drive	Length	Width	Thickness	Stress	Reaction force
Unit			mm			gf
Case. 1	0.089	1.93	0.22	0.0492	859.0	12.26
Case. 2	0.077	1.94	0.24	0.0494	834.8	11.91
Case. 3	0.097	1.99	0.21	0.0494	842.5	11.64

4. Conclusions

In this paper, we fabricate probe tip that is used at test process to semiconductor. Optimization method using response surface analysis is used for design of probe tip and fabricate processes are used for electro-plating and maskless lithography system. Through this paper, we can confirm possibility of applying to probe tip. The paper contents are as follows.

1) Fabricate nickel thin film with electro-plating used for probe tip fabrication.

2) We confirm properties of the electro-plating nickel like hardness, modulus and yield strength. The yield strength value is 882.7 Mpa.

3) Through characterization of nickel that is fabricated using electro plating, it differs from general nickel properties. So we use properties of nickel using electro-plating that we measure.

4) To fabricate probe tip, use maskless lithography system through exposure probe tip figure pattern on photoresist.

5) Through lapping process, adjust thickness of probe tip and improve surface condition. Also, lapping occurs on micro-work hardening on nickel.

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