Reed Switches Developed Using Micro-machine Technology

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An element with a compact contact, measuring 0.56 × 0.056mm, was realized with a micro-machine technology[1] by using the commonly implemented methods of a photolithographic technology, plating technology and etching technology. Adhering this element substrate to a glass substrate and then dividing it into individual pieces, made it possible to realize a micro-machine reed switch measuring 2.0 × 1.0 × 0.75mm.

What are reed switches?

The structure of a reed switch consists of a pair of reed pieces made of magnetic material enclosed in a glass tube[2]. A piece of reed is required to have electrical and mechanical characteristics according to specifications and is formed using a press process to create the designed contour. Further, a contact-plating surface is formed on the leading edge of the reed piece by applying metals with a high melting point, such as rhodium and iridium, to the plating process. Both ends of the glass tube are heat fused and sealed. Since inert gases are trapped inside the sealed glass tube, the contact section of the reed switch is blocked off from the external environment and therefore, the structure is capable of sustaining a constant environment. As a result the reed switch is highly reliable because the contact section is not influenced by the external environment over a long period of time.

The structure of a reed switch is shown in Figure 1. A reed switch with these characteristics needs to have two sealing sections with a length of at least 1.0mm in order to install a pair of reed pieces positioned facing each other and sealed inside a glass tube using conventional manufacturing methods of heat fusing. For this reason further miniaturization of reed pieces with adequate spring characteristics had been difficult and the manufacturing of reed switches measuring 5mm or less in a stable manner a formidable task.

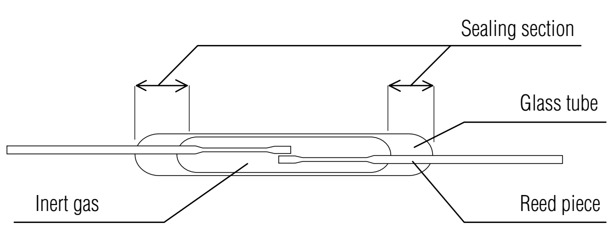


Fig. 1 Structure of a Reed Switch.

How to miniaturize reed switches

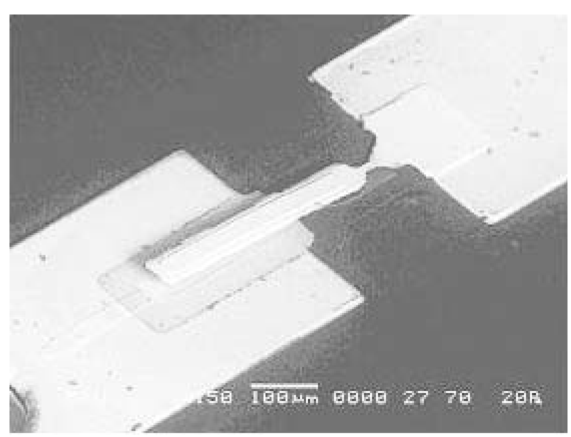
We decided, therefore, to aim for the creation of a reed switch that is formed not by conventional manufacturing processes, but rather with a completely new technology. The micro-machine technology is a powerful technology to be considered and we decided to examine the possibility of manufacturing compact reed switches using this technology.

We selected a cantilever structure[3] that involves the forming of a beam using a micro-machine technology for the structure of the element. A magnetic drive was selected as the driving method for the contact section, just like the reed switch. Furthermore, the chip resistance was referenced for the packaging of the micro-machine reed switch, which was presumed to be a surface mounting-type.

(1) Formation of elements

A variety of essential elemental technologies, such as a film forming technology, photolithographic technology, etching technology in micro-machine technology, are all based on the semiconductor micro-fabrication technology. By using a micro-machine technology, it is possible to achieve structures with very small dimensions.

A micro-machine reed switch, developed by using micro-machine technology, has the characteristic feature that allows the contact elements to be formed simply by repeating the pattern forming a number of times with a photo- lithographic technology and electrolytic plating. Contact elements are formed through the layering of two



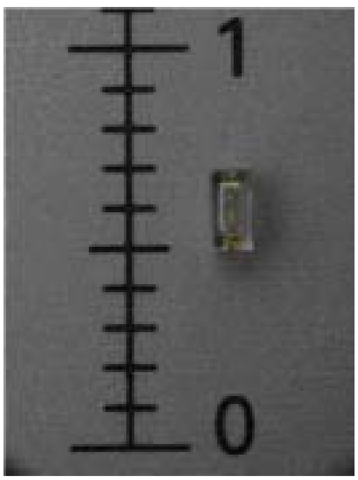
Phot. 1 External view of a contact element on a micro-machine reed switch.

types of plating films. At the end of the process a contact gap is formed through an etching process on the sacrificial layer composed of the plating and substrate metal film. Contact elements are formed through quite simple processes, as described above. An external view photograph of the contact element on a micro-machine reed switch is shown in Photo 1. Magnetic material that generates a magnetic attraction when magnetized by the influence of an external magnetic field is located inside the cantilever beam that becomes the contact point and the lower electrode.

(2) Packaging

The package size inevitably becomes larger when a method for packaging is considered wherein substrates, on which contact elements are formed, are fixed inside the package before wires are connected. Therefore, as we examined ways to reduce the wasted space in the package itself we came to the conclusion that we should adopt a shape, which is derived by using the substrate itself as the package. In this case there is a need to electrically connect the electrode formed in the package with the electrode of the contact element. For this reason a through-hole was installed and plating film was formed on the surface of this through-hole to configure a structure that connects the two electrodes.

A photograph of an external view of the package of a micro-machine reed switch is shown in Photo 2.



Phot. 2 External view of package of a micro-machine reed switch.

Contact element forming substrates

The size of the substrate was to be four inches as an assumption for the development of the micro-machine reed switch for reasons including ease of acquiring relevant facilities, ease of implementation and the favorable prospect of securing stable conditions.

The micro-machine reed switch that we developed does not require a control circuit or a signal processing circuit. Further, because the contact elements become molded by the layered plating films it was not necessary to turn the substrate itself into an element with a contact element structure. For this reason the substrate with which the element of the micro-machine reed switch is formed does not need to be a silicon substrate since the use of a glass substrate, ceramic substrate or even a plastic substrate is possible as well. The requirements for substrates to be used are shown below:

(1) The substrate surface must be highly insulated.
(2) Implementation of plating processes must be possible.
(3) The roughness of the substrate surface must be at a level that maintains the flatness to within ±1μm so there will be no effects, regardless of the multiple layering of plating films formed by electrolytic plating.
(4) The forming of through-holes on the entire surface of the substrate must be possible.
(5) Incorporating precisely arranged and precisely processed through-holes must be possible.
(6) It would be desirable for substrates to be transparent as element protective substrates and element forming substrates will be adhered together.

After taking into considering the above items, we have selected the glass substrate as the substrate for use. Because the plating process is required for the forming of elements a thin metal film needs to be attached to ensure that electrical conductivity is provided on the surface of the glass substrate.

Adhesive properties of glass substrates and substrate metal films

Concern arose for the degree to which the adhesive properties can be secured when attaching the substrate metal film to the glass substrate. For this reason an evaluation was conducted for determining the attachment condition of metal film on a glass surface and the differences in adhesive strengths depending on the selection of various methods used to form the film. The standard used for this evaluation is shown in Table 1. A diagram depicting the outline of the evaluation glass substrate structure is shown in Figure 2. The results of the evaluation are shown in Table 2 and Figure 3. Through all this the strength of the substrate suffered because the glass itself became brittle through the influence of chemical treatments, even though the

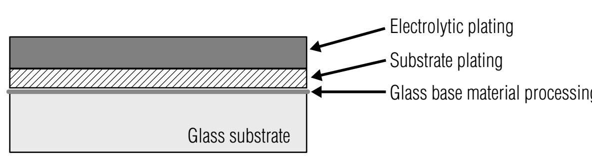


Fig. 2 Description of an evaluation glass substrate structure.

Table 1 Evaluation standards for the adhesion strength of different film forming methods.

	Standard 1	Standard 2	Standard 3	Standard 4	Remarks
Glass base material processing	Chemical treatment	Abrasive blasting	Zinc oxide	Degreasing	—
Substrate plating 0.2 μm	Electroless NiP	Electroless NiP	Electroless NiP	Ni sputter	Electroless Cu
Electrolytic plating 5 to 6 μm	Cu	Cu	Cu	Cu	Cu
Substrate	Glass	Glass	Glass	Glass	Glass epoxy

Table 2 Adhesive property evaluation results.

Glass base material processing	Chemical treatment	Abrasive blasting	Zinc oxide	Degreasing	Glass epoxy
Substrate plating 0.2μm	Electroless NiP	Electroless NiP	Electroless NiP	Ni sputter	Electroless Cu
Electrolytic plating 5 to 6μm	Cu	Cu	Cu	Cu	Cu
Tensile test average	4.8	0.0	4.4	3.7	9.9
1	3.6	0.0	7.0	2.4	10.8
2	6.0	0.0	5.0	3.7	10.6
3	3.3	0.0	4.0	3.4	9.9
4	6.8	0.0	3.0	5.8	9.2
5	4.4	0.1	2.9	3.2	8.8
Cellophane tape test (Peeling pad /5)	2/5	3/5	0/5	0/5	0/5
External view after etching	NIP residue & conductivity exist	NIP residue & conductivity exist	Zn film Ni-P film residue & conductivity exist	Good	Good
External view after tape test	Black film attached and no conductivity	Peeling from glass interface	NiP with tape, Zn film peeling and no conductivity		

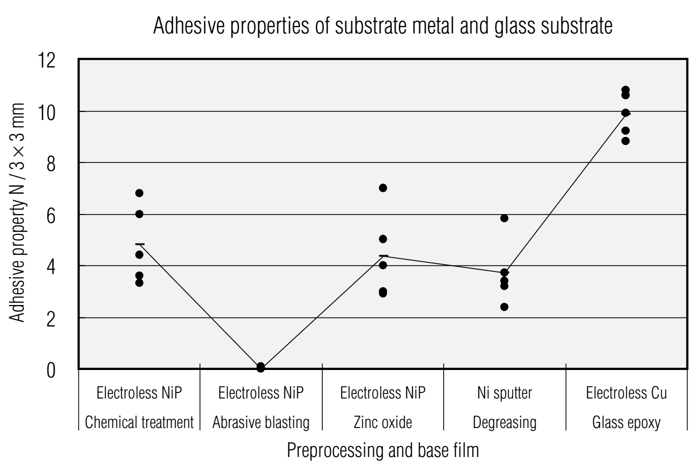
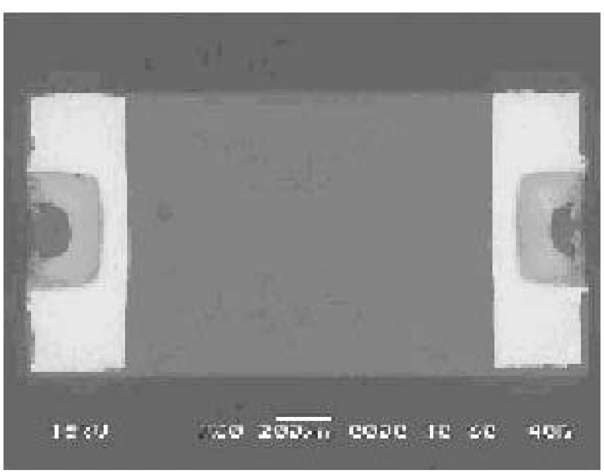


Fig. 3 Evaluation results for the adhesive strength of different film forming methods.

adhesive strength of the electroless NiP substrate with the glass did improve somewhat. This situation demonstrated it was no longer possible to eliminate all the zinc oxide in processes that involve the etching of iron chloride only. As a result a nickel substrate film from sputtering was selected. It was possible to verify that the adhesive prorerties (peel strength) was 2N or more with the nickel substrate film from sputtering. While this adhesive properties presented no problems during the processes for forming contact elements it was not adequately strong enough to form electrodes on the package. For this reason an electrode shape that brought about an anchoring effect was selected for the electrodes of the package to increase the adhesive strength of the substrate after mounting. This electrode shape is shown in Photo 3. Once the substrate was mounted, solder was put into the anchoring section to fix it in place, thereby improving the adhesive strength of the solder joint.



Phot. 3 Electrode shape of a micro-machine reed switch package.

Contact element protective substrates

In order to protect the contact elements and to package them it was necessary to have an extra substrate. A substrate made of the same material and of the same size as the element forming substrate, on which a process was performed to cover the formed contact elements, was selected as the element protective substrate. An engraving process using sand blasting was performed to form an indentation measuring 0.15mm over the entire surface of the substrate.

The element protective substrate and the substrate on which an element was formed were attached together using an adhesive agent, a scribe process was then performed, after which individual pieces were separated to obtain the individual final products of micro-machine reed switches.

Prototype evaluation results

(1) Element characteristics

A comparison between the target specifications for the development of the micro-machine reed switch and the results of the prototype evaluation is shown in Table 3. The results indicated that the contact point resistance was 0.5Ω, a figure that was higher than the targeted specification value. Investigations are under way to get to the bottom of this from both the perspective of beam structure and process. In terms of the beam structure a review is being conducted on the relationship between the magnetic attractive force and the contact force. As for the process, investigations are under way regarding the contamination conditions of the contact surface in terms of the effects from residual substances from etching and adhesive gas.

Table 3 Comparison of targeted specifications for the development of a micro-machine reed switch and the results of a prototype evaluation.

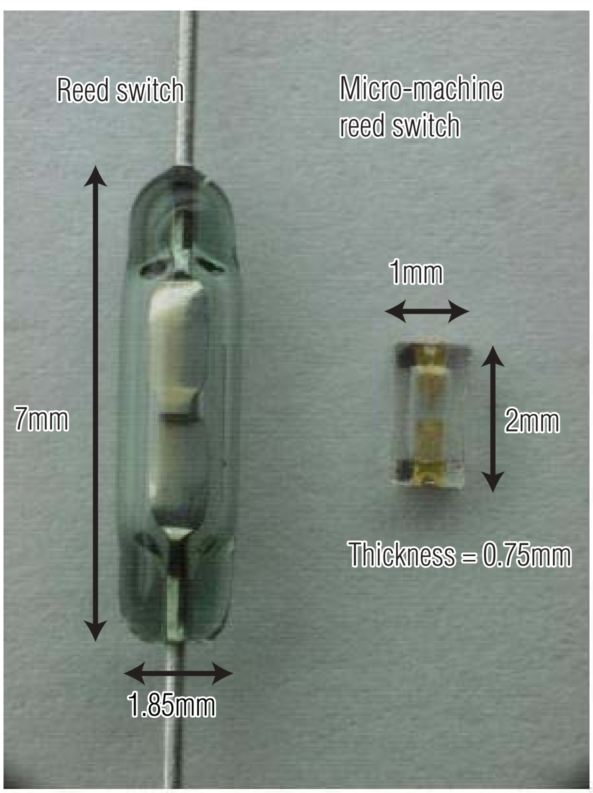
Characteristic item	Conditions	Targeted specifications	Evaluation results
Contact resistance	1V-1mA/10mT	0.2Ω	0.5Ω
Max. switching current	10mT/10Hz	50mA	50mA
Max. switching voltage	10mT/10Hz	5V	5V
Max. electric current	10mT	100mA	150mA
Life	Non-loaded: 10mT/10Hz	1×10^7 times	1×10^7 times
Response speed 1V-1mA	1V-1mA 10mT/10Hz	Operating time: 5ms Recovery time: 5ms	Operating time: 2ms Recovery time: 1.5ms

(2) Solder fixing strength for package electrodes

Electrodes were fixed using solder and the adhesive properties (peeling strength) of the package electrodes were verified. The results showed a value of about 7N indicating that the adhesive strength at the solder joint had increased.

Conclusion

In order to further miniaturize reed switches with the current conditions we implemented a micro-machine technology as well as a photolithography technology, plating technology and etching technology to make it possible to fabricate a contact element. As a result it became possible to create packages with dimensions of 2.0 × 1.0 × 0.75 mm, realizing a micro-machine reed switch that is an ultra-compact. External views of a conventional reed switch and a micro-machine reed switch are shown in Photo 4.



Phot. 4 External views of a reed switch and micro-machine reed switch.

Future Tasks

The current status demonstrates that the formation of elements and the process of packaging have been determined. From the prototype evaluation results we found that the characteristics satisfying our targeted specifications have been obtained except for contact resistance. We are planning to implement improvements to attain the targeted values for contact resistance in the future as well. Furthermore, it is necessary for us to accelerate the rate of development in order to respond to the demands of many users regarding micro-machine reed switches.

References

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