ANISOTROPIC CONDUCTIVE JOINING

Miloš SOMORA, Slavomír KARDOŠ
*Department of Technology in Electronics, Faculty of Electrical Engineering and Informatics,
Technical University of Košice, Letná 9, 042 00 Košice, tel. 055/602 3211, E-mail: Slavomir.Kardos@tuke.sk

SUMMARY

The main emphasis was laid to the new approaches in tasks solving by using of standard electrotechnologies and available production facilities. This work reports about anisotropic interconnections usability as an alternative of soldered joints in production process at equipment, what is generally used for reflow of standard lead solder between contact areas. Practical results of the performed study indicate that realized joints with applied anisotropic conductive adhesive have comparable electrical resistance with soldered interconnections. The anisotropic conductive paste application demonstrates their suitability for bare copper and gold plated contacts conductive joining. The lower mechanical strength is the less relevant with concerning of operating conditions.

Keywords: *anisotropic conductive joining, anisotropic conductive adhesives.*

1. INTRODUCTION

Solder joints proceeds redevelopment due to lead solders elimination from permitted soldering materials. One opened up way is the utilization of lead free solders what are compounds of various alloys based on two, three or four metals. Utilization of anisotropic conductive adhesives represents another advanced way for undismountable joints formation.

2. ANISOTROPIC CONDUCTIVE JOINING

An anisotropic conductive adhesive (ACA) consists of thermoplastic and thermosettic polymers, which are filled with conductive particles. Instead of pure metallic character of solders, the fillers are relative tenuously distributed, so despite of metallization by high conductive metals they obviously have lower electrical conductivity. While the soldered joint is metallurgical, the adhesive joint is formed by springy mechanic contact between adherends and conductive particles in polymer matrix. Application range of ACA is hence mainly delimited from electrical properties terms because of limited current loadability.

The ACAs are manufactured in the form of pastes and films and they are non-conducting in unapplied state. Contact areas with deposited adhesive are interconnected with component contacts by relative high mechnical pressure. There are created multi-parallel electrically conductive contacts by pushing of conductive particles together. The particles besides of contact areas remain sparsely distributed, so the isolation state still remains unspoiled. Thereat the ACA can be applied non-selectively through the whole contact area.

Polymer thick-film technologies (PTFT) represent the extension of standard thick-film technologies. In many applications they are the only useful alternative for creation of thick-film structures. They have simple production processes, low production expenses, integration possibility of passive devices including potentiometers. They are limited by temperature range, higher resistivity of conductors than of copper plated ones, higher power load and lower solderability.

Polymer thick films are the conductive, resistive and dielectric layers in topological structure of thick-film circuitry, generally at planar substrate. Standard types of the printed circuit boards (PCB), ceramics and flexible foils are possible to use as substrates for this technology [1, 2].

Epoxides, polyimides and acryles are used as supporting materials for polymer thick-film pastes. Polymer based pastes have short-time usability, usually six months at proper storing conditions. Used fillers in conductive pastes are obviously Ag, Cu and Ni. In resistive pates there are carbon compositions [3, 4].

In screen-printing process the polymer paste is forced trough the opens in mesh onto substrate by squeegee. Production of polymer thick-film layers is a sequence of screen-printing and hardening steps, repeated for each layer, at conditions for individual PTF paste.

Generally, the polymer thick-film pastes do not require the drying after screen-printing and their hardening is currying out by thermal or ultraviolet radiation [5]. Thermal hardening is realized in standard box or in continuous furnace at range of 80-140ºC for thermoplastic pastes and 150-250ºC for thermosettic pastes. It is possible the microwave heating. Dielectric pastes obviously require ultraviolet hardening.

PTF contacts are realized in the same motive as conductive paths and they are covered by chemically more stable PTF carbon layer for prevention of silver atoms migration [3].

Manufacturing of touch panels and membrane keyboards, production of PCB-PTF hybrid modules, chemical sensors, and modifications of standard PCBs and at repairs represent main areas of PTFTs utilization [3, 6].

3. EXPERIMENTAL JOINTS

Chosen sample substrates was based on the standard copper plated FR4 laminate and finished by strip connector at corner with 4 x 10 mm dimensions and 0.55 mm raster of contacts. Surface of contacts and of through-holes were galvanic coated by thin gold layer (Fig. 1).

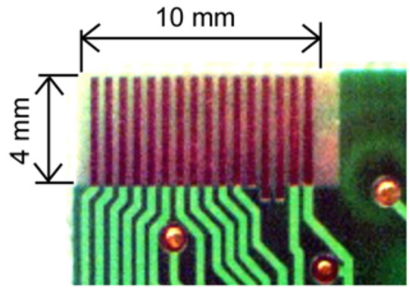

Fig. 1 FR4 rigid substrate with gold coated connector contacts.

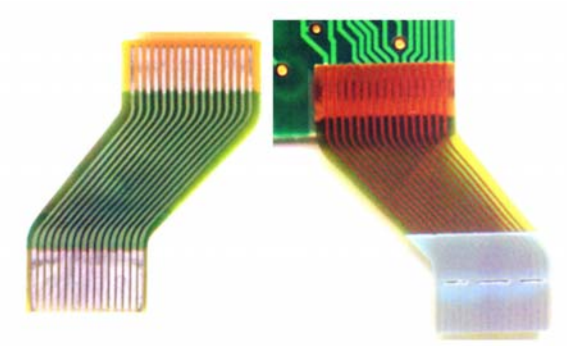

Fig. 2 Polyimide foil cable (left) joined onto rigid FR4 substrate (right).

The flexible foil cables were produced from polyimide foil and finished by standard lead-solder coated strip connector at both terminations. The foil-cable connectors (Fig. 2 left) are in standard production process connected onto rigid substrates (Fig. 2 right) by reflow soldering.

Loctite 3447 standard anisotropic conductive paste was chosen for realization of monitored conductive joints.

ACA type	Adhesion paste / filler	Application technique	Hardening conditions
Loctite 3447	epoxy base / 7 µm Au plated Ni particles	dispensing or screenprinting	180°C @ 5 s & pressure of 0,5 - 1 kg/mm^2

Tab. 1 The basic parameters of Loctite 3447 [7].

The reflow equipment Covatec SA SR10-1135/1 with one substrate feeder was chosen for foil connector contacting. Thermal process of conductive adhesive has different character in confrontation with reflow soldering. So thermal profile at the reflow head has to be adapted and is the compromise between temperature and hardening time.

The adaptation dependency curves were created because of temperature gradient from the heat source to the adherends emerged and they were based on the set of temperature measurements. The temperature of 180°C for Loctite 3447 adhesive was readout by temperature of 348°C at the heat source.

The raw cuts of substrate pieces before surface mounting were selected for anisotropic conductive adhesives application. Corresponded foil connectors without solder metallization were prepared. Protected metallization is useful, but unprotected copper foil surface is convenient in this case, because of adhesive conductive particles penetration into adherends surface.

It is really necessary to solve the problem of technologic operations sequence before ACA application in industrial praxis.

Both operations, screen-printing and tape punching, require using of flat substrate. However, keyboard substrates and other module types obviously contain of surface mounting devices, which are attached by machine onto substrate sheet stock. This technologic step in compared to ACA tape is not possible after ACA paste application. In addition, used production equipment generally enables treatment of single substrate only. So, it is necessary to apply the ACA onto single substrate. The best way represents their application directly after attaching of foil connector.

In case of automatic line assembly, there is no prolongation in the production process. But in operator performed line, the process brings the increasing of manufacturing expenses.

The miniature screenprinting equipment was made with 200 mesh screen and simple rectangle motive for application of ACA paste. The raw cut of 3x10 mm tapes with protecting foil was prepared for application of ACA tape.

Loctite 3447 anisotropic conductive paste was deposited onto screen by injection dispensing. After manual screenprinting, the substrate was stocked by purified foil connector. After vacuum fixation of sample, the adapted hardening process was performed at 8 s hardening time.

The process was repeated for whole 12-pieces series of samples.

4. MEASUREMENT OF JOINTS PROPERTIES

Measurement at 13 leaded connector contacts was realized by RLCG bridge. Processing of values obtained at substrates with applied Loctite 3447 anisotropic conductive adhesive with 8 s hardening time is in Tab. 2.

The last measurement series was realized at 12-pieces set of substrates with applied lead solder for mutual confrontation. Statistic processing of acquired electrical resistance values is also shown in Tab. 2.

Joined samples	Contact resistance [mΩ]	Standard deviation
Loctite / 8 s	28,45	7,09
Lead solder	24,96	5,53

Tab. 2 Electrical resistance statistics with standard deviation of measurement.

Mechanical peeling tests were performed for considering of realized joints mechanical properties analysis. The test conditions and continuances are specified in the international standard (STN IEC 326-2 (359010) - Printed Circuits Boards. Testing Methods) [8] and were realized at tension equipment LLOYD Instruments LRX Model Level 23. Generally, the strengthness in peeling is denoted by the minimum force at width unit of wire, what is needed for its peeling-off from adjacent surface of substrate.

Statistical processing of values obtained at substrates with applied Loctite 3447 anisotropic conductive adhesive with 8 s hardening time and at substrates with applied lead solder is in Tab. 3 and behavior diagrams during the peeling tests at Fig. 3 and 4.

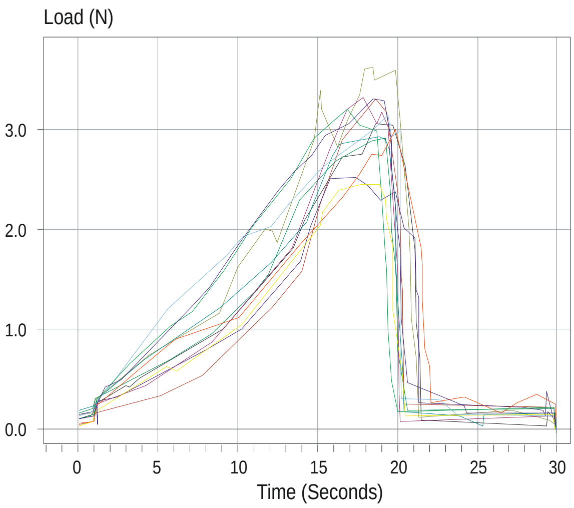

Fig. 3 Behavior diagram of mechanic strength of joints with applied Loctite 3447 anisotropic conductive adhesive at 8 s hardening time.

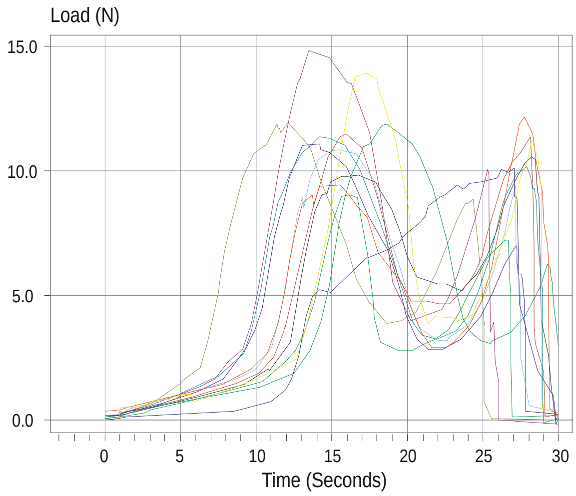

Fig. 4 Behavior diagram of mechanic strength of joints with applied lead solder.

Joined samples	Specific strength [N/mm]	Standard deviation
Loctite / 8 s	0,31	0,32
Lead solder	1,16	1,51

Tab. 3 Statistics of terminal strength values of contacts with applied Loctite 3447 anisotropic conductive adhesive at 8 s hardening time and with applied lead solder.

5. RESULTS AND DISCUSSION

Electrical resistance measurement at samples with applied Loctite 3447 anisotropic conductive adhesive presents small value dispersion (Tab. 2), and then good process repeatability. Even better results can be anticipated after its implementation into batch production process. In contrast, the dispersion value acquired data of joints within sample is noticeable, what indicates that the processing head must be more coplanar with the substrate compared to soldered joints. Otherwise the boundary joints become conductive particles insufficiently pressed between adherends. It corresponds to higher values of standard deviation at boundary joints No.12 and 13.

Comparison of electrical resistance values at samples with applied Loctite 3447 anisotropic conductive adhesive in Tab. 2 with values at samples through applied lead solder in Tab. 2 shows to the slightly better values at soldered joints.

At the soldered joints, the mechanical stress is transferred to contact area only. Adhesive joints have the acting force distributed to all connector area, what contributes to higher stressability of joints. However, it cannot be expected, that adhesive joints excels the metallurgic joints, which mechanical stressability obviously is above the adhesion properties of copper foil onto foil or rigid substrate. These premises were confirmed by tests of mechanical stressability. Adhesion joints with applied Loctite 3447 anisotropic conductive adhesive takes in average only 25% of mechanical strength compared to soldered interconnections (Tab. 3), which caused copper foil ripping from the substrate at peeling tests.

Mechanical stress dependencies of adhesive joints indicate to the different load force profile during the peeling tests (Fig. 3) compared to soldered joints (Fig. 4) because of the joint shape and of the joint material structure.

6. CONCLUSION

The topic of this work was utilization of anisotropic conductive adhesives in industrial praxis. Main tasks of the work were the methodology setup and practical realization of anisotropic interconnections between foil connectors and rigid substrates based on the polymer thick film technologies.

The temperature profiles between foil connector and rigid substrate contacts were measured in the preliminary work phases and adaptation of temperature behaviors were formed afterwards.

The needed hardening profile peak temperatures were readout for particular adhesives by this way. Resultant behaviors will be applicable for any adhesive material in the future.

The resistance values at samples with applied Loctite 3447 anisotropic conductive adhesive suggested to be near-comparable to values at samples with applied lead solder after the joints resistivity measurements.

Under reviewing of mechanical stressability in point of view of acceptability in applications, there is proper to consider that foil cable is bent in 180˚ in test process as in typical application. Actuating force to foil cable in zero position was 0.2 N in average, what represents only 10% of averaged maximal strain.

Each approach has own significant properties and field of applicability. The process transformation is so less expensive as simplest adaptable are the existing production facilities.

Projects VEGA 1/3138/06 and 1/3167/06.

REFERENCES

[1] PIETRIKOVÁ, A., SOMORA, M.: Vývojové trendy materiálov pre hrubé vrstvy. Monografia, Vyd. OTA s.r.o., 1998, ISBN 80-7099-316-2, 110 s

[2] SOMORA, M., URBANČÍK, J.: Study of Long Term Characteristics of Selected PTF Materials. 1-st International Symposium on Microelectronics Technologies and Microsystems, Rzeszow, Poland, 1997, ISBN 83-7199-022-7, s. 51

[3] HALBO, L.: Polymer Thick-Film Technology. Lobo Grafisk AS, Oslo, Norway, August 1990

[4] SOMORA, M., URBANČÍK, J., KOLESÁR, F.: Polymer Thick Film Dielectrics in Industry Applications. 12-th International Conference DISEE 98 – Dielectric and Insulating Systems in Electrical Engineering, Bratislava, Častá Píla, s. 191-194

[5] PIETRIKOVÁ, A., SLOSARČÍK, S.: Výrobné procesy v mikroelektronike. Technická univerzita v Košiciach, 2000, 100 s., ISBN 80-7099-340-5

[6] BANSKÝ, J., SLOSARČÍK, S., PODPROCKÝ, T.: Hrubovrstvové hybridné senzory. Royal Unicorn s.r.o., 1999, 96 s., ISBN 80-968128-3-1

[7] Loctite 3447 Anisotropically Conductive Paste, Technical Information Sheet. Henkel Loctite Corporation, USA, June 2003

[8] STN IEC 326-2 (359010) Dosky s plošnými spojmi. Skúšobné metódy. Úrad pre normalizáciu, metrológiu a skúšobníctvo SR, 1994

[9] SOMORA, M., URBANČÍK, J., KOLESÁR, F.: Reliabillity Aspects of the Batch Production Based on PTF Technology. IMAPS / NATO Advanced Research Workshop, Bled, Slovenia, May 10-13, 1997

BIOGRAPHIES

Miloš Somora (Dr.h.c. prof., Ph.D.) professional activity is connected with the study and evaluation of the electrical and physical properties of materials applied in hybrid microelectronics. He is focused also on utilisation of Pt and other thick film materilas in thermometry and on synthetis of ceramic superconductors for application in telecomunication. His research work is also oriented to improvement of the polymer thick film technology. He received his Ph.D. degree at Technical University of Brno, Czech Republic, 1980. Untill September 1998 he was the Head of the Department. During years 1997-2000 worked as a rector of Technical University of Košice.

Slavomír Kardoš (PhD.) finished his diploma thesis „Assembly and Interconnection Techniques in Microelectronics“ at the Department of Technologies in Electronics, Technical University of Košice in 1998. The topic of his present work is oriented to interconnection techniques and fine thick film technologies. He received his PhD degree in 2007 in Electrotechnology and Materials at he same department.