Development of a high hertz-stress contact for conventional batch production using a unique scribing technology

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Abstract. Gradually the electronic devices are getting more compact dimension with respect to the width and thickness. As a result, the contacts are becoming thinner and which leads the contact to be loose and unstable contact. In commercial stamping method, connector tip diameter should be more than 300µm due to its size limitation. Consequently, the connector contact resistance is becoming higher due to weak contact force. To overcome this problem there were few more basic research using MEMS and Electro Fine Forming (EFF) technology to make high Hertz-Stress Contact (5µm) due to the limitation in the commercial stamping process and the result was in satisfactory level. However, since the MEMS and EFF fabrication is costly therefore, a new method is introduced in this paper using the commercial Phosphor Bronze stamping method to reduce the production cost. Moreover, scribing method is used to make tip on the contact. Accordingly, more compact fine pitch contact is successfully fabricated and tested with 5µm High Hertz Stress without using the MEMS and EFF technology. Hence the manufactured contact resistance becomes less than 20mΩ ±5mΩ.

1. INTRODUCTION

Nowadays, developing countries are expanding rapidly. Hence, countries are more depending on the technology and machineries such as the electric machines, electronic devices, and vehicle related devices. Then, according to the research, electronic devices are getting more compact (Figure 1) with time and leads to a high demand on coming up with more compact contacts and in next decade electronics world needs more compact connector for a connector market which is reported by Sangyo-Joho Limited Japan [1-2]. A contact provides an independent connection between two elements of an electronic system without unacceptable signal distortion or power loss. On the other hand, miniature, light and high functional electronic devices have been developed using high functional LISs called SOC (System-on-Chip) [3-5]. The development of a miniature size, light and high performance electronic devices has been accelerated for further development of the highly-networked information society. Thus, this raises the query whether those emerging countries are using currency conventional
technology or not. Subsequently, the answer is “no”. They will use the latest technology in a single step. Because of that, miniature connectors with smaller pitches have been required in order to satisfy the specification of these electronic devices. Narrow pitch Board-to-Board (BtoB) interface connectors are also required. It is well understood that less than 50μm pitch connector will be required in the Laptop PC area within next 5-7 years. However, the present commercial connector’s minimum pitch is 250μm due to the existing limitation in commercial stamping manufacturing method. Therefore, this research will develop a breakthrough technology to solve current problem for next generation fine pitch connectors. Moreover the future developed connector should be developed in low cost fabrication process.

![Graphical representation on Contact density vs year](image1.png)

Figure 1: Graphical representation on Contact density vs year

Once a connector is designed than it is required to ensure detachable connection and no unacceptable distorted signal passes through the contact. Therefore, contact normal force is a vital key point to ensure stable connection in maintaining this requirement. Once the contacts are getting more compact, than the contact normal force will be getting smaller due to the reduced size and space limitation. Therefore, the sufficient normal force has to be reduced due to its size limitation. Thus, the electrical connection becomes unstable due to the presence of corrosive layer on the contact surface. The contact force is limited to the size of beam as it is known by general equations in material science. Therefore, it is becoming a challenge to the future development to come up with a stable electrical performance contact with high durability using Low Normal Force (LNF) contact and it is going to be the main target of this research as of (Figure 2) showed relationship between the Contact Pitch versus the Normal force of a contact.

![Relation between Connector Pitch vs Normal Force](image2.png)

Figure 2: Relation between Connector Pitch vs Normal Force
Here,

\[ \text{Spring Rate} = K = \frac{EWH^3}{4L^3} = \frac{EW}{4} \left( \frac{H}{L} \right)^3 \]

\[ \text{Elastic Range} = \frac{2L^2 \sigma_{\text{yield}}}{3EH} = \frac{2L^2 \epsilon_{\text{yield}}}{3H} \]

Extensive studies are performed on the proposed LNF contact with the existing contacts features [13] to overcome the unstable contact dilemma which mainly are due to lack of high hertz stress and reduced normal force (Figure 3). In order to justify this basic idea, it was required to find out some related information on required contact force, and flexible required durability of the contact. Thus the ground research focused in the high Hertz-stress contact properties shown in Figure 4 to realize the prospective solution on the above mentioned problem. Initially, it was an idea that, if a very sharp tip contact is fabricated than the connection will be more stable at the contact point and the current will pass easily.

![Figure 3: Comparison between with conventional contact with Low Normal Force Contact](image)

![Figure 4: Resistance Comparison between with High vs low Hertz-Stress](image)

According to the past research, we have developed an excellent material Ni-Co for contact spring [5] in MEMS and EFF process and could develop a LNF contact and the contact performance was also in satisfactory level and durability performance was within the acceptable range. Although a suitable contact with appropriate R is the Key factor for LNF and it is yet to be optimized. In past research has tried to optimize an appropriate R using several size (r=5 to 200\( \mu \)m) by the same LNF contact. To
fabricate this miniature contact, a MEMS technology is used because the existing pressing and injection moulding method is not compatible with the high-density packaging required in the advanced IT market [3-8, 15]. This research focuses on a fabrication of micro interposer by combining UV thick resist photolithography and Ni-Co fine electroforming technology. This fabrication method is expected to develop high precision micro interposer and high-density packaging in mass production and is very essential to realize micro order devices. The business value of this contact will be utilized on the Test Interface Connection area. For example, test sockets for IC-devices, test board I/F for IC-tester, and High speed board to board for I/O device. Furthermore, on a Medical Equipment area like 3D transducer interconnection for ultra-sound, X-Ray sensor I/O for CT scanner is also necessary.

In order to increase Hertzian stress [9-12] of contact point of the terminal have to be lower radius (sharp) to stick to the upper terminal. A sphere (radius R, elastic contacts $\nu_2, E_2$) pressed by a load $F$ into a flat substrate (with elastic constants $\nu_1, E_1$). The load is supported over a circular area whose radius, $a$, is given by: [9]

However, MEMS and EFF technology is not suitable for industrial batch production since this process is time consuming and economically expensive. Therefore, a cost effective process is main target to meet in order to fulfil the industrial demand and this research is conducted to satisfy the industrial demand.

2. FUNCTIONS

To achieve the industrial demand, a contact has to establish a separable connection between two elements and also should be able to supply undistorted signal through its contact. Both requirements are depending on the connector application and its electrical and environmental requirements. Separable contact gives the flexibility on easy placement [15], easy repair, upgrading, and maintenance or interconnects ability. Undistorted signal flow depends on the resistance within the connecting point. Lower the contact resistance the better signal passes through the contact.

3. MODELLING

A number of possible solutions are gathered and in order to find the best possible design to meet the industrial requirement, an analysis is done through Pugh method and scribing method is chosen out of the all proposed possible design.
In order to make the stable contact in using Low Normal Force material the contact is being modelled from thin Phosphor-Bronze substrate and a dual tip is made on the substrate by scribing method (Figure 7) is used to make a stable contact on the connecting point. Throughout this process a Low Normal Contact Force is being modelled and analyzed its properties in different environment.
4. FABRICATION

To facilitate the proposed contact, a micro interposer combining UV thick resist photolithography and Ni-Co fine electroforming fabrication process was adopted to satisfy the above-mentioned specification. SEM (scanning electron microscope) photographs of the structures which are formed by the Ni-Co electroforming. A SEM photograph of the designed contact is shown in Figure 8.

![SEM Figure of Dual High Hertz-Stress Contact Tip](image)

5. EXPERIMENTAL RESULTS AND ITS VALIDATION

A number of environmental test are conducted on the contact force versus contact resistance. The following at Figure 9 shows the initial resistance, resistance at humidity-temperature cycling test and temperature life test. To conduct the environmental test it have ensured the selected samples contact forces were stable for all of the contacts and the average maximum normal force was around 0.16N and the contact resistance was approximately below 30\(\mu\Omega\) which reflects a good contact resistance within the acceptable range. For lowest radius \(r = 5\mu m\) contact. We measured \(n=5\) samples for each type of structure. The lowest radius \(r = 5\mu m\) contact resistance was more stable than the largest \(r = 200\mu m\) was checked from the initial data. Also the middle range contact radius \(r =25\mu m\) and \(50\mu m\) was unstable than the smaller \(r =5\mu m\).
6. FUTURE DEVELOPMENT

We are currently conducting a number of studies on the further development on the design, fabrication, and characterization. In order to go for industrial production system in commercial stamping method we need to do further experiment to replace with this new proposed design.

7. CONCLUSION

Due to the recent demand in the industrial production it is required to produce more compact contact in using conventional batch production. In reality, the similar quality contact is only achievable in using MEMS and EFF technology but these contacts production cost is higher and not suitable for gross production due to slow manufacturing process. Thus, it was a big challenge to come up with the similar type of contact in the commercial production. In this research a no of possible design is studied and it has been indentified scribing technology is the best design to fulfil industrial demand and the contact are within the required criteria which is tested through a number of environmental test. Throughout the test the contact resistance decreased drastically which was the major aim in this research. Consequently, in this basic research we have identified the commercial contact resistance is within the 20 mΩ to 30 mΩ.

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