Microcrimping of fuse-elements and terminations of sub-miniature-fuse links

Prof. Dr.-Ing. Florian Haberey, Dipl.-Ing. Michael Heek,
Dipl.-Ing. Michael Wendt

1 Introduction

Nowadays the most common method to connect a fuse element with the connections of a fuse is by soldering. When soldering, the fuse element is joined with the ections (via the solder) in a way that a gas-proof contact surface comes into existance avoiding any oxide or surface coatings of the contacts.

For fuses with a high rated value materials like silver or copper are generally used as fuse elements which can be easily soldered even with non-activated soldering flux. However, these materials have the disadvantage that the tin or lead contained in the solder diffuse in the copper and silver material and weakens the fuse element at the soldered joint. During diffusion intermetallic phases are caused reducing the melting point. This often causes problems especially for very thin fuse elements as these fuse elements are often weakened already during soldering.

In order to reduce this problem or to be able to produce even smaller currents, materials of a high electric resistance like nickel, platinum, tungsten oder constanta are frequently used . These materials have a considerably higher melting point compared to silver or copper.

It is, however, a disadvantage of such materials, that it is very hard to solder them with flux materials of a very low activation. Due to this a trick can be applied by tinning the fuse element with the galvanic process; this, however, is an expensive solution. For cost reasons and also for reasons of environmental protection it is advisable to do without galvanization.

Above problem in particular affects miniature fuses as - due to their small distance to each other - they require a highly resistive wire to achieve small ratings. As the joining pieces of miniature fuses consist of tinned copper, high temperatures must not be applied, the flux materials must be of low activation avoiding a corrosion of tin and copper.

Due to above problems we decided to launch a project in cooperation with the Institute for Materials in Electrotechnics at Bochum University with the aim of finding a way to join such fuse elements without a galvanic surface and without soldering with tinned copper terminations.

The requirements for this would be as follows:

The joining technique to be developed must produce gas-tight contact surfaces; otherwise oxid and other surface coatings might occur on the joining terminations and the fuse elements. This technique should be resistant to mechanic stress and environmental influence; at the same time it shall represent a good transition resistance. This technique should be developed for miniature fuses only. The joining technique was called **"microcrimping"**.

All tests were to be carried out on standard fuse bases. A wire consisting of tungsten (∅ 4,4 μm) as well as a wire consisting of silver copper (∅ 28 μm) were used and tested as fuse element.

2 Experiment

The first attempts to carry out the "microcrimping" method were done with the help of a simple pair of pliers. These attempts already showed the problems of this technique. Special photographs showed that the thin wire does not find any contact with the junctions. On top of this extremely large cavities had formed, caused by a loosening of the microcrimping connection after the pressure of the pliers was relieved. Therefore it was not possible with the help of this relatively simple method to produce the required contact area resistant to corrosion.

During the second attempt the contacts were pushed together with the help of a pair of shaped pliers and the pliers turned to and fro under pressure. Due to the shape of the pliers' jaw the contact surfaces did not shift towards the pliers, but rubbed against each other and against the wire positioned between them. Therefore, both contact surfaces got "smeared" against each other. Checking this contact area the junctions showed a high bond strength and did not open after a relieve of pressure. The fuse element was embedded between the contacts; a cavity surrounding the fuse element could not be observed.

On the basis of these elementary investigations an apparatus was constructed with the help of which it was possible to carry out definedly above bonding technique. (see **fig. 1**).

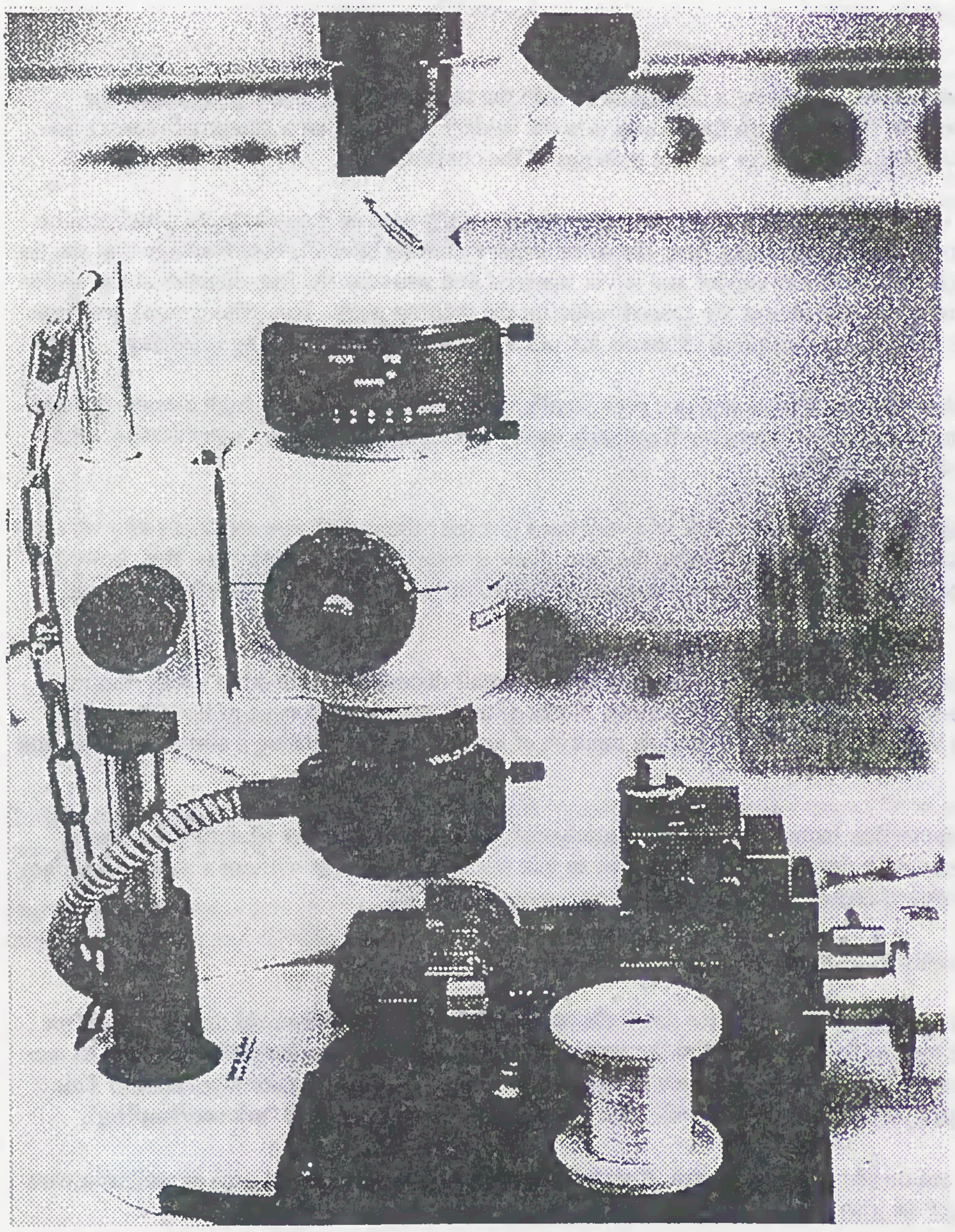

Fig. 1: Microcrimping apparatus.

With the help of this device it is possible to carry out the crimping and smearing method with a defined and constant force. The device consists of two jaws which can be pushed together definedly with a torque screw wrench. The jaws of the device are fitted like a pair of shaped pliers. This shape is used to dig into the contacts from the outside. Finally the jaws can be shifted towards each other by 10 μm with a small lever.

For the production of fuses following steps are to be carried out:

The round tinned copper terminations are pressed in the fusing area fitted with a cap; this is done with another tool at 1.5 kN. After pressing the joint ends are roughly pre-folded. These pre-folded fuse bases are fitted in the device; the fuse element is put under the pre-folded joint terminations and tightened.

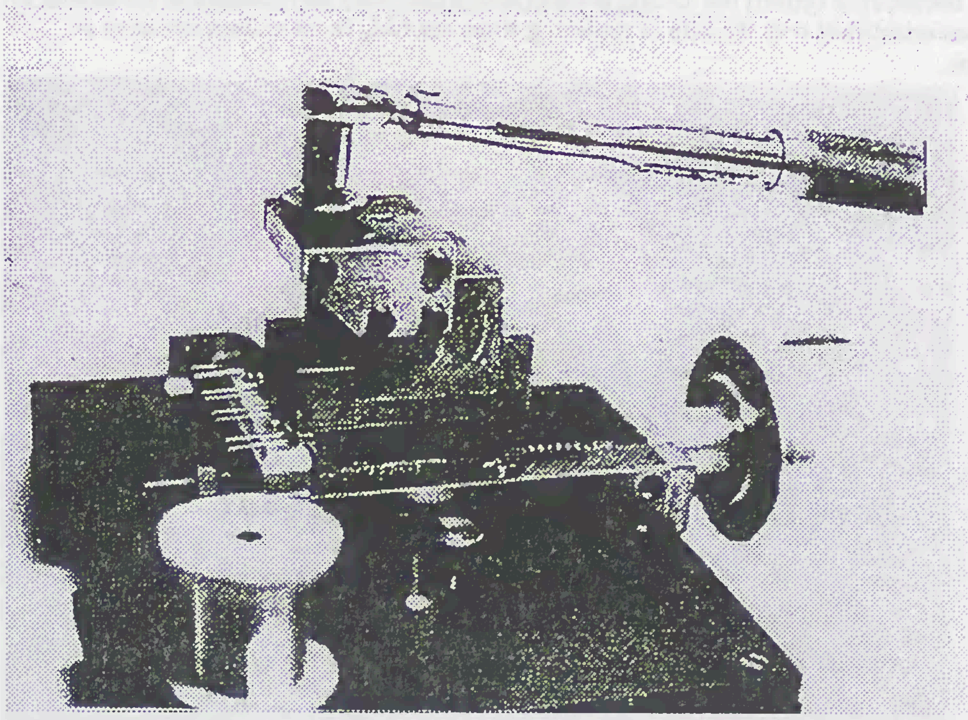

Fig 2: Crimping process.

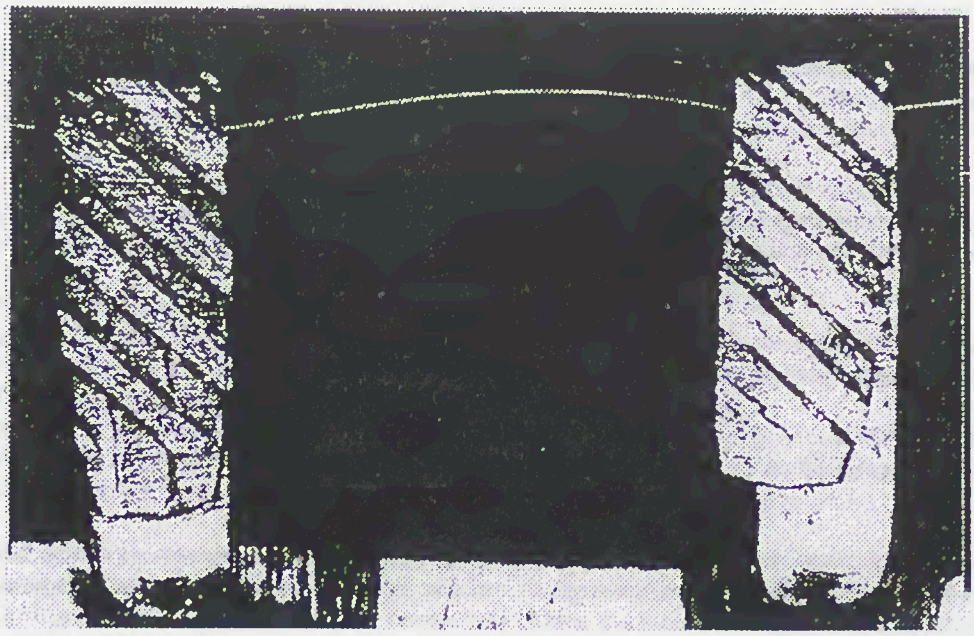

Fig. 3: Microcrimped fuse.

After this, the fuses are crimped at a defined turning moment of 6 Nm and the contact surfaces "smeared" towards each other with the simple mechanism of the apparatus.
After this the fuses are crimped once more at a defined turning moment of 9 Nm. By this it can be avoided that the contacts do not open up after opening the device.

The force necessary for squeezing the contacts around the fuse element is decisive for a good result of microcrimping. For this reason it is necessary to convert the turning moment which can be set reproducably to a crimping force. This dependance was established with the help of stretching strips resulting in the calibration curve as shown in below illustration.

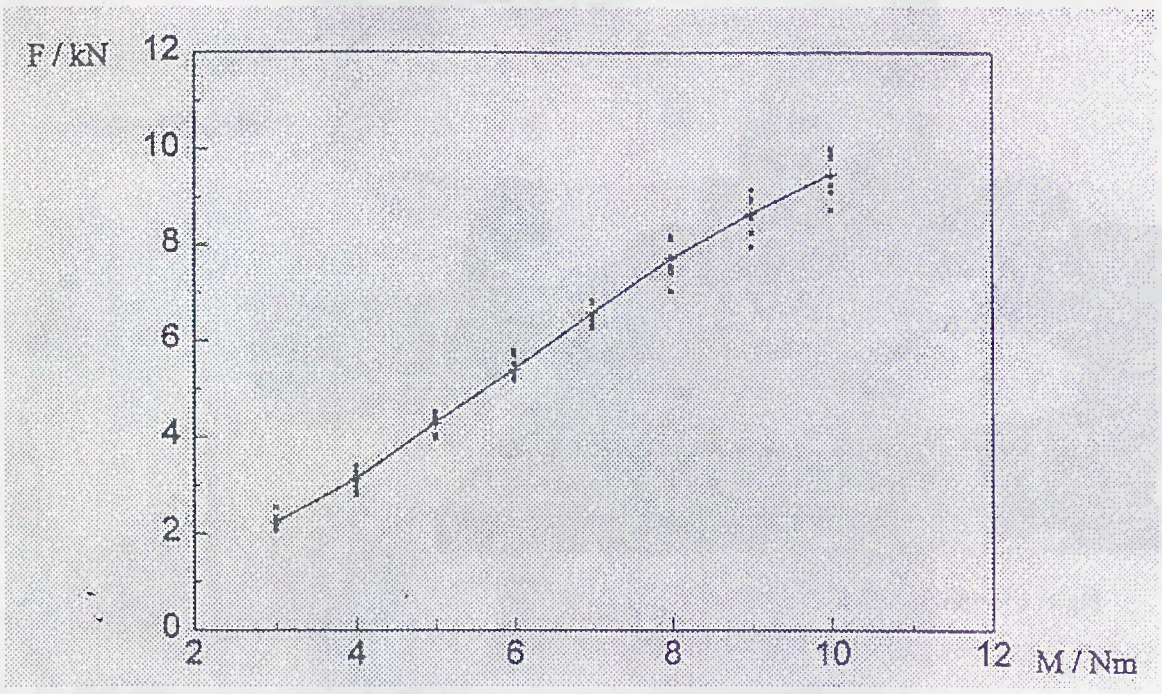

Fig. 4: Dependance between turning moment (M) and force (F)

After the production of the fuses these underwent various tests. A large part of the joints were polished in order to carry out analyses with the scanning electronic microscope. Here, attention is particularly paid to cavities between the contacts and the fuse element, and and an elementary distribution for the determination of possible diffusion processes is carried out.

The remaining fuses had to withstand electric, thermic and mechanic tests. Therefore the cold resistance as well as the characteristic of the fuses were tested. A pulse test was also carried out.

For the determination of the resistance to aging, some fuses underwent changes in temperature (thermic shock) (50 cycles à 2 h; - 40° C, + 100° C) and others were exposed to damp heat. (150 h; + 40 °C;
95 % r.h.).

In order to test the mechanic stability of the fuse element in microcrimping, some fuses underwent a vibration test (24 cyles à 15 min.; 10 - 2000 Hz; function stroke in the scope of < 60 Hz: 1.5 mm; acceleration in the scope of > 60 Hz: 10 g).

3 Results

150 fuses with a tungsten fuse element of a diameter of 4.4 µm were produced. These fuses showed following results for above tests:

The investigation in the scanning electronic microscope showed that the fuse element has a good all-side contact to the contact terminations. Diffusion processes were not found.

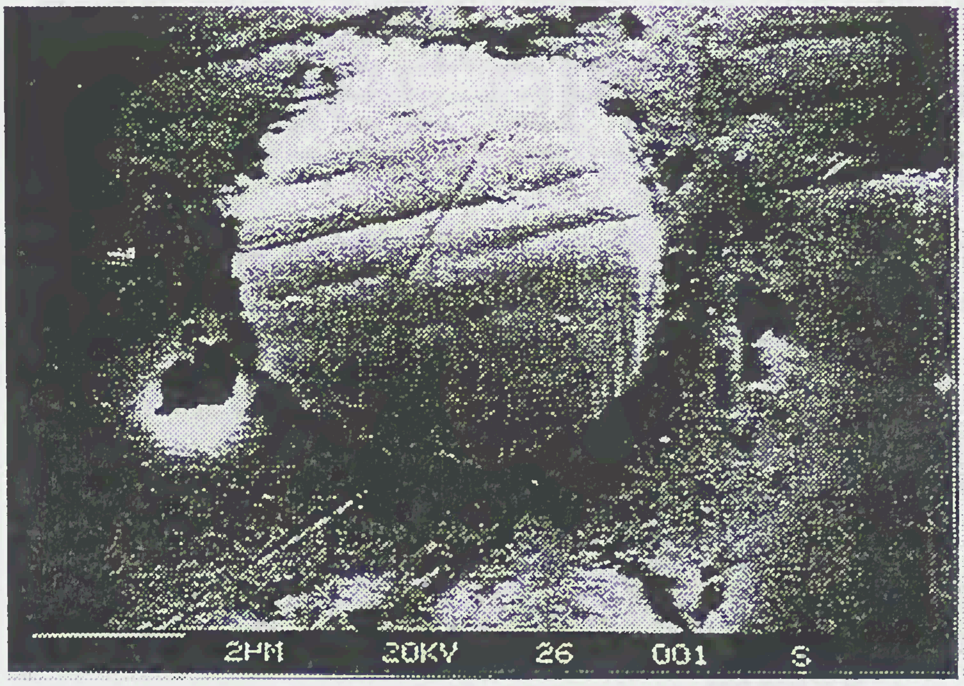

Fig 5: Scanning electronic microscope photo of crimped joint. (Centre: Tungsten wire)

The cold resistance measurements of the fuses showed values that were distributed closely. The measurement of the characteristic showed that the fuses produced in the microcrimping process fulfil all requirements to a fuse. In a pulse test with 60 % of the measured I^2t-value, the fuses were exposed to more than 40.000 pulses without switching off.

In all thermal tests the increase in cold resistance of the fuses was established and assessed. No substantial increases could be found.

No failure was registered during the vibration test.

Furthermore 100 fuses with a fuse element consisting of silver copper with a diameter of 28 µm were produced. These fuses, too, underwent above tests and showed following results:

When investigating the fuses with the scanning electronic microscope, the fuse element was found to have a good all-side contact to the contact terminations. No diffusion processes could be found.

The resistance measurements of the fuses represented values of a relatively tight distribution. The measurement of the characteristic showed that the fuses produced in the microcrimping process fulfil all requirements to a fuse. During a pluse test with 60 % of the measured I^2t-value the fuses were exposed to more than 40.000 pulses without switching off.

During all thermic tests the increase of the cold resistance of the fuses was established and assessed. No substantial increase was found in any of the tests.

During the vibration test one failure was registered. Here the fuse element disconnected next to the joint contact.

4 Conclusion

Tests have shown that it is possible to produce fuses with very thin fuse elements by way of microcrimping. As such joints ensure a permanent electric contact only when the contact partner is free of suface coatings, the device was manufactured that way that surface coatings are split. This is achieved by rubbing both contact surfaces under pressure with the fuse element positioned between them. The condition achieved like this is then frozen by another microcrimping procedure. By this, the clean surfaces produce a tight, permanent mechanic and electric connection.

One of the most important factors for microcrimping is the pressure to be exerted on the contacts. The optimum pressure during the tests was 9 N/cm². A considerable reduction of the pressure did not result in a firm connection between contacts and fuse element. When, however, increasing the pressure considerably, the fuse element gets sheared off. Inferior Microcrimping contacts can be selected by applying the measurement of the cold resistance.

The electrical tests of the fuses als well as their exposure to pulses have revealed that the fuses produced in the microcrimping method fulfil all requirements to a fuse.

The mechanic and thermic tests have shown that (similar to the soldering technique) the fuse elements have a tight contact to the joint terminations. Especially the vibration test has revealed that the adhesive properties of the fuse element between the two contacts is so good, that there were no failures.

Due to the diffusion analysis with a scanning electronic microscope no diffusion processes could be observed; therefore this possibity can be ruled out for this production technique.

Comparing the microcramping joints as described above and the facts resulting from the tests with already known procedures, the joint technique of microcramping represents an alternative to the conventional soldering technique

5 References

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FUSE OPERATION