Clamping Connection between Flexible Electrodes and External Wires

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Abstract: Flexible electrodes are widely applied to many fields such as sensor, flexible printed circuit board, photovoltaic cell, cell phone, digital camera, and liquid crystal display and so on. Aim at the connecting problem between flexible electrodes and external wires; the detachable clamping connection was firstly brought forward to solve the aim problem under normal temperature. And on the basis of such idea, the corresponding clamper was designed and fabricated further by mechanical procedures. Then verifying and comparing experiments were done and observed. Experiment results illustrate that the detachable clamping connection is correct and effective and that such connection could solve the aiming problem without high temperature welding procedure. And furthermore it's also known that clamper doesn't change the main characteristics of signal transmission. The detachable clamping connection is very useful and effective for the connection between flexible thin film conductor and common wires when they can not be directly welded together under high temperature.

Keywords: Clamping connection, flexible electrode, external wire, piezoresistive principle, connecting electrode.

1. INTRODUCTION

Flexible electrode has quite wide application. Flexible printed circuit board (flexible printed circuit board, FPCB) which can be freely bent and coiled and folded has been widely applied to almost all fields of the modern industry such as mobile phone, liquid crystal display, digital camera, portable computer, printer, and automobile and so on. Flexible electrode is the necessary component in the FPCB because it is used to connect all components including terminal electrodes. Flexible electrode is also used to transfer the signal to the FPCB output terminal, but at present it is very difficult to join flexible electrode with external wire together under the normal temperature. Of course, there have been some relative literatures on the electrode research [1-4].

Flexible electrode has been widely developed, but the connection with external wire is very difficult at present. Katarzyna Kurzatkowska, Dmitry Schakowsky, Jerzy Radecki *et al.* utilized gold electrode to design and fabricate a sensitive amperometric sensor for measuring the human serum [5], but connection method with external wire was not involved. Chao Ma, Minoru Taya and Chunye Xu designed and fabricated a flexible electro chromic device based on indium tin oxide (ITO) coated with polyethylene terephthalate (PET) [6]; Chia Lin, Yutao Lee, Shih-Rung Yeh, *et al.* developed a novel flexible carbon nanotube (CNTs) electrode array for neural recording [7]; but these flexible electrodes were difficultly connected with external wires. Matthias Gruhn, Werner Rathmayer developed an implantable electrode which permitted alternate extra cellular nerve recording and axon simulation in freely behaving crayfish [8]; such electrode consisted of a double hook made from 20μm thin platinum that was fitted to various nerve diameter, but this electrode was so thin that it could be only implanted into extra cellular nerve and that it can not be directly acted with external wire. Zhou Gaofeng, Zhao Yulong and Jiang Zhuangde gave out a strip double sensing layer pressure sensor for interface pressure distribution, and they developed flexible electrodes for the pressure distribution of this sensor [9]; but they did not mention the thought or method of connecting flexible electrodes with external wires. Huajuan Pan, Yong Yang fabricated $LiCoO_2$ thin films by radio-frequency sputtering technique [10]; as a thin film cathode of thin film battery, they utilized the sputtering power to control the size of As-deposited $LiCoO_2$ thin film and also to avoid the negative effects of high temperature annealing process, instead of the annealed $LiCoO_2$ thin film. Pierre Thibault, Pantxo Diribarne, Thierry Fourier, *et al.* utilized the flexible electrodes to measure parameters of capacitive sensor for multi-purpose measurements [11]. These electrodes were made from a thin metallic film, but it's not found that the specific connection method between flexible electrode and external wire was narrated and developed. Mark E. Roberts, Stefen C.B., Mannsfeld, *et al.* fabricated a flexible, plastic transistor-based chemical sensor to realize the stable operation in water, but electrode connection problem was not mentioned and solved in this article [12]. Among the

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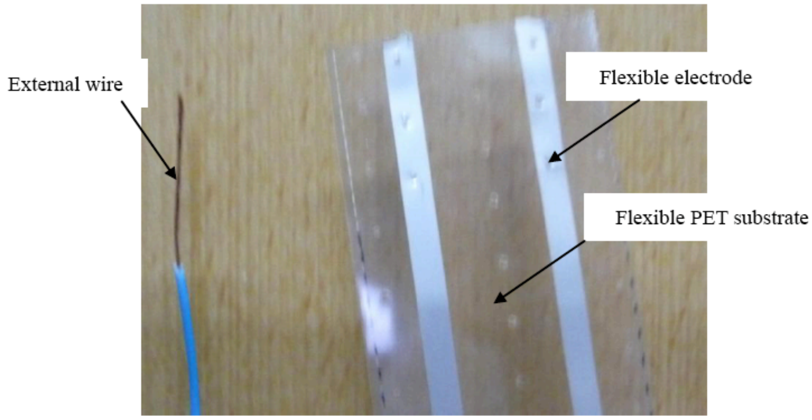


Figure 1: Illustrating comparison between external wire and flexible electrode with plastic substrate.

above literatures, flexible electrodes were mainly applied to micro devices such as micro sensor or thin film battery and so on; but as the PET substrate on which flexible electrodes such as silver electrode were printed or deposited, it did not endure the very high temperature such as 150℃ above because polymer melting point is very low. Hence flexible electrode could not be directly connected with the external wire and the welding procedure could not be utilized here. In Figure **1**, it's obviously difficult to directly weld flexible electrodes into external wires. Hence the connecting problem between flexible electrode from plastic substrate and external wire has to be studied and solved for signal transmission, especially for signal transmission from flexible thin film sensors or other flexible film devices.

Aim at the connecting problem between flexible electrode and external wire, we put forward the thought of the detachable clamping connection to fluently transmit electronic signal. Furthermore relative clamper was designed and fabricated to testify the given thought. Firstly, the detachable clamping connection is narrated and explained in detail. Then, the clamper for testifying experiment was designed and fabricated. We gave out the experiment method, content, used tools and operation course respectively. And we draw the experimental curves by Microsoft Excel 2003. Finally; we analyzed and discussed the experiment results. According to analysis and discussion, we gave our conclusions on the detachable clamping connection.

2. REALIZATION AND DESIGN

2.1. Requirements

Realizing the given connection needs to satisfy certain requirements. Flexible electrodes from plastic substrate can not be directly and reliably welded into external wires such as flexible electrode in Figure **1** because they only endure lower work temperature. If above connection needs to be realized, the following requirements should be firstly satisfied:

1) Electrodes have to be flexible, which are printed or deposited on the plastic film with lower work temperature;

2) External wires are common wires which are connected into the A/D converter or electronic circuit;

3) Connecting electrodes have a high conductivity relative to common conductor;

4) Fabricating procedures are easily realized and executed;

5) Combination mode between flexible electrodes and external wires is easy and reliable and available;

6) The useful signal meets with no any baffle when it is transferred from flexible electrodes to external wires;

7) The designed procedure could be realized according to present processing level;

8) The whole fabricating cost should be acceptable.

Of course, flexible electrode needs to have a certain width for application, but it also has some limitations. The width of electrodes should be ensured and accepted according to the actual requirements so long as the width of electrodes doesn't affect connection. However, film electrodes deposited on the single silicon are too small and crisp to meet with above requirements. Here the detachable clamping connection is not realized and applied for such case.

2.2. THOUGHTS OF REALIZATION

The aim problem needs to be solved by the detachable clamping connection. According to the above requirements, the flexible electrode and external wire in Figure **1** may satisfy all given conditions. After components in Figure **1** will be specially observed and analyzed, the detachable clamping connection should be adopted because such contact can not be limited by the work temperature of material. And it could ensure that two kinds of film conductors tightly touch each other. Clamping connection means that two kinds of film conductors touch each other to fluently transfer detecting signal and that there is no any insulator between them. Some auxiliary tools are also used to fasten the surface contact between two kinds of conductors. The specific course of the detachable clamping connection will be explained in the following. Middle component is introduced not only to keep the tight contact with flexible electrode but also to stably joint with external wire, such component will realize the connection and signal transmission between flexible electrode and external wire. In fact, flexible electrode only touches the surface of connecting electrode and there is no any melting point between them. Middle component can be connecting electrode or signal processing printed circuit board. Middle component connects flexible electrode from plastic substrate to external wire. Here, middle component has to have a high conductivity and a certain rigidity to ensure the detecting signal could be transferred comfortably. At the same time, signal processing printed circuit board may be also used to substitute middle component for converting and processing signal; but FPCB should keep detachable because it is inevitable to repair components in measurement device. That's to say, the connecting mode of FPCB terminal has to be the same as that of connecting electrode. Connecting electrode needs to tightly touch the surface of flexible electrode. The position of connecting electrode may be adjusted if necessary. Actually such connection is a kind of detachable connection and two electrodes could be easily detached under the common conditions. Other auxiliary tools can be also utilized to fasten above connection. As middle component, connecting electrode is adopted to satisfy actual connecting situation. Here the above narrated connection mode is called to the detachable clamping connection.

In the course of realizing above connection, the following contents need to be noticed. Firstly, the contact with the flexible electrode has to be always detachable and such contact could be easily realized for plastic substrate. Secondly, external wire should be firmly and tightly adjoined to the middle component. The connection between external wire and middle component is not limited to the work temperature of plastic substrate. Thirdly, the realizing course and mode should keep easy and simple.

2.3. SIGNAL TRASMISSIONS

In order to understand the relationship of signal transmission, some parameters in circuit needs to be expressed by relative letters. Assuming the impedance of detecting component is variable and the resistance of connecting electrode is constant, the connecting model and its equivalent circuit are given out in Figure **2**. Here, the connecting electrodes adopted are copper electrodes for principal experiment; and their resistances are respectively R_1 and R_2. Furthermore, the resistances of two connecting electrodes should be equal, signed as constant R because they have same geometric parameters. Variable impedance Z may be variable resistance or inductance or capacitance, which is up to the working effect of measurement devices. Here, the terminal voltage U_{out} in Figure **2** is transferred to the processing circuit.

In Figure **2**, the relationship of signal transmission is analyzed and deduced in the following:

Flexible electrode is mainly connected to the flexible thin film sensor; and sensor can be regarded as a variable resistance or inductance or capacitance. In terms of the circuitry theory, the following equation (1) could be obtained:

$$U_{out} = \left(R_1 + R_2 + Z\right) I = \left(2R + Z\right) I \tag{1}$$

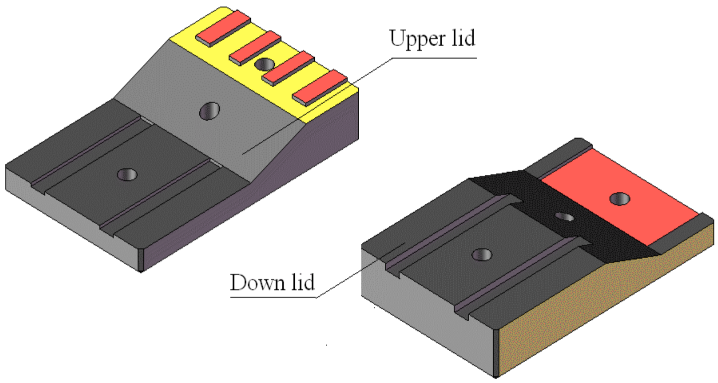
For a constant current source, the expression on the variable impedance is gained in equation (2):

$$Z = \frac{U_{out}}{I} - 2R \tag{2}$$

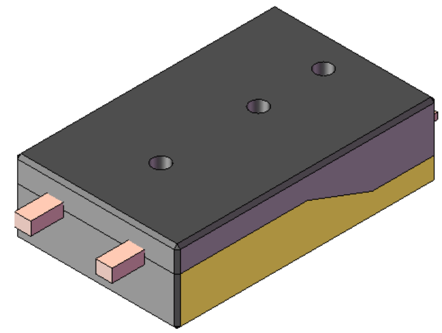
For the given sensor in Figure **2**(**a**), the impedance of sensor is regarded as a variable resistance because sensing principle is piezoresistive principle. Judging from the expression of equation (2), the measuring voltage is proportional to the resistance of sensor.

The measuring voltage should satisfy the following condition because the resistance of sensor is always greater than zero. Then equation (3) could be obtained:

$$Z = \frac{U}{I} - 2R > 0 \text{ namely, } U > 2IR \tag{3}$$



(**a**) major components for connection.



(**b**) 3D assembly solid.

Figure 2: The mechanical clamper for the connection between flexible electrode and external wire.

Conditioning circuits and A/D (Analogue/Digital, A/D) converting circuits should be included in the processing circuit. If processing circuit as middle component, transmission relationship needs to be further deduced and analyzed.

2.4. Clamper Design

According to the above narration, we know that clamper could achieve the detachable clamping connection between flexible electrode from plastic substrate and external wire. Actually clamper is here regarded as a connector or analogy signal processor. Connecting electrode is a transitional component, which has to satisfy the above mentioned requirements of connecting flexible electrodes with external wires. Clamper has the function of fastening and guiding the connecting electrode.

Some materials can be selected when clamper is designed; but the insulative problem needs to be noticed. Clamper has to be insulative because connecting electrode as conductor is embedded into clamper. The following materials could be adopted to fabricate clamper: organic glass, lumber or insulative hard plastic. In order to testify the detachable clamping connection, lumber is used firstly for experiment because lumber is easily machined and absolutely insulative.

Then such clamper is designed in Figure **2**. Relative components are explained in the following:

In the upper lid of Figure **2**(**a**), there are two grooves which guide and fixture the connecting electrodes. Of course, the width of groove should keep equal to that of connecting electrode. In the down lid of Figure **2**(**a**), these two grooves are used to make connecting electrodes do not deviate from the scheduled direction. At the same time, these two grooves could ensure that connecting electrodes tightly touch with flexible electrodes. The connection mode is expressed and hinted in Figure **2**(**b**). The holes in clamper are utilized to fasten the whole clamper after connecting electrodes are embedded to stably touch with flexible electrodes.

The total width of clamper is 50mm, and the length is 80mm and the thickness is 22.5mm.The dimension

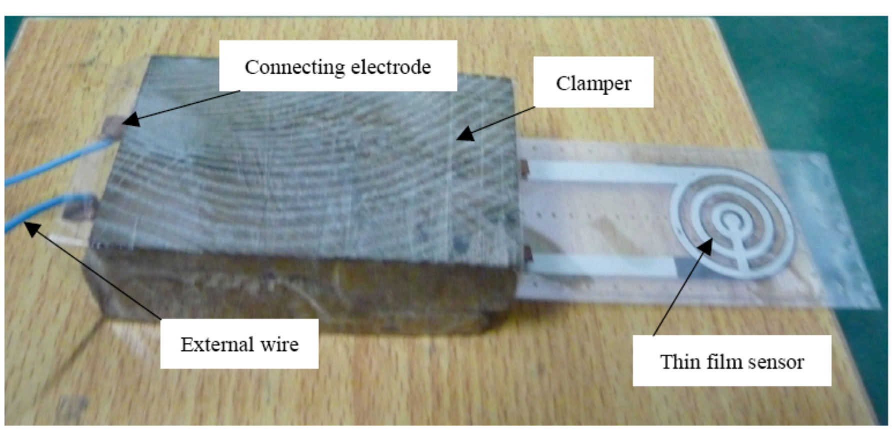


Figure 3: Actual detachable clamping connection device.

of clamper is used to complete the normal operation. If the given clamper is applied into the commerce, the dimensions of clamper may become smaller than given dimensions.

2.5. Clamper Fabrication

The clamper is fabricated by common procedures such as turning and milling and drilling procedures. Firstly, we prepared a block of lumber; and then we machined lumber through turning and drilling procedures and made its dimensions equal to the scheduled dimensions; then the connecting electrodes were machined by common methods of fabrication; then these connecting electrodes machined were embedded into the slot of upper lid. Finally, the clamper was fastened by transparent tape. Here the transparent tapes were adopted to expediently regulate the clamper assembly. The fabricated clamper was seen in Figure **3**. According to the connecting mode of Figure **2**(**a**), the actual connection relation was actualized in Figure **3**. Flexible thin film sensor was regarded as variable resistor here.

3. EXPERIMENT PREPARATION AND RESULTS

3.1. Experiment Experiments

(1) Experiment strategies: Experiment aim was to testify whether the detachable clamping connection was correct and feasible, and whether the given method was simple and effective. Hence the digital multimeter could be adopted to measure the total resistance and to verify the above connection. The specific experiment strategies and steps were the following:

Figure 4: Displaying result of clamper experiment.

Firstly, the clamper was tightly buttoned on the flexible electrode printed on the plastic substrate. The connection mode between flexible electrode and connecting electrode was detachable clamping connection. External wires were linked to another terminal of connecting electrodes.

Secondly, anode and cathode of multimeter were respectively linked to the external wires of clamper by red and black Table pens. Here, such connection could be easily broken. For an example, the brass tapes were coiled into the red and black Table pens of multimeter.

Thirdly, the multimeter was turned on to observe whether there was a digital signal on the screen after the alternative switch was dialed to the resistance position. Such clamper would simply verify the detachable clamping connection if the sensor resistance was seen on the screen of multimeter. Otherwise, if not, the relative connection would be checked to find whether there existed the phenomenon of given connection.

(2) Experiment preparations: The following tools needed be prepared for experiment: 1) a digital multimeter; 2) flexible thin film sensor with flexible electrode which was printed or deposited on the plastic substrate; 3) external wires; 4) transparent tape; 5) record paper; 6) ball-point pen; 7) camera. A digital multimeter was used to display the total resistance and to observe whether measurement signal could be delivered to digital multimeter through the designed clamper. In experiment, flexible thin film sensor provided variable resistance and flexible electrode for experiment. External wires were used to give out the common case of circuitry connection. Here wires were selected at random so long as the selected ones could represent the common case. Transparent tape was used to fasten the clamper to casually or slightly adjust connection. Record paper and ball-point pen were utilized to record some experimental data. Camera was utilized to record some crucial scenes in experiment such as photos of device connection.

3.2. Testifying Experiments

According to the above narration, experiment device and content were built and explained. The switch of power in digital multimeter was turned on. And then the total resistance was displayed on the screen of multimeter in Figure **4**. In order to find the difference between direct connection and indirect connection,

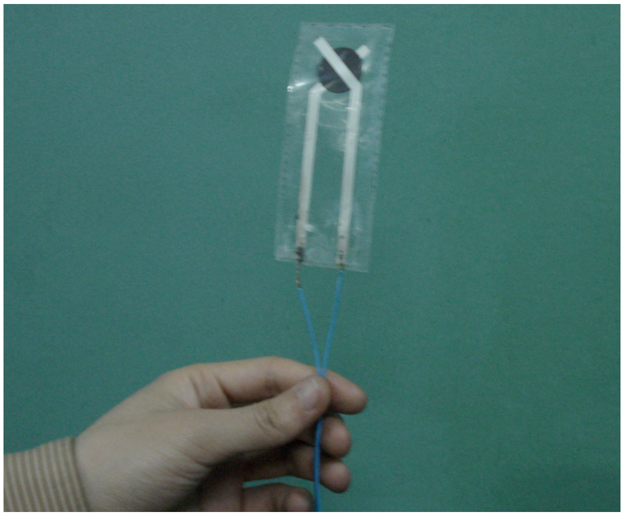


Figure 5: Photo of direct connection between flexible electrodes and external wires.

direct connection between the flexible electrode and external wires needed also to be done and analyzed to draw objective conclusion. The photo of direct connection was seen in Figure **5**. Such connection was realized and fixed by conductive silica because the substrate of flexible electrode was plastic without enduring high temperature.

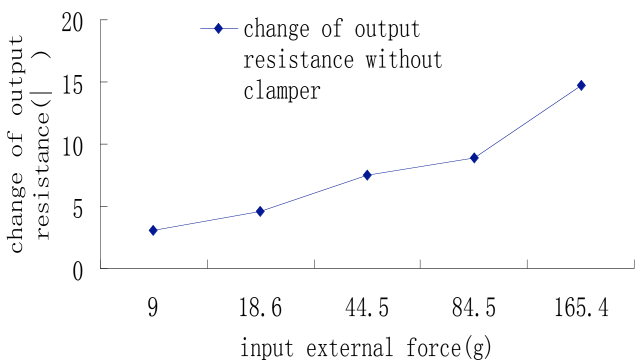


Figure 6: Testing graph without clamper based on the single-point force sensor.

Certainly, comparing experiment needed to be also done to observe the affect and difference between above two cases. When flexible electrode was connected to external wires through the designed clamper, the output data would be written down to be converted into graphs for analysis and discussion. After the designed clamper was removed, the same experiment with same loads was done in terms of the same course.

3.3. Experiment Result Statistics

Basic data were tested and recorded to supply some basic information for detachable clamping connection. The whole dimension of clamper is 80mm×50mm×22.5mm. The resistance of connecting electrodes is 2.1Ohm.The width of connecting electrodes is 5mm and their length is 95mm.The original resistance of flexible thin film sensor is 30.6 Ohm which includes the resistance of two connecting electrodes and the width of flexible electrode from the thin film sensor is 5mm.In order to observe the affectivity of the detachable clamping connection, other data were also measured through external point force.

The tested data were converted into relative curves by Microsoft Excel 2003. The experimental curve without clamper is given out in Figure **6**, which imposed force is the same as the case with the clamper. Through observing the graph of Figure **6**, it's known that the change of output resistance rises with the increase of the imposed force.

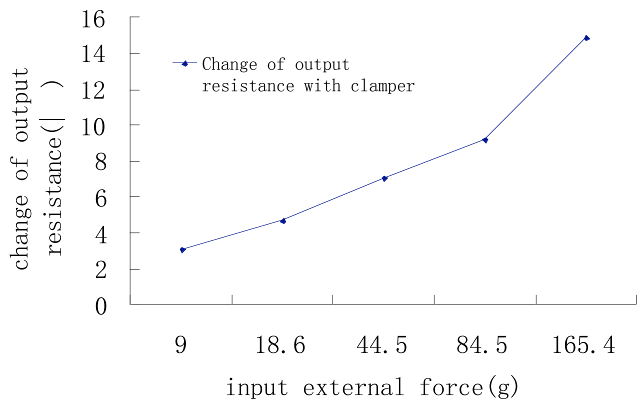


Figure 7: Testing graph with clamper based on the single-point force.

At the same time, the same experiment was also done on the base of device in Figure **4**. The testing curve with clamper was also obtained on the basis of the same force, seen in Figure **7**.

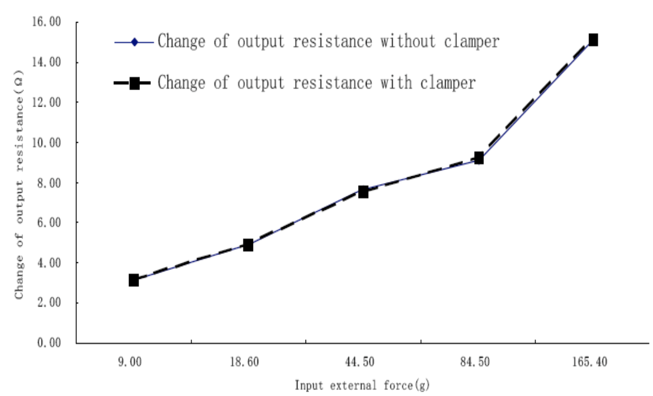


Figure 8: Testing comparison of two cases between clamper and non clamper.

In order to contrastively analyze above two curves, they were drawn in the same Figure **8**.

4. ANALYSIS AND DISCUSSION

4.1. Clamping Connection Analysis

Some points need to be careful when the detachable clamping connection is completed**.** There should be no any insulative film of metal oxide on the surface of flexible electrode. Otherwise, signal transmission will not be completed by detachable clamping connection because the metal oxide can not conduct any electronic signal between flexible electrode and connecting electrode. Of course, in the course of contact, it should be avoided that the point or line touching case occurs because they easily lead to disconnection. And in the flexible electrodes there should not be any pores, shrinkage, mixed jumbles because they further debase the conductivity of electrode.

As electrode, some conductive metals may be also used such as gold, silver or red copper and so on. In experiment, we utilized conductive silver paste to fabricate flexible electrode through silk screen printing procedure. Yellow brass was used to make the connecting electrode. The thickness of flexible electrode is 0.1mm because the too thick electrodes could further increase the additional resistance such as R_1 and R_2 in Figure **2**. If the thickness of electrode is increased greatly, the measurement range of testing equipment would have to be accordingly improved; such is very adverse to testify the detachable clamping connection by digital multimeter given in the section 2.2. However the width of flexible electrode could be adjusted or changed according to the actual cases.

If external wires were directly connected to flexible electrodes, the safe connection would be difficultly ensured and guaranteed. For the foundation layer of flexible electrodes was plastic and for it only endured a low temperature, the foundation layer and flexible electrodes would be seriously destroyed in welding procedure of high temperature. Even though external wires were constrainedly welded into flexible electrodes through conductive silica, external wires would gradually get away from flexible electrodes because silicon gel was so crisp that it could not tightly fixture the connection between flexible electrodes and external wires. At the same time, flexible electrodes would slightly sway and vibrate relative to external wires when flexible electrodes were moved from one place to another one; then crack would occur in the connecting section. If flexible electrodes were moved for several times, external wires would completely break away from flexible electrodes. Then flexible electrodes would be interrupted with external wires. Hence, the direct connecting mode in Figure **5** will have to be given up in actual application.

In Figure **4**, nowadays the given test mode was only used for verifying experiment, not for the industry device. The external wires were connected to the digital multimeter, not to the detecting circuit because the digital multimeter could easily display total resistance and because the resistance change was easily known for analysis. When the imposed force was changed, a new resistance would be displayed on the screen of multimeter. After we subtracted new resistance from original resistance, then we could obtain the resistance change caused by exerted force. Therefore, such testing device could be utilized to testify the detachable clamping connection.

Specific relationship between external force and resistance change of sensor will be analyzed in the following:

If the current of detecting circuit is a constant, we know that current I keeps unchangeable. When no any external force is imposed on the flexible thin film sensor in Figure **4**, the original resistances from clamper and the flexible thin film sensor are R_{11}, R_{22} and Z_0 respectively. After a point force F is exerted on the given sensor, the corresponding resistances are R_{11}, R_{22} and Z_1 respectively. For a piezoresistive sensor, the relationship between external force and resistance change of sensor is listed out as follows:

$$\Delta Z = K\frac{F}{EA}Z_0 \tag{4}$$

Here, K is the proportional coefficient, E is the elastic module of sensing material, A is the touching cross section imposed by external force, Z_0 is the original resistance of sensor. Then we could get the resistance Z_1 of device in equation (5):

$$Z_1 = Z_0 - \Delta Z = Z_0 - K\frac{F}{EA}Z_0 \tag{5}$$

Then, the displaying value D_1 on the screen of multimeter is the following equation (6) under external force F:

$$D_1 = R_{11} + R_{22} + Z_1 \tag{6}$$

The displaying value D_2 without external force is listed in equation (7)

$$D_2 = R_{11} + R_{22} + Z_0 \tag{7}$$

In order to eliminate the negative effect of additional resistance, we subtract equation (6) from equation (7), and then we could obtain the resistance change ΔR listed in equation (8):

$$\begin{aligned} \Delta R &= D_2 - D_1 \\ &= \left(R_{11} + R_{22} + Z_0\right) - \left(R_{11} + R_{22} + Z_1\right) \\ &= Z_0 - Z_1 = \Delta Z \\ &= K \frac{F}{EA} Z_0 \end{aligned} \tag{8}$$

According to equation (8), we could know that the additional resistances in clamper could be eliminated by subtraction algorithm in theory.

In experiment, some components can be substituted, but the detachable clamping connection can not be changed at random. If the connecting mode in Figure **2** is applied to other fields, the flexible thin film sensor may be substituted by relevant devices so long as output electrodes of device are flexible electrodes. If a flexible printed circuit board substitutes connecting electrode to be embedded into clamper, the connecting mode of interface terminals has to be same as that in Figure **2**(**a**). And the printed circuit board should be placed into the guide groove of down lid. Terminals of clamper should keep the original connecting mode not to affect the relevant operation. In clamper, if the two terminals of connecting electrodes are placed into the same level, the pressure that is imposed on the surface of flexible electrodes will be further weakened because the actual terminals are not completely in the same level. Furthermore, the line touching mode or point touching mode is easily caused by the harsh touching surface. Hence two terminals of connecting electrode needs to be located in the different level seen in Figure **2**(**a**).

Of course, the original resistance of sensor has to be calibrated. In detecting external force, the original resistance of sensor is also possibly changed when there is no external force. Hence the resistance of sensor needs to be adjusted to original resistance without any force at first time. A rheostat needs to be in tandem with external wires. Adjusting the resistance of rheostat may make resistance of sensor return to original value.

4.2. Analysis Of Experiments

The shape of connecting electrode should accord with actual clamping mode and their layout may be rectified in terms of clamper. Connecting electrodes should keep certain rigidity, especially in the terminals of clamper, to ensure that connecting electrodes could reliably pin flexible electrode. And connecting electrodes are folded into the given shape in Figure **2**(**a**) to increase the pressure between flexible electrodes and connecting electrodes, and also to ensure that external wires could be easily fixed or welded onto connecting electrodes. The width of connecting electrodes should be greater than that of flexible electrodes; such could ensure that connecting electrode completely covers the touching surface of flexible electrode. The distance between two adjacent electrodes may be adjusted according to the actual requirements. In experiment, the distance of two adjacent electrodes was about 20 mm and we used the transparent tape to fixture the clamper. If the above given clamper is applied to actual industry, the fixing bolt and nut have to be used here and the relative dimensions need to be changed or adjusted.

The device and measurement in Figure **4** are explained and analyzed here. The displaying resistance is a total resistance which includes the resistances of two connecting electrodes and sensor. The obtained data is affected by the resistance of connecting electrodes; hence the negative effect of connecting electrodes has to be eliminated for analysis. If the displaying resistance subtracts the original resistance, the adverse effect of connecting electrode will be further weakened even eliminated. The specific process analysis has been narrated in section 4.1. According to above narration, we did with the obtained resistance data and converted them into curves by Microsoft Excel 2003.

The graph without clamper in Figure **6** is narrated and construed. Through observing the displaying graph, we know that the resistance change rises with the increase of external force; hence we could understand the quantity of external force that causes the resistance changes. The trend of graph basically accords with the significance of equation (8). Here the flexible electrodes have to be exposed outside to make that multimeter's contacts enough touch flexible electrodes. And the connecting mode in Figure **5** could not be utilized in actual application because joints are too crisp to complete the signal transfer. Under the conditions of same load, the same experiment was also done on the device in Figure **4**. Similarly relative graph was obtained in Figure **7**.

The trend of output graph in Figure **8** cannot be largely changed relative to that of Figure **6**. Figure **7** is the case with clamper that is designed and fabricated for the detachable clamping connection. Clamper is used to testify whether the detachable clamping connection is correct and available. The graph in Figure **7** displays that the change of resistance also rises with the increase of external force. The graph trend in Figure **7** is the same as that in Figure **6**; such graph illustrates that the given clamper could realize the detachable clamping connection between flexible electrodes on plastic substrate and external wires, and that clamper does not change the trend of curves. In order to further recognize and compare the clamper effect on experiment results, we put the above two graphs together shown in Figure **8**.

Detachable clamping connection could realize and complete the connection between the flexible electrode and external wires. Figure **8** shows that above two graphs almost overlap under the same loads; and it illustrates that clamper doesn't not seriously affect the signal transmission from flexible thin film sensor. Hence we know that the detachable clamping connection brought forward in this article is right and available, and that clamper may achieve the given connection and doesn't change the output characteristic of flexible thin film sensor. Furthermore, the clamper could not seriously distort the measurement results of external force. Subtraction arithmetic could effectively eliminate the negative effect of additional resistance in terms of Figure **8**. Comparing the direct connection between external wire and flexible electrode, the detachable clamping connection could effectively avoid the vibration of electrodes and crack at connecting point. Furthermore, such mode does not almost affect the measurement results and it could be fit for common case between any flexible electrode and external wire.

But above detachable clamping connection has some apparent disadvantages, for an example such connection could not work under high temperature. Firstly, such connection easily realizes the connection between different film electrodes without rigorous requirement; however such connection is not completed under highly transient temperature. Secondly, the detachable clamping connection may complete the detachable connection between two thin and flexible objects, but such connection is not used to thick and rigid objects. Thirdly, at present the detachable clamping connection could not be applied to the micro connection in the MEMS (MicroElectroMechanical Systems, MEMS) field, especially in the assembly of micro devices; furthermore operation of connection is very difficult for micro connection; Finally, connecting electrodes also affect the results of measurement shown in Figure **8** for they have a certain resistance, and furthermore such resistance is inevitable if there is connecting electrode.

4.3. Discussion On Existing Problem

There are a certain problems relative to industrious application. They are the following:

First, the above clamper was crude and only done in laboratory at present. It's unknown whether the detachable clamping connection will be completely applied to industrious field. Hence, the specific connecting mode in industry needs to be further studied and explored.

Second, the given clamper was designed and fabricated only for the verifying experiment. In fact, the actual mode of clamping connection is very different from the experiment device though they have the same principle, for they have the different work conditions. Hence, the clamper used for the industrial field will be further designed and fabricated.

Third, the embedding mode on signal processing circuit board was not researched to be fastened in the clamper; and the specific shape and dimensions of circuit board should be discussed and designed in future.

Fourth, if the surrounding gas reacts with flexible electrode or connecting electrode, the conductivity between them will become worse even non-conducting. Hence the specific work circumstance needs to be further refined and confirmed to avoid the corrosion of surrounding gases.

5. FUTURE WORK

In future, the following work needs to be done:

1) The specific clamper in industrial application needs to be further explored and given out.

2) In realizing the detachable clamping connection, other effects and limited conditions need to be observed and researched.

3) It needs to be known and explored how the clamping depth of electrode affects the conductivity between flexible electrode from plastic substrate and external wires.

4) It will be further studied whether the detachable clamping connection may be applied to other field such as connection between semiconductors. It's known whether above connecting mode could completely avoid point or line connection.

5) New connecting principle needs to be also explored further to realize the same function.

6. CONCLUSIONS

In terms of above whole content, the detachable clamping connection can solve the connecting problem between the flexible electrodes from plastic substrate and external common wires. Such connection is correct and available and effective which can be applied to the indirect connection between flexible electrodes and external wires. By the testifying experiment, the designed clamper may realize and complete the detachable clamping connection between two film conductive materials when such connection can not be achieved by high temperature welding procedure. It's also known that the clamper don't change the signal transmission from flexible thin film sensor. The detachable clamping connection can effectively avoid the limit of welding procedure under high temperature circumstances and effectively solve the aim problem. The detachable clamping connection could also supply a new method for similar connection in other field such as the connection between film conductive ceramic and film electrode on plastic.

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