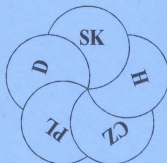


UNIVERSITY OF ŽILINA IN ŽILINA
Faculty of Mechanical Engineering
Department of Materials Engineering

International Colloquium



ADVANCED MANUFACTURING AND REPAIR TECHNOLOGIES IN VEHICLE INDUSTRY

Žilina – Terchová, Slovakia

21 - 23 May, 2012



Európska únia
(európsky sociálny fond)



Agentúra

Ministerstva školstva, vedy, výskumu a športu SR
pre štrukturálne fondy EÚ



Moderné vzdelávanie pre vedomostnú spoločnosť/Projekt je spolufinancovaný zo zdrojov EÚ

Žilinská univerzita / EDIS – Editing Centre ŽU

© Žilinská univerzita, 2012

ISBN 978-80-554-0533-9

ADVANCED MANUFACTURING AND REPAIR TECHNOLOGIES IN VEHICLE INDUSTRY

The 29th International Colloquium, May 21 - 23, 2012
Žilina – Terchová, Slovakia

The International Colloquium has been organized regularly year after year since 1983 and will be concerned with recent research and development of all aspects of "Advanced Manufacturing and Repair Technologies in Vehicle Industry".

International Scientific Committee:

prof. Ing. Otakar Bokúvka, Ph.D. (SK)
prof. Ing. Eva Tillová, Ph.D. (SK)
prof. Ing. Peter Palček, Ph.D. (SK)
prof. Ing. János Takács, Ph.D. (H)
Ing. Balázs Vehovszky, Ph.D. (H)
prof. dr. hab. inż. Stanisław Borkowski (PL)
Assoc. prof. Ing. Robert Ulewicz, Ph.D. (PL)
prof. dr. hab. inż. Ferdynand Romankiewicz (PL)
Assoc. prof. dr. Ing. Libor Beneš (CZ)
Assoc. prof. Ing. Eva Schmidová, Ph.D. (CZ)
prof. Dr. Ing. Peter Ottlinger (D)
prof. Dr. Ing. Hannes Neumann (D)

All papers are reviewed by members of the Scientific Committee.

SK - University of Žilina, Žilina
CZ - University of Pardubice, Pardubice
H - Budapest University of Technology and Economics, Budapest
PL - Częstochowa University of Technology, Częstochowa
- University of Zielona Góra, Zielona Góra
D - Hochschule für Technik und Wirtschaft, Dresden

National organizing committee:

prof. Ing. Eva Tillová, Ph.D., prof. Ing. Otakar Bokúvka, Ph.D., prof. Ing. Peter Palček, Ph.D.,
Ing. Mária Chalupová, prof. Ing. Ján Salaj, Ph.D., Mgr. Alena Törökóvá,
Ing. Eva Carmen Polácková, Ph.D.

Welcome, we hope you are going to have a pleasant stay at Žilina - Terchová

Žilina, May 2012

CONTENTS

<i>Hurtalová L., Tillová E., Chalupová M.</i> CHARACTERIZATION OF MICROSTRUCTURES IN SECONDARY (RECYCLED) AlSi12Cu1Fe CAST ALLOY	5
<i>Romankiewicz R., Romankiewicz F.</i> THE INFLUENCE OF MODIFICATION FOR STRUCTURE AND FRACTURE MORPHOLOGY OF ALLOY AlSi12Cu2Fe	10
<i>Đurinková E., Tillová E., Chalupová M., Radek N.</i> EFFECT OF LASER SURFACE TREATMENT ON THE AlZn10Si8Mg CAST ALLOY	14
<i>Farkašová M., Tillová E., Chalupová M.</i> EFFECT OF Sb-MODIFICATION ON THE MICROSTRUCTURE OF AlSi6Cu4 CAST ALLOY	20
<i>Borowiecka-Jamrozek J.</i> MICROSTRUCTURE AND PROPERTIES OF HOT PRESSED Fe-50 % Co MATERIALS	26
<i>Vehovszky B., Cziráki Á.</i> INVESTIGATION OF HYDROGEN ABSORPTION PROCESS IN Mg-BASED MELT- SPUN ALLOYS	31
<i>Żórawski W., Bokúvka O.</i> MICROSTRUCTURE AND TRIBOLOGICAL PROPERTIES OF PLASMA AND HV OF SPRAYED COMPOSITE COATINGS	43
<i>Bauernhuber A., Dömötör F., Szabó A.</i> COMPLEX DIAGNOSTICS OF THE CUTTING PROCESS OF HYBRID METAL STRUCTURES WITH IMPROVED SPECIMENS	52
<i>Guagliano M., Trško L., Bokúvka O., Nový F.</i> INFLUENCE OF SURFACE HARDENING ON FATIGUE PROPERTIES OF AISI 316Ti STAINLESS STEEL	58
<i>Ulewicz R., Mazur M., Nový F., Szataniak P.</i> FATIGUE PROPERTIES OF SELECTED GRADES OF STEEL APPLIED IN SEMITRAILERS CONSTRUCTION AND AGRICULTURAL MACHINES	64
<i>Krynke M., Seledak J., Borkowski S.</i> THE NUMERICAL MODELLING OF SLEWING BEARINGS	71
<i>Porubčan J., Palček P., Blažek D.</i> AMPLITUDE DEPENDENT INTERNAL FRICTION OF COMERCIAL PURITY ALUMINIUM AT ROOM TEMPERATURE	76
<i>Blažek D., Palček P.</i> MEASURING OF INTERNAL FRICTION BY THE RESONANCE METHOD	82
<i>Liptáková T., Alaskari A., Halamová M., Fajnor P., Dodek A.</i> INFLUENCE OF FLOW ON COPPER CORROSION PRODUCTS IN PIPELINES SYSTEM	88
<i>Zatkalíková V.</i> PITTING CORROSION OF AISI 316 Ti STAINLESS STEEL AFTER HNO ₃ PASSIVATION	93

<i>Vojšovičová M., Liptáková T.</i> RHEOLOGICAL EVALUATION OF THERMOPLASTIC POLYMER MATERIAL AFTER EXPOSURE IN ALIPHATIC n-HEXANE	99
<i>Weltsch Z., Hlinka J.</i> THE EFFECT OF REFLOW ON WETTABILITY OF LEAD FREE SOLDER	105
<i>Bauernhuber A., Markovits T.</i> LASER ASSISTED HYBRID JOINING OF STEEL AND PLASTIC MATERIALS	111
<i>Halas O., Švanda P.</i> INVESTIGATION OF SOME PHYSICAL AND MECHANICAL PROPERTIES OF ALKALI ACTIVATED BY FLY ASH	122
<i>Krmela J., Beneš L., Krmelová V.</i> EXPERIMENTS OF TIRE AS COMPLEX LONG-FIBRE COMPOSITE	129
<i>Žmindák M., Riecky D., Dudinský M.</i> FINITE ELEMENT IMPLEMENTATION OF DELAMINATION IN COMPOSITE PLATES	139
<i>Szataniak P., Ulewicz R., Nový F., Mazur M., Törökóvá A.</i> NEW MATERIALS AND REQUIREMENTS FOR CONSTRUCTION MATERIALS APPLIED TO CAR SEMITRAILERS	148
<i>Schmidová E., Hanus P.</i> CONDITIONS FOR MARTENSITE FORMATION IN AUSTENITIC WELD LAYERS	157
<i>Hopko A., Meško J., Koňár R.</i> DEFINITION OF A HEAT SOURCE IN PROGRAM SYSWELD, USING DIFFERENT PROTECTIVE GASES	163
<i>Koňár R., Mičian M.</i> SIMULATION OF WELDING AT THE PERMANENT REPAIR OF GAS PIPELINES WITH STEEL SLEEVES	169
<i>Krynke M., Selejdak J., Borkowski S.</i> THE ANALYSIS OF DAMAGE TO PITCH SURFACES OF SLEWING BEARINGS	177
<i>Brezničan M., Fabian P., Meško J.</i> THE NUMERICAL SIMULATION OF METALLURGICAL AND MECHANICAL CHARACTERISTICS OF QUENCHED BEARING RINGS	182
<i>Baňáková A., Meško J., Fabian P., Brezničan M.</i> ISOTHERMAL REFINEMENT OF BEARING RINGS MADE FROM 100Cr6 STEEL	190
<i>Urgela D., Pastirčák R., Sládek A., Maďaj R.</i> PRODUCTION OF CASTING MOULDS BY PATTERNLESS PROCESS	199
<i>Hlaváčová I., Turňa M.</i> INTERMETALLIC COMPOUNDS FORMED BETWEEN LEAD-FREE SOLDERS AND Cu SUBSTRATES	208
CONTENTS	213
AUTHOR INDEX	215

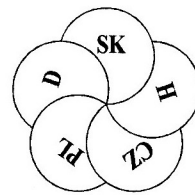
Name : 29th International Colloquium
ADVANCED MANUFACTURING AND REPAIR
TECHNOLOGIES IN VEHICLE INDUSTRY

Printed : EDIS, Editing Centre, University of Žilina in Žilina,
Slovakia, 2012

Prepared : University of Žilina in Žilina, Slovakia
Faculty of Mechanical Engineering
Department of Materials Engineering

Design : Mgr. Alena Töröková

ISBN 978-80-554-0533-9



THE EFFECT OF REFLOW ON WETTABILITY OF LEAD FREE SOLDER

Zoltán Weltsch, József Hlinka

Abstract

Surface conditions on Printed Circuit Board (PCB) final finishes have an important impact on the wetting behaviour with lead-free solder. The improvement of wettability in liquid Sn 96.5 Ag 3 Cu 0.5 Solder alloy on PCB substrate was measured with a sessile drop method at 523 K temperature. Wetting properties was determined in normal atmospheric air and inert atmosphere. The wetting angles increasing with the number of reflows both atmosphere. The effect of the atmosphere has a huge importance of the oxidation which manifests itself of the measured wetting angles. One of the most important factors to the wetting properties is the amount of oxygen in the soldering atmosphere. Using the inert atmosphere is crucial to Pb-free solders, particularly after reflows.

Keywords: wetting, sessile drop method, soldering, reflow, Pb free solder.

1. Introduction

Soldering is the most popular joint technique in microelectronic and optoelectronic industries which technologies are widely used in the vehicle industry [1-4].

Increasing global customer demand for miniaturised, hand-held and pocket electronic products has been a key driver in the design, development and wide application of high-density area array package format [5]. Electronics manufacturing industries have utilised advanced Integrated Circuits (ICs) packages such as Micro-Ball Grid Arrays (IBGA), Chip Scale Packages (CSP), Flip Chip (FC) technology and Surface Mount Resistors (SMR) to achieve the manufacture of smaller, lighter, faster and cheaper products. However, the assembly of these surfaces mounts packages and the reliability of the products are challenged by crucial manufacturing process steps. The use of ultra fine pitch packages makes the stencil printing process more critical to produce a reliable solder joint [6]. The most important step in the SMT production process be-sides paste printing is the reflow soldering process [7]. The solder reflow profile is one of the key variables in the electronics manufacturing process that significantly impacts product yields [8]. The manufacturing challenges associated with both solder paste printing and reflow soldering increases as electronic device size decreases. The increasing manufacturing difficulties are because at very small aperture sizes, the rheological dominancy of surface tension over paste viscosity impacts negatively on the printing process. The outcome may include overfill of stencil cavity with solder paste. The consequence of this outcome may lead to printing defects such as solder slumping and bridging. A vital key to achieving urgent customer satisfaction on further miniaturisation of electronics with good solder joint reliability is the in-depth understanding of the solder paste transfer efficiency through [9].

Due to worldwide environmental concerns, public sentiments and market strategies, as well as governmental regulations on the use of toxic Pb in the electronic products, the conventional Sn-Pb solders are under strict scrutiny. Therefore, many Sn-rich alloy systems have been developed as alternative candidate Pb-free solders, which have attracted much researches and trial applications in recent years [10]. With combination of process attributes (modestmelting point and reasonable solderability), comparable electrical performances and good mechanical properties, the Sn-Ag-Cu system is one of the potential choices [11].

[†] Budapest University of Technology and Economics, Faculty of Transportation Engineering, Department of Vehicles Manufacturing and Repairing. Institution address: Bertalan L. u. 2., 1111 Budapest, Hungary.

Although great effort has been made for more than 10 years to get the Pb out of electronic industry, until now, there are still some tough barriers needed to override for a widespread and uniform industrial acceptance of favourable solder alloys and matched materials plus processes [12-13]. Besides the lack of legislation, the high cost and insufficient backup data of Pb-free operation (compared to the well-established Sn-Pb soldering system) are cautious consideration nowadays [11].

In the soldering process, the molten solder wets the substrate, and the interfacial reaction occurs at the solder-substrate interface, thus forming the soldering joints. Therefore, the wetting property between solders and substrates is crucial to the reliability of the soldering joints [14-15].

This study experimentally determines the wetting properties using the sessile drop method at normal atmosphere and inert as atmosphere, and determined the effect of the reflow at both atmosphere. The length of the original scientific article should be between 10 and 20 double line spacing pages and length of short communication should be between 6 and 10 double line spacing pages.

2. Experimental conditions

The investigation solder was Senju M705-GRN360-KV Lead-free Solder Paste. The manufacturer promise:

- Very stable solder paste viscosity over a longer period
- Clear flux residues combined with excellent joint cosmetics
- Excellent wettability
- Reduced flux residue cracking and occurrence of side balling.

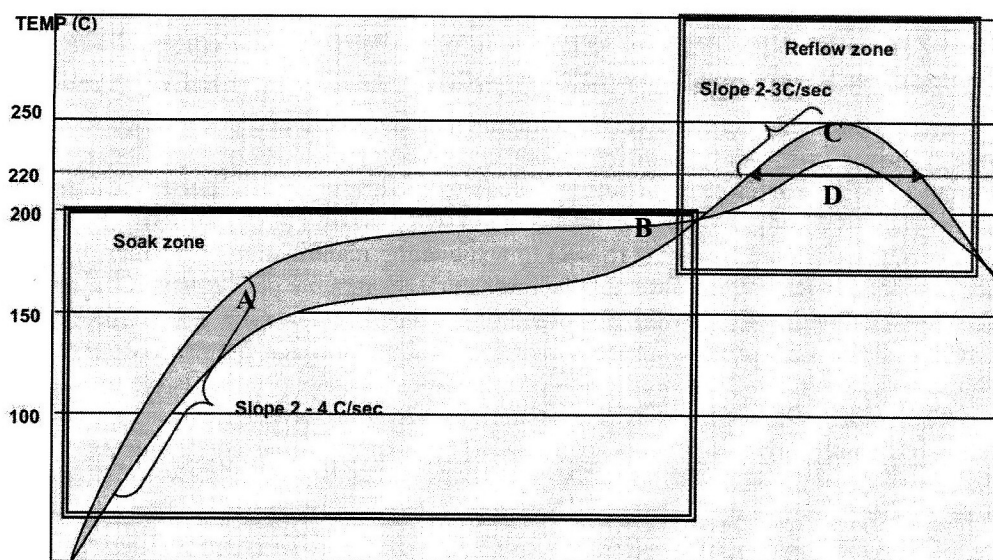


Fig. 1. Solder profile (Soak zone 60-120 s, Reflow zone 30-60 s)

All investigated substrates consist of the same base epoxy PCB material with two copper layers, upside and bottom side. The copper layer thickness is approximately 35 μm and the immersion tin final finish is directly deposited on the copper. The layer thickness of immersion tin amounts to approximately 1 μm . Figure 2 displays a cross section of the typical PCB configuration.

Wetting experiments were performed in sessile drop equipment following the method described in Ref [16]. The substrate and the soldering alloy were positioned into the middle of furnace at ambient conditions.

At inert atmosphere the pressure was then reduced to 0.1 Pa at room temperature in the chamber. The vacuum was replaced by a 10^5 Pa 99.999 % Ar gas. This procedure was repeated 3 times.

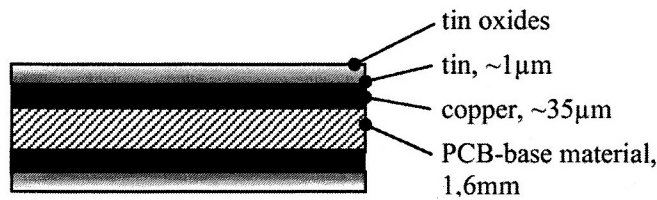


Fig. 2. Cross section of a typical PCB configuration with immersion tin final finish [19]

Subsequently, the temperature was raised to soldering temperature ($\sim 523\text{K}$) using a heating rate of 4 K/s . Since only a small portion of the gas chamber is heated, the pressure around the droplet remains at about 10^5 Pa during the run of measurements.

The contact angle was directly measuring the profile of the drop, fixing and processing the data, using self-made evaluation software. Though the uncertainty of this software is below 1° , the total uncertainty of the measured values is higher: $\pm 3^\circ$.

After the measuring process at 523 K , the furnace was switched off and cooled slowly to the ambient temperature (the whole cooling time is around 25 minutes). Subsequently the furnace was opened and the solidified sample was removed.

3. Results and discussions

Two records of the samples after the measurement process were shown in Fig. 3. The molten solder made a lenticular shape in the top of the square shaped PCB chips. The oxide layer centralized on the top of the solder. The flux spread around the solder. The solder spread test shows significantly different results under air and Argon atmosphere. Sample Fig. 3. A was made under air atmosphere and flux covers smaller surface of the PCB than sample Fig. 3. B, which was measured under Argon atmosphere.

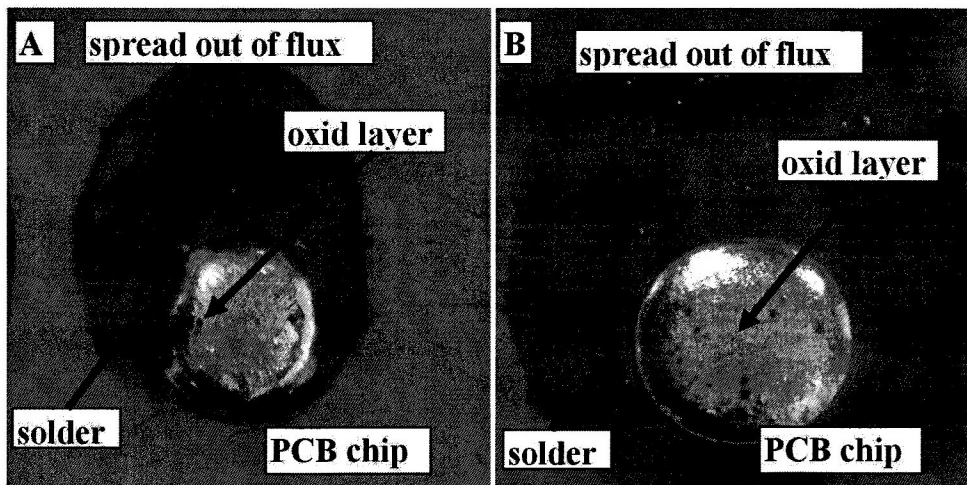


Fig. 3. Solder spread test with lead free solder alloy on PCB

3.1 Pore formations in the solder

Porosity is a common problem when using solder pastes and reflow soldering. There are a certain number of publications that explained the influencing factors of pore formation [17-18].

Porosity is easily formed, because the examined solder paste normally contains 11.5 volume percentages of volatile components (e.g. flux). Flux vapour will be produced during reflow soldering due to thermal decomposition. Some gases may be entrapped between the flat surface of the printed circuit board (PCB) and the solder, and cause pore formation upon cooling. The surfaces of the pores are smooth and usually bright, indicating that the porosities were formed mainly by entrapped gases.

In that section it is necessary to present achieved results of own research in details e.g. research or calculations illustrating them in details and legibly by pictures, diagrams, metallographic photos, results, calculations, tables etc. and giving in details causal and result relations between stated facts confirming or excluding data known from the literature. That section should have a character of a scientific discussion, although in order to do that the separate section can be created and in the given one only the information about achieved results of researches can be included. In short papers you should rather limit yourself to a discussion.

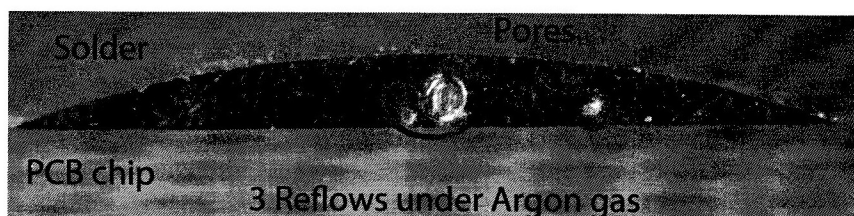


Fig. 4. Pores in the cross section of solder

3.2 Wetting angle measurements

The Fig 5 show the measured wetting angles of the solder pastes on PCB chips as a function of reflows beside different measuring atmospheres. The effect of different atmosphere is easily definable. The measured wetting angles when using Argon atmosphere is about 12° . This value is in the well solderable range. On the contrary the wetting angles under Argon atmosphere is around 24° . This value is twice more than the other one. It means that the solderability deteriorate when the solder was measured under air. The effect of increasing number of reflows increases the wetting angle values beside both measuring atmospheres. The wetting angles increased 12° to 16° when used Argon atmosphere and increased 24° to 28° when measured in air atmosphere. The increment of the wetting angle approximately 4° between the samples with 3 reflows and without reflows. The explanation of the difference between the wetting angle values is the different oxygen concentration. Common role, that the oxygen deteriorates the wettability. That's why the values of the measurements under air are higher than under Argon. These differences indicate an increasing thickness of the tin oxide layer.

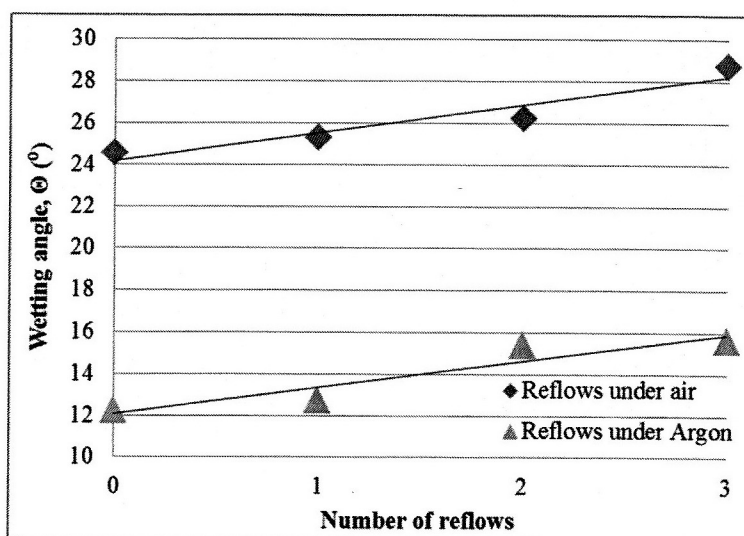


Fig. 5. Wetting angle measurements of Sn 96.5 Ag 3 Cu 0.5 alloy on PBC substrates at 523 K

3.3 Cross section study

To investigate the reaction kinetics of the Cu/solder joints a microscopic cross-sectional study is necessary. A microscopic image of the sample Shown in Fig. 6. During heating up the molten solder reacted with the Cu layer and formed different types of intermetallic compounds at the Cu-solder interfaces.

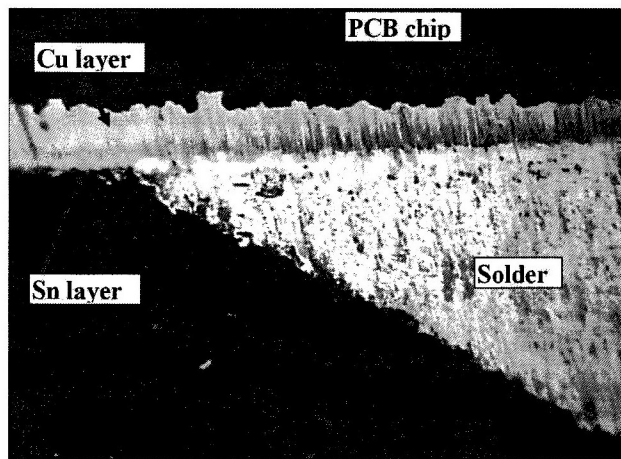


Fig. 6. The investigated solder interface

3.4 Topography measurements

The samples were scanned with an atomic force microscope to determine the PCB surface topography after the reflows. It was expected that the wetting parameters are deteriorate when the number of reflows increasing. The topography result shows the Fig. 7-8. The numbers of reflows are increasing the surface oxidation on the PBC. At inert atmosphere the surface oxidation less than standard atmosphere.

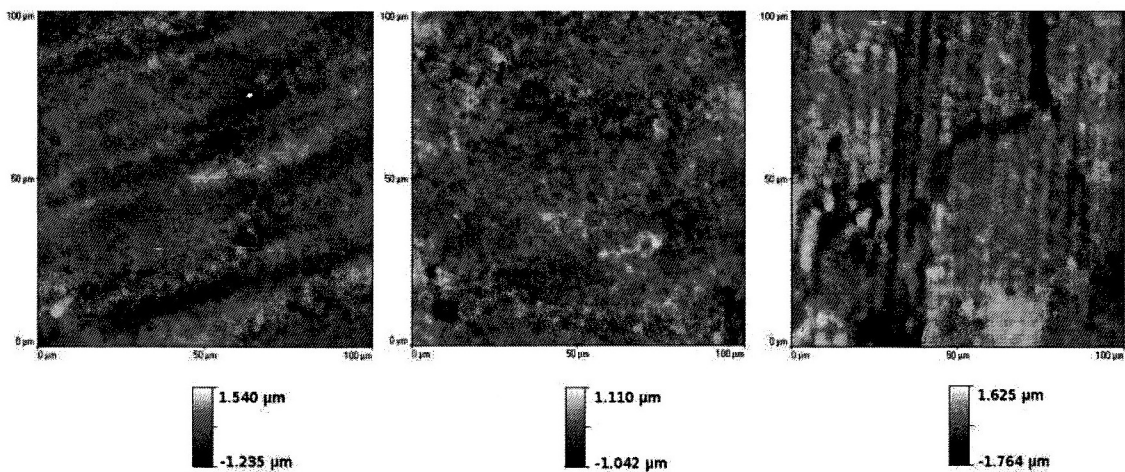


Fig. 7. Topographic pictures of heat treated samples under Argon gas with 1-2-3 reflow

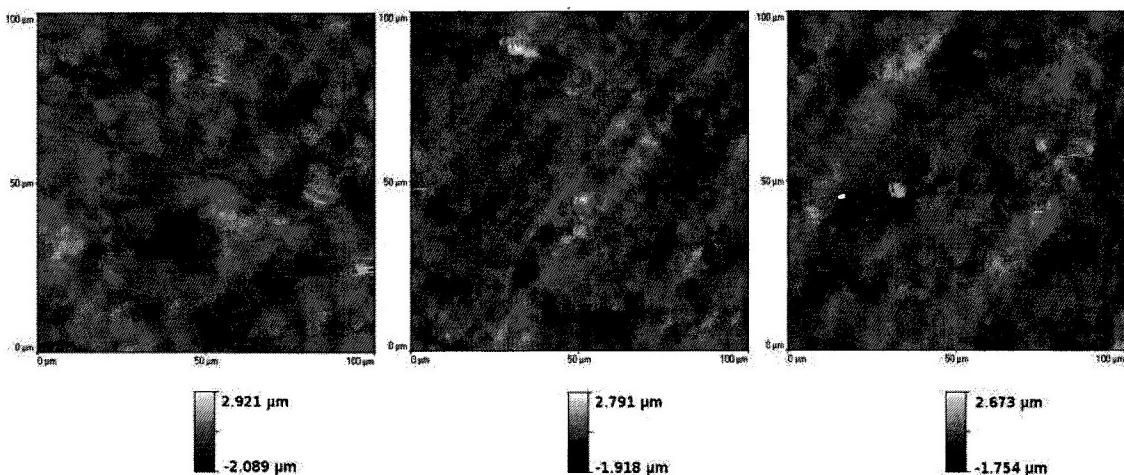


Fig. 8. Topographic pictures of heat treated samples under air with 1-2-3 reflow

4. Conclusions

The reflow and atmosphere dependence of wetting angle are measured on PBC substrate for Sn 96.5 Ag 3 Cu 0.5 melts.

- It was found, that the reflow dependence of the wetting angle is remarkable, with increasing the reflow numbers the wetting angle increasing circ. 4° both atmosphere.
- The soldering atmosphere has a huge importance at Pb free soldering, at inert gas atmosphere the wetting conditions circ. 12° wetting angle better than standard atmosphere.
- At inert gas atmosphere the flux of the Senju M705-GRN360-KV Lead-free Solder Paste working better and spreading out more than standard atmosphere
- Some gases may be entrapped between the flat surface of the PCB substrate and the solder, and cause pore formation upon cooling.
- The PBC topography measurements clearly shoes that the standard atmosphere and the number of reflows increasing the surface oxidation, which affect the wetting conditions too.

Acknowledgements

This work has been supported by the Hungarian Scientific Research Fund (OTKA) through grant No. K-73690.

References

- [1] Judd, M. and K. Brindley: Soldering in Electronics Assembly, 2nd ed., Newnes, Oxford, UK (1999).
- [2] J. H. Lau: Solder Joint Reliability of BGA, CSP, Flip Chip, and Fine Pitch SMT Assemblies McGraw-Hill, NY, USA (1997).
- [3] K. N. Tu: Solder Joint Technology: Materials, Properties, and Reliability, Springer, NY, USA (2007).
- [4] Ch.Ch. Fu, Ch. ch. Chen: Investigations of wetting properties of Ni-V and Ni-Co alloys by Sn, Sn-Pb, Sn-Cu, and Sn-Ag-Cu solders, Journal of the Taiwan Institute of Chemical Engineers 42 (2011) 350-355.
- [5] E.H. Amalu, N.N. Ekere, R.S. Bhatti, G. Tarkyi: Investigation of effects of reflow profile parameters on lead-free solder bump volumes and joint integrity, in: AIP Conference Proceedings. Accepted for presentation at the International Conference on Advances in Materials and Processing Technologies (AMPT 2010), vol. 1315, 2011, pp. 639-644.
- [6] S. Aravamudhan, D. Santos, G. Pham-Van Diep, F. Andres: A Study of Solder Paste Release from Small Stencil Apertures of Different Geometries with Constant Volumes, in: Proc IEEE transaction on Technology Symposium: International Electronics Manufacturing Technology (IEMT) Symposium, SEMICON West, 2002, pp. 159-165.
- [7] Weidmuller: (2002), Application Information, available @ www.weidmueller.com.
- [8] A. Pietrikova, L. Livovsky, J. Urbancik, R. Bucko: Optimisation of Lead Free Solders Reflow Profile, ISSE St. Marienthal, Germany, 2006.
- [9] E.H. Amalu, W.K. Lau, N.N. Ekere, R.S. Bhatti, S. Mallik, K.C. Otiaba, G. Tarkyi: A study of SnAgCu solder paste transfer efficiency and effects of optimal reflow profile on solder deposits, Microelectronic Engineering 88 (2011) 1610-1617.
- [10] M. Abteu, G. Selvaduray: Mater. Sci. Eng. 27 (2000) 95-141.
- [11] W.H. Zhong, Y.C. Chan, M.O. Alam, B.Y. Wu, J.F. Guan: Effect of multiple reflow processes on the reliability of ball grid array (BGA) solder joints, Journal of Alloys and Compounds 414 (2006) 123-130.
- [12] C.M. Garner, V. Gupta, V. Bissessur, A. Kumar, R. Aspandiar: Proceedings of the Third EPTC, Singapore, December 5-7, 2000, pp.6-9.
- [13] P. Casey, M. Pecht: Proceedings of the Fourth International Symposium of EMP, Taiwan, December 4-6, 2002, pp. 15-24.
- [14] Y.Y. Chen, J.-G., Duh, B.-S. Chiou: The Effect of Substrate Surface Roughness on the Wettability of Sn-Bi Solders, J. Mater. Sci.: Mater. Electron., 11, 279 (2000).
- [15] Yost, F. G., F. M. Hosking, and D. R. Frear, The Mechanics of Solder Alloy Wetting and Spreading, Van Nostrand Reinhold, NY, USA (1993).
- [16] J. Hlinka, Z. Weltsch, J. Berzy, A. Szmejkál: Improvements of Sessile Drop Method for the Wetting Angle Determination, Perner's Contact, Special Issue 2, Volume VI, Pardubice (2011), pp. 64-71.
- [17] G. Humpston, D.M. Jacobson: Principles of Soldering and Brazing, ASM International, 1993, pp. 122-127.
- [18] Y.C. Chan, D.J. Xie, J.K.L. Lai: Experimental studies of pore formation in surface mount solder joints Materials Science and Engineering B38 (1996) 53-61.
- [19] T. Hetschel, K.J. Wolter, F. Phillipp: Wettability Effects of Immersion Tin Final Finishes with Lead Free Solder, 2nd Electronics Systemintegration Technology Conference, Greenwich, UK.