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MEMS and EFF technology based micro connector for future miniature devices

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Abstract. The development of a miniature; size, light and high performance electronic devices; has been accelerated for further development. In commercial stamping method, connector pitch size (radius) is more than 300µm due to its size limitation. Therefore, the stamped contact hertz stress becomes lower and less suitable for fine pitch connector. To overcome this pitch size problem a narrow pitch Board-to-Board (BtoB) interface connectors are in demand for the current commercial design. Therefore, this paper describes a fork type micro connector design with high Hertz-Stress using MEMS and Electro Fine Forming (EFF) fabrication techniques. The connector is designed high aspect ratio and high-density packaging using UV thick resist and electroforming. In this study a newly fabricated micro connector’s maximum aspect ratio is 50µm and pitch is 80µm is designed successfully which is most compact fork-type connector in the world. When these connectors are connected, a contact resistance of less than 50mΩ has been attained by using four-point probe technique.

1. INTRODUCTION

The recent developments in miniature according to the size, and performance have been accelerated for the further development and the devices has been developed by high functional large scale integration chip design; called System on chip (SOC) method [2]. In the commercial design industries are using pressing and injection moulding technique and the contact minimum pitch has to be more than the 300µm. In the commercial design therefore it is required to meet this minimum criterion to make a good connector. However, connector manufacture with less than 300µm by this technique it is difficult and not compatible with high-density packaging, which is required in the advanced IT (Information Technology) market [3]. Therefore, high-density micro connectors-with a smaller pitch less than 100 µm are one of promising connecting tools for current electronic devices. At the same time, it is also in need to comprehend high-density wrapping with narrow pitch to meet the aforesaid demand [2-4]. Therefore, this paper focuses on micro connectors’ construction by combining UV thick resist photolithography and Ni electroforming [1]. This technique is well-matched to produce a high-

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density packaging and high precision micro connectors in mass production. A fork type micro connector is designed including socket/plug with a connector pitch radius of 80µm has been fabricated [2] using UV thick photo-resist and Ni electroforming to facilitate the commercial specifications of high-density packaging and better performance electronic devices. However, this micro connector design was done on elastic properties of bulk Ni at normal temperature, whereby plastic deformation of the socket was induced in a long-lasting temperature humidity testing leads to permanent deformation of Ni. In identifying the newly developed contacts characteristics and performance it is required to perform environmental test is conduct at the temperature range of -40 OC to +85 OC [5] at 30 minutes per steps or one hour cycle.

2. CONNECTOR DESIGN

Figure 1 shows the dimension of the plug and socket of the proposed connector. In using UV thick photo-resist [5] (THB-130N) is used to form the mould of the proposed connector and the connector can be designed with the minimum dimension of thickness 50µm and width 15µm with the minimum gap between to connector is 15µm and the maximum aspect ratio supposed to be 3.3 of the mould for electroforming.

The fork-type micro connector shape in Figure 1 is planned and it can be fabricated using a mono-layer structure and the design is justified in Table 1 with the commercial specification and identified its strength over the commercial demand. The number of photo-masks required for fork-type connectors is less than that of cantilever-type, and the fork-type has been adopted. Once the connectors plug and socket is completely connected than, the connector will be able to transmit stable signal without any interruption. If contact force between the connectors are not strong enough or gaps occurs within the connecting point than, shaky contact resistance occurs and leads to unstable signal transmission. For this reason, it is important to secure the contact force during design process.

![Figure 1: Schematic of socket and plug terminals.](image-url)
Table 1: Comparison of designed micro connector over the commercial connector specifications

|                          | Commercial connector | Micro connector |
|--------------------------|----------------------|-----------------|
| Classification           | Board to board       | Board to board  |
| Structure                | Fork-type / Cantilever-type | Fork type      |
| Pitch                    | 300 μm               | 80 μm           |
| Number of pins           | 20 - 100             | 100             |
| Allowable current        | 500 mA               | 10 mA           |
| Contact resistance       | 5 mΩ                 | 50 mΩ           |
| Temperature              | Operating temperature: -20°C - 85°C (Including the exothermic temperature 30°C) | Operating temperature: -20°C - 85°C (Including the exothermic temperature 30°C) |
|                          | Storage temperature: -40°C - 85°C | Storage temperature: -40°C - 85°C |
| Contact force            | 290 mN / pin         | 5 mN / pin      |
| Packaging density        | 3 pin / mm           | 12 pin / mm     |
| Fabrication technology   | Pressing and injection molding | Photolithography Micromachining Technology |

Therefore, this study focuses on fabrication of micro connectors by combining electroforming and UV thick resist photolithography. This method makes it possible to realize high-density packaging and high precision micro connectors in mass production.

According to FEM analysis for load–deflection relation of a single cantilever of the socket terminal, the dimensions are identified to meet the specific normal force to make a stable contact. Figure 7 reflects finite elements modelling. Ni is chosen as the contact material. Therefore, Young’s modulus $E = 200$ GPa and poison’s Ratio $\nu = 0.3$ are used for the analysis [4]. 4.5 mN contact force is achieved when the displacement is 5 μm.

The schematic view is also provided below in figure 2 and 3 to visualize the designed micro connector in real design.

![Figure 3: Schematic view of assembled micro connector.](image)

3. FABRICATION

The high aspect ratio micro interposer increases the contact resistance. Consequently, it improves the reliability of electrical signal transmission. A fabrication process of the micro interposer
combining UV thick resist photolithography and Ni fine electroforming was adopted to satisfy the above mentioned specification. In order to make the terminal thicker, UV thick negative type photo resist is necessary. In this research we tried to fabricate a low resistance contact using a new process for a Ni sandwich type structure as shown in Figure 4. The previous contact resistance was 200mΩ. The target of our contact is less than 50mΩ. Therefore, a thick contact and an Au sandwich type contact are decided to fabricate and the process is explained in the following Figure 4. Fabricated plug terminals by Ni electroforming are showed in Figure 5 also fabricated socket terminal is displayed in Figure 5.

![Fabrication Process](image1)

**Figure 4: Fabrication Process**

![Fabricated plug terminals by Ni electroforming.](image2)

**Figure 5: Fabricated plug terminals by Ni electroforming.**
4. EXPERIMENTAL RESULTS AND ITS VALIDATION

Connection was confirmed for single pair of plug (Figure 5) and socket (Figure 6) terminals on the prototype connector. The plug terminal was separated from the substrate and was inserted in the socket terminal manually under microscope observation.

Contact resistance between the single plug and the single socket was measured by the four-point probe method (see Figure 9-11). The value of contact resistance was measured at approximately \(50\ \text{m}\Omega\).
Figure 8: Contact Force (mN) vs Displacement (µm)

\[
y_{\text{max}} = \frac{Fl^3}{3EI}
\]

; Cantilever displacement and force relation

\[
I = \frac{hw^3}{12}
\]

; Cross-section equation

Here,

Socket displacement, \( y_{\text{max}} = 5\mu\text{m} \)
Contact force, \( F \geq 5\text{mN} \)
Socket length, \( l = 200\mu\text{m} \)
Contact thickness, \( h = 50\mu\text{m} \)
Socket contact width, \( w = 15\mu\text{m} \)
Young Modulus, \( E = 207\text{GPa} \)

Therefore, Force applied on the contact (for 5µm displacement), \( F = 5.4\text{mN} \)
Figure 10: Schematic view of Measurement of contact resistance by four-point method

Figure 11: Equivalent circuit diagram of four-point method

Total resistance \( RT = A + \frac{(B+X)}{2} + C \)

| Steps | 1     | 2     | 3     | 4     |
|-------|-------|-------|-------|-------|
| Temp (°C) | -40   | +85   | -40   | +85   |
| Time (min) | 30    | 30    | 30    | 30    |

Figure 12: Environmental condition
5. FUTURE DEVELOPMENT

To increase contact normal force, the material need to be changed and our future research will be proceed to indentify the suitable material to make more stable contact. On paper [6-7] there are studies conducted on the EFF technology to develop new material NiCo in order to increase the material strength drastically. By using the similar smart material it is possible to come up with more stable contact resistance near future.

CONCLUSION

Due to the recent demand in the industrial production it is required to produce thinner contact which supposed to be more stable and less contact resistance to fulfil the commercial demand. In this research it has been proved that better contact is being produced by MEMS and EFF. The prototype micro connector was fabricated by combining UV thick resist photolithography and Ni electroforming. The size of the terminal of fabricated micro connector thickness was 50 µm, and minimum width 15 µm. Throughout the experimental test we have identified the contact force rage was 2.08 mN to 3.76 mN, and the average value was 3.11 mN. At the same time the contact resistance was approximately 50 mΩ. We also successfully fabricated 100 micro connectors. The maximum aspect ratio of each fabricated micro connector was 3.3 and the terminal pitch is 80 µm. In the future development, connectors with higher aspect ratio will be fabricated to realize commercial micro connectors.

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