"FLASHSOLDERING" - A NEW PROCESS FOR REFLOW SOLDERING INSULATED MAGNET WIRE TO ELECTRONIC CONTACTS

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Abstract: FlashSoldering is a new non-contact reflow soldering process specifically developed for terminating fine insulated copper magnet wire to a special electronic contact without the need for added solder or flux. Two components comprise the FlashSoldering system. The first component is a unique electronic contact used to locate and retain very fine insulated copper magnet wires during the soldering process. The electronic contact can be manufactured in the form of single SMT contact "feet" embedded in a plastic housing or in a continuous lead frame capable of being over-molded after the FlashSoldering process is complete. The second component is a diode laser which is then used to simultaneously remove the insulation and reflow solder the wire to the contact without damaging or contacting the wire. Extensive testing using 100 micron (.004 inch) diameter heavy polyimide and polyurethane-nylon insulated copper magnet wire has proved that FlashSoldering is a repeatable process. Additional testing will be necessary to determine the practical maximum and minimum magnet wire diameter range. Applications include terminating miniature toroidal transformers, DC-DC converters, LAN filters, and more. The receptacle or lead frame is scaleable to production requirements.

Key Words: DC-DC Converter, Diode Laser, Electronic Contact, FlashSoldering, insulated magnet wire, LAN filer, miniature toroidal transformer.

I. INTRODUCTION

A. Present Manufacturing Process and Problems

Small toroidal transformers, ranging in diameter from 3 to 9 mm (.12 to .37 inches) are manufactured by hand or automation by winding very small gage magnet wires around the toroid. These magnet wires typically range in diameter from #38 AWG (.004 inch/100 um) and smaller and predominantly use polyurethane-nylon as the insulation material. Once the toroidal transformers are wound, they must be mounted and each lead wire terminated to an electronic contact in a component package form that facilitates mass reflow soldering to rigid or flexible printed circuit boards by the end user. Presently, two different toroidal transformer mounting systems are used in the industry, depending on the number of toroidal transformers that must be placed in a single component package.

Single toroidal transformers are typically glued to the bottom of an open plastic box that has tin/lead plated contact pins embedded in the plastic housing for terminating the transformer lead wires. After gluing the toroidal transformer in the housing, each transformer lead wire is hand wrapped around a contact pin. The toroidal package assembly is then solder dipped to simultaneously remove the wire insulation and reflow solder between the magnet wire and contact pins.

Multiple toroidal transformers and other surface mount components (SMT) such as resistors and capacitors are most often mounted on a dual in-line package (DIP) or "gull wing" SMT style lead frame. After automatically placing and mass reflow soldering the chip resistors and capacitors to the lead frame, each toroidal transformer is then glued to the lead frame. Each transformer lead is then hand wound around a lead frame terminal. Solder dipping simultaneously removes the wire insulation and creates a solder joint between the wire and terminal. This sub-assembly is then selectively epoxy coated to protect the toroid and terminated leads during the final over-molding encapsulation process.

If polyimide insulated magnet wire (ML) is used in place of polyurethane-nylon insulation in either the single or multiple toroidal packages, then an additional step of mechanically hand stripping the magnet wire must be added to the assembly processes described above since polyimide can not be removed by the solder dipping process.

The present manufacturing processes produce a combined production and field failure rate as high as 5%.

These failures are caused by hand stripping, multiple handling, and inconsistencies in creating a thermal strain relief loop between the toroid and terminating pin.

B. FlashSoldering System - A New Manufacturing Approach

"FlashSoldering" is a new term developed by the authors to describe a non-contact reflow soldering process for terminating fine polyimide (ML) or polyurethane-nylon insulated copper magnet wire, .004 inches (100 um) or smaller in diameter, to a special electronic contact without additional solder or flux. The benefits of this new manufacturing approach include improved connection reliability, no wire damage, non-contact soldering, no additional solder or flux, elimination of solder pot dipping with potential solder bridging, no harmful chemical or mechanical wire stripping required when using polyimide insulated wire, and less hand labor. This new manufacturing process requires two components in order to be successful, a special electronic contact design and a diode laser.

II. DISCUSSION

A. Electronic Contact - First System Component

The electronic contact used in the FlashSoldering process represents a sophisticated heat transfer system. The electronic contact has multiple functions: a) capture and securely hold the insulated magnet wire during diode laser heating, b) protect the magnet wire from over-exposure to the laser heating, c) transfer heat building up in the contact to the wire capture slot area to remove the magnet wire insulation, and d) transfer solder from the surrounding contact surfaces to the now exposed copper wire.

The thermal characteristics of the contact are critical to both the insulation removal and reflow soldering process. Alloys such C17410 are thermally too conductive and dissipate the heat away from the wire capture slot. Conversely, alloy 42 is thermally too resistive and prevents the heat from reaching the slot. In either case, if the heat does not build up in the area behind the wire capture slot, the insulation does not separate from the copper wire nor does the plated solder flow properly to the copper wire.

The FlashSoldering electronic contact represents a right angle or "L" shape when viewed from the end as shown in Figure 1. The "L" shape design facilitates inserting the magnet wire into the contact's wire capture slot, which is located on the inside corner, and protects the magnet wire during laser heating by reducing the area of exposed magnet wire.

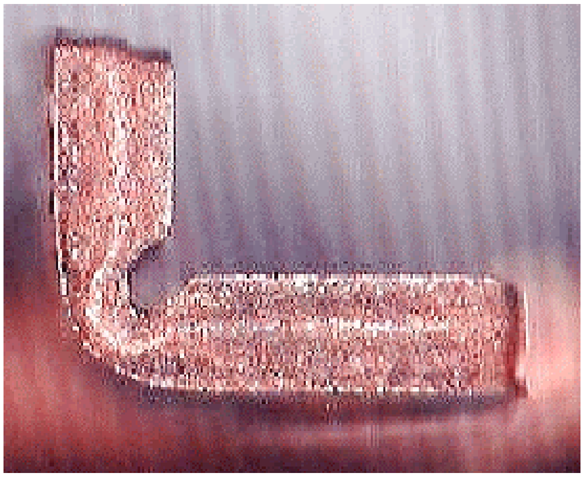

Figure 1 - End view of FlashSoldering electronic contact

Inserting #38 AWG polyurethane or polyimide insulated magnet wire into the wire capture slot is not as difficult as it might seem. As previously mentioned, the right angle shape of the contact provides a guide to inserting the wire. Using a modified dental tool, the authors were able to lock the magnet wire into the wire capture slot without the assistance of any magnification systems simply by feeling the "snap" of the wire as it locked into the wire capture slot. Semi-automated techniques are available for assisting with the magnet wire insertion process. Figure 2 shows the magnet wire locked in a single SMT contact.

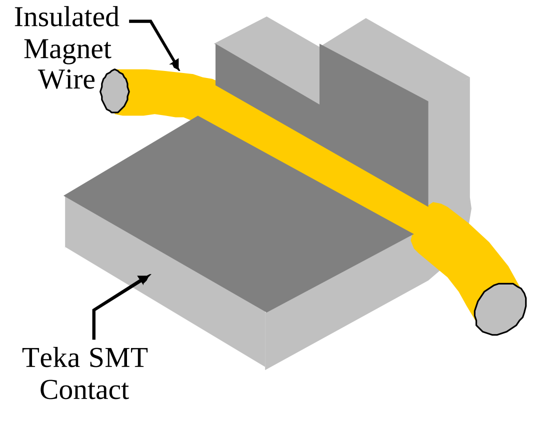

Figure 2 - Magnet wire locked in SMT contact

The FlashSoldering Contact with its wire capture slot offers an added benefit in that it ensures that the length of wire stretching between the toroidal transformer to the contact can contain a small amount of slack for strain relief purposes under temperature cycling conditions. A uniform wire length offers more consistent electrical inductance, which is very important in the 900 MHz to 1200 MHz frequency region where many toroidal transformers operate.

B. Diode Laser - Second System Component

Pulsed YAG lasers, with an operating wavelength of 1024 nano-meters, have been used in the past to try to simultaneously remove magnet wire insulation and reflow solder paste or plated solder between the contact pin and magnet wire. These experiments have not been highly successful because the peak power nature of YAG laser causes: a) pitting or blow out of the copper wire, b) incomplete insulation removal, c) solder paste expulsion or vaporization, and d) uncontrollable solder ball formation that can cause electrical shorts in the final product.

The advent of continuous operation, solid state diode lasers, with an operating wavelength of 820 nano-meters, now makes possible reflow soldering of solder paste or plated solder without all of the detrimental characteristics produced by the pulsed YAG laser. Testing by the authors demonstrated that diode laser heating technology can be successfully used to remove polyurethane-nylon or polyimide insulation from #38 AWG and smaller magnet wire.

However, testing on polyurethane and polyester insulated magnet wire was not successful. These insulation materials tend to burn and flow, leaving a gummy residue that interferes with solder reflow.

The laser beam is primarily focused on the contact just above the wire capture slot. This action ensures that the heat will conduct down and below the wire capture slot.

Focusing the laser beam directly on the embedded magnet wire causes the magnet wire to "bow out" of the wire capture slot during heating. In this focusing mode, the amount of direct laser beam exposure on the magnet wire is limited to approximately 20% of the total laser beam diameter. Figure 3 shows the diode laser beam focused on the upper portion of the electronic contact.

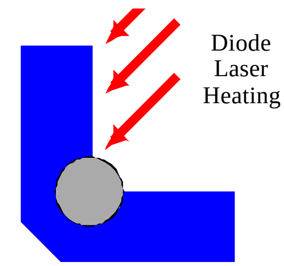

Figure 3 - End view electronic contact with magnet wire captured in slot and diode laser beam focused on upper contact surface

C. Testing Approach

Prototype SMT contacts .040 inches long (1.0 mm) by .030 inches high and wide (0.75 mm) by .010 inches thick (0.125 mm) were fabricated from a variety of beryllium-copper, copper, nickel, and steel alloys. Alloy C17200 proved to provide the best thermal balance, given prototype dimensions. The contacts were plated with 90/10 tin/lead, .0005 inches thick (12.5 microns).

A 15 watt diode laser, with a fiber optic and lens system for energy delivery, was used to create an infrared spot of .020 inches in diameter (0.50 mm). Experimenting with different energy levels determined an optimum pulse energy of 11 watts at 0.2 seconds worked for this application.

D. Results

Figure 4 shows an entire prototype FlashSoldered contact containing a #38 AWG polyurethane-nylon insulated copper magnet wire. The amount of stripped insulation outside of the contact can be controlled by the laser energy.

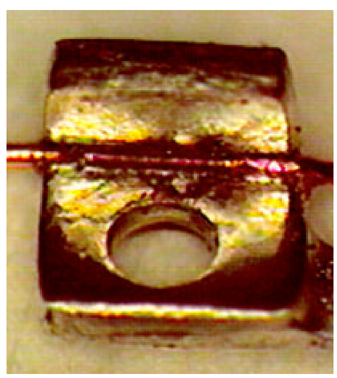

Figure 4 - Complete prototype electronic contact with FlashSoldered polyurethane-nylon magnet wire.

Figure 5 shows a longitudinal section of wire capture slot. The contact is .040 inches (1.0 mm) wide.

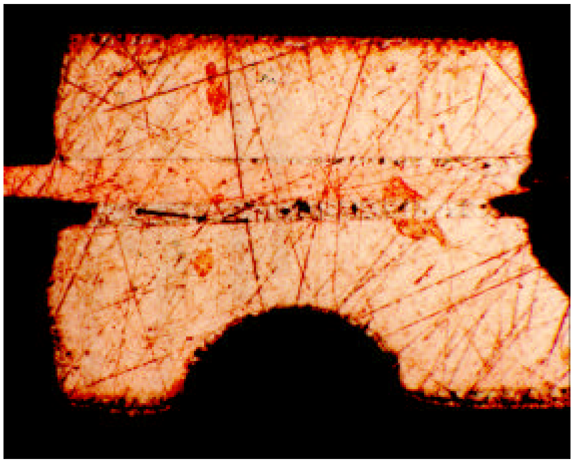

Figure 5 - Longitudinal cross section of the reflow soldered wire capture slot with #38 AWG wire.

Figure 6 shows with the #38 AWG (.004 inch/100 micron) copper wire surrounded by the 90/10 solder without any voids.

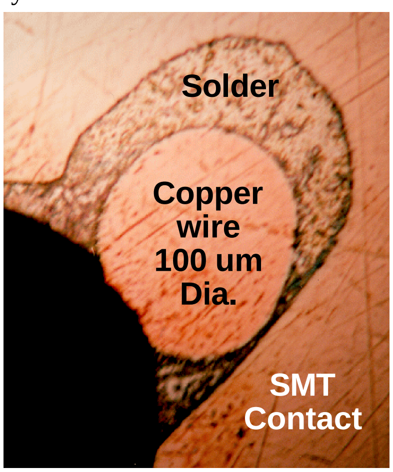

Figure 6 - 500x magnification of a typical FlashSoldered wire capture slot cross section.

E. FlashSoldered Contacts - Subsequent Processing

The FlashSoldering process creates an "oxide skin" on the 90/10 plating exposed to the diode laser beam. In addition, a small amount of insulation residue resides on the contact. Concerns about both of these items led the authors to reflow solder completed contacts onto printed circuit board pads using standard 63/37 tin/lead solder paste in a convection reflow oven.

Figure 7 shows that all surface contaminants were completely removed during reflow soldering by the flux contained in the 63/37 solder paste.

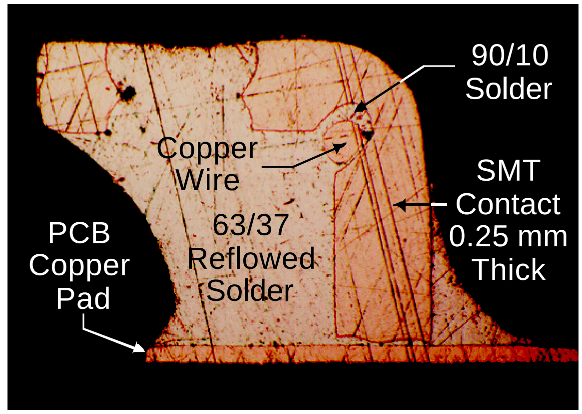

Figure 7 - Electronic contact reflow soldered to printed circuit board using 63/37 tin/lead solder paste.

III. CONCLUSIONS

The miniature toroidal transformer industry has reached the limits of its current processing capabilities.. FlashSoldering offers the industry a way to improve productivity and at the same time reduce overall failure rates, package size, and required assembly manpower.

IV. ABOUT THE AUTHORS

David Steinmeier - Co-author

David is an internationally recognized expert in the field of micro-joining miniature and micro-miniature metal components. He is the author of many metal joining articles that have been published in leading industry journals such as *MD&DI* for the medical industry and *AWS* for the American Welding Society.

Mike Becker - Co-author

Mike Becker is an expert in high speed assembly and manufacturing processes with over 20 years experience. He is currently focused on designing and developing high density interconnect solutions for the electronic connector industry. Mike is the holder of several patents in the area of high density electronic interconnections.