Circuit World

Emerald Article: Selection and qualification of polymers for rigid and flexible interconnect applications

Florian Schuessler, Klaus Feldmann, Thomas Bigl

Article information:

To cite this document: Florian Schuessler, Klaus Feldmann, Thomas Bigl, (2007), "Selection and qualification of polymers for rigid and flexible interconnect applications", Circuit World, Vol. 33 Iss: 2 pp. 36 - 42

Permanent link to this document:

<http://dx.doi.org/10.1108/03056120710750247>

Downloaded on: 28-01-2013

References: This document contains references to 14 other documents

Citations: This document has been cited by 1 other documents

To copy this document: permissions@emeraldinsight.com

This document has been downloaded 272 times since 2007. *

Users who downloaded this Article also downloaded: *

Florian Schuessler, Klaus Feldmann, Thomas Bigl, (2007), "Selection and qualification of polymers for rigid and flexible interconnect applications", Circuit World, Vol. 33 Iss: 2 pp. 36 - 42

<http://dx.doi.org/10.1108/03056120710750247>

Florian Schuessler, Klaus Feldmann, Thomas Bigl, (2007), "Selection and qualification of polymers for rigid and flexible interconnect applications", Circuit World, Vol. 33 Iss: 2 pp. 36 - 42

<http://dx.doi.org/10.1108/03056120710750247>

Florian Schuessler, Klaus Feldmann, Thomas Bigl, (2007), "Selection and qualification of polymers for rigid and flexible interconnect applications", Circuit World, Vol. 33 Iss: 2 pp. 36 - 42

<http://dx.doi.org/10.1108/03056120710750247>

Access to this document was granted through an Emerald subscription provided by FRIEDRICH ALEXANDER UNIVERSITAET ERLANGEN
NUERNBERG

For Authors:

If you would like to write for this, or any other Emerald publication, then please use our Emerald for Authors service.

Information about how to choose which publication to write for and submission guidelines are available for all. Please visit www.emeraldinsight.com/authors for more information.

About Emerald www.emeraldinsight.com

With over forty years' experience, Emerald Group Publishing is a leading independent publisher of global research with impact in business, society, public policy and education. In total, Emerald publishes over 275 journals and more than 130 book series, as well as an extensive range of online products and services. Emerald is both COUNTER 3 and TRANSFER compliant. The organization is a partner of the Committee on Publication Ethics (COPE) and also works with Portico and the LOCKSS initiative for digital archive preservation.

*Related content and download information correct at time of download.

Selection and qualification of polymers for rigid and flexible interconnect applications

Florian Schuessler, Klaus Feldmann and Thomas Bigl

Institute for Manufacturing Automation and Production Systems (FAPS), University of Erlangen-Nuremberg, Germany

Abstract

Purpose – This paper seeks to give an overview on the benefits and challenges of moulded interconnect devices-technology and the use of flexible printed circuits (FPC) in electronics production.

Design/methodology/approach – Each process step was adapted to the boundary conditions of manufacturing three-dimensional substrates and FPC. The substrate materials were examined under the specific requirements of electronics production with a special focus on the thermal stability of the materials and the adhesiveness of the metallization.

Findings – The use of thermoplastics as substrate materials for electronic devices offers high potential but new challenges, e.g. the higher coefficient of thermal expansion of thermoplastics, have to be taken into consideration as well. In most cases, standard machines for surface mount technology can be used with few modifications. Research has shown that even components with very fine pitches can be used successfully on alternative substrate materials.

Research limitations/implications – The paper covers a selection of possible thermoplastic materials that can be used in electronics production. Depending on the requirements of the application and the operating environment other substrate materials open up a large variety of possible solutions.

Originality/value – The paper details the most promising thermoplastic materials for use in electronics production as rigid and FPC. Furthermore, it gives information about manufacturing guidelines for the production of three-dimensional circuit carriers.

Keywords Electronics industry, Thermoplastic polymers, Printed circuits, Component manufacturing, Soldering, Metallizing

Paper type Research paper

Introduction

The integration of mechanical and electrical functions into mechatronic systems has advanced significantly during in recent years. Because of the ongoing decentralization of electronic devices, research on the possibilities of further integration will be an important topic. Benefits of integration such as miniaturization are heavily dependent on the fields of application and the peripheral surroundings. Two of the most applicable technologies for these highly integrated devices are the moulded interconnect devices (MID) technology and flexible printed circuits (FPC). By combining the mechanical and electrical functions of devices, a wide creative freedom in housing design becomes possible. However, this in turn leads to new challenges for the manufacturing technologies. Additionally, the substitution of the standard substrate materials by new materials such as thermoplastics has influenced the processes in electronics production. Besides, the customization of standard manufacturing technologies, the development, respectively, and modification of new production concepts becomes more and more necessary. Therefore, the interdependencies of new materials, manufacturing systems and production concepts become more and more important.

Starting with the choice of suitable materials and the possibilities of shaping, metallization and structuring of the substrates, this paper discusses the challenges regarding the build-up of rigid and flexible printed circuit boards made of thermoplastics and the associated process steps in electronics production. Reliability issues are also discussed.

Substrates for rigid and flexible printed circuit boards

The selection of a substrate material is of great importance, since the material properties are the main influencing factors on the mechanical, electrical and thermal properties and, therefore, the solderability of the material. Unlike standard PCBs, which are made of thermosetting materials, MIDs are made of thermoplastics, offering the possibility of welding, melting and plastic deformation. Depending on their properties, their usage and their price, thermoplastics are classified into commodity, technical and high-temperature plastics. The last group of materials is particularly interesting as a substitute for the standard FR-4 PCB, as the lead-free soldering processes can reach maximum temperatures of 260°C or even up to 280°C temperatures that only high-temperature thermoplastics can withstand. Thermoplastic materials have the intrinsic problem of a high coefficient of thermal expansion (CTE), especially above their glass transition temperatures. To reduce the expansion during reflow, almost all materials are filled with a stabilizer, primarily glass fibres or glass spheres. This can dramatically improve reflow behaviour and reliability, but sometimes leads to anisotropic material properties. Especially for thin, flexible materials, there is a risk of anisotropic orientation of the glass fibres, which results in disadvantageous properties

The current issue and full text archive of this journal is available at www.emeraldinsight.com/0305-6120.htm

Circuit World
33/2 (2007) 36–42
© Emerald Group Publishing Limited [ISSN 0305-6120]
[DOI 10.1108/03056120710750247]

(Feldmann and Gausemeier, 2006; Forschungsvereinigung Räumliche Elektronische Baugruppen 3-D MID, 2004)

An overview of common thermoplastic base materials for rigid substrates is shown in Figure 1. ABS, as an example for commodity thermoplastics, exhibits good hardness and is plateable in a galvanic process, but is not solderable in standard reflow processes since its glass transition temperature lies in the range of 85-100°C. Although PBT has good thermal stability, it is not solderable in a lead-free reflow process, but shows good electrical properties. PBT is not plateable in a galvanic process, but metallisation using a PVD-process and hot embossing is possible. A technical thermoplastic with very high potential is PPS, which offers high hardness and is solderable even in a lead-free process. Because of its high chemical resistivity, a chemical metallization is difficult. An example of a high-temperature thermoplastic is LCP. Because of the self-energizing adjustment of the LCP-molecules during solidification, the material has a very anisotropic behaviour regarding the mechanical properties. LCP offers very high continuous operating temperatures of 185-250°C, which allows soldering (Forschungsvereinigung Räumliche Elektronische Baugruppen 3-D MID, 2004).

In the majority of cases FPC are based on polyimide (PI). This thermosetting material offers very good performance, high thermal stability and a consistent CTE over the whole temperature range without the need for a filler material. Disadvantages, when compared to other materials, are the very high price and its tendency to absorb water. Other materials such as LCP and PEEK are cheaper at almost the same thermal stability and equal performance. Thus, they are suitable for soldering even at the elevated temperatures which are required for lead-free soldering. One very important point for the choice of a flex substrate material is the plateability with copper, which is essential for structuring of the circuitry. For flex substrates PET, PEN, PI, PEEK, LCP (and rarely PA) are usually chosen. Alternatively, polysiloxane can be used. This material consists of a glass fibre matrix filled with siloxane and additional materials (Wölflick and Feldmann, 2003).

Structuring of moulded interconnect devices

The manufacturing and structuring of MID can be carried out with different kinds of concepts. The manufacturing process has to be chosen in relation to the requirements. Because of this, different kinds of manufacturing processes were established in order to satisfy the specific needs. For each application an appropriate concept is available. Figure 2 shows a range of varying manufacturing processes, which are divided into shape forming, metallization and structuring processes.

Two of the manufacturing processes with the highest sales volume are hot embossing and two shot moulding. Hot embossing is a very easy to use process with little investment cost and relatively high throughput that does not need any galvanic processes for metallization. A copper foil with a surface finish to prevent the copper from oxidation, is pressed onto the thermoplastic substrate under heat and pressure by a stamp that has the circuit layout embossed on it. The embossed structures shear off the metallized foil on the areas of the substrate that do not have to be metallized. The adhesion of the metallization on the PCB can be realized in two ways: either by using a thermally activated adhesive layer or an inorganic layer. The two shot moulding process is very common because of its freedom in designing the PCB, although it is quite expensive and only becomes cost-efficient above 100,000 parts/year. In the first shot, the circuit structure is formed with a material that can be endowed with palladium ions. In the second shot, a thermoplastic is used, on which no copper can be precipitated. In a galvanic process copper is applied onto the ionized thermoplastic of the first shot and a surface finish can be applied afterwards (Feldmann *et al.*, 2002; Forschungsvereinigung Räumliche Elektronische Baugruppen 3-D MID, 2004).

The manufacturing process is very dependent on the material properties and the design-engineering guidelines. Limiting factors are, for example, the processing temperature, the chemical resistivity and minimum cross section thickness that can be realized with the chosen thermoplastic. The complexity of the circuit (e.g. minimal layout structures, number of layers, maximal current capacity) is very important for finding the appropriate manufacturing process as well as

Figure 1 Thermoplastic base materials (overview)

Material		Solderability		
		Reflow	Selective	
		SnPb	SnAgCu	
Polypropylene	PP	-	-	+
Acrylonitril-Butadienstyrene	ABS	-	-	+
Polybutylenterephthalate	PBT	0	-	+
Polyamide	PA	0	-	+
Polyphenylensulfide	PPS	+	+	+
Polyetherimide	PEI	+	+	+
Liquid Crystal Polymer	LCP	+	+	+

Figure 2 Manufacturing techniques for MID

the possible device design (e.g. miniaturization, integration and connection elements). Of course, economic aspects such as material, process and investment costs also have to be taken into consideration (Forschungsvereinigung Räumliche Elektronische Baugruppen 3-D MID, 2004).

Process chain in electronics production for rigid substrates

For the packaging of integrated circuits made of thermoplastics, usually the same processes are being used as for the standard surface mount technology. Owing to the specific properties of the MID, certain process steps have to be modified. For example, the accessibility of the machining surface for the application of the interconnection material or the assembly of the components can be very limited because of the geometry of the substrate. In addition, the constricted thermal stability of the thermoplastics used as substrate material is a very critical factor during soldering.

The interconnection material, i.e. solder or conductive adhesive, is applied via stencil printing or dispensing. On planar printed circuit boards, stencil printing is the most efficient process, because the deposits of interconnection material are applied simultaneously onto the PCB. In this case, the process can be taken over without any extensive adjustments for thermoplastics. If the interconnection material has to be applied not only on planar but also on inclined surfaces, the stencil printing process is not applicable. In this case the dispensing technology has to be used. The interconnection material is applied in a sequential way, which makes the process slower but, on the other hand, offers a very high flexibility. Furthermore, the required machining surface area is evidently less. With an applicable dispensing head, even dots which are not on planar surfaces can be processed. The limiting factors for the dispensing process are the size of the dispensing head and the corresponding minimal distances

between two walls of the substrate or near bars (Figure 3) (Feldmann and Gausemeier, 2006; Forschungsvereinigung Räumliche Elektronische Baugruppen 3-D MID, 2004; Wölflick and Feldmann, 2003).

Similar to the application of the interconnection medium, the useable assembly concepts are strongly dependant on the geometry of the MID (Figure 3). Planar thermoplastic substrates with a geometry that does not exceed the z -lift (e.g. reinforcements, bars) can be treated with standard SMT assembly machines without major adjustments to the assembly process. With comparatively little effort, the processing window can be expanded quite easily by increasing the z -lift of the assembly machine. However, the placement of components on free form surfaces requires the use of new assembly concepts. One possible system solution is represented by a six-axis robot. With the use of a robot, whereas the substrate is fixed, very complex substrate geometries can be assembled because of the flexibility of the six-axis robot. However, the assembly accuracy and the assembly performance are clearly lower than on standard assembly machines. The basis of the second concept is an SMT-assembly machine that is modified in two ways. On the one hand, the z -lift was increased and on the other hand a work piece carrier that is movable in three axes was implemented. For the assembly process of each component, the substrate is positioned upright to the assembly head, enabling the components to be placed onto the substrate in vertical direction. Thus, the assembly accuracy of the SMT machine can be preserved and only the assembly capacity decreases because of the more complex positioning (Feldmann *et al.*, 2001; Wölflick and Feldmann, 2003).

Reflow soldering is the most common technique for joining electronic parts. Basically, the heat transfer can be achieved by radiation, convection and condensation. Because of the unbalanced heating of components of different sizes during radiation soldering and hence the large heat difference on the

Figure 3 Assembly guidelines for manufacturing MID-devices

substrate, this process is used only to a minor degree. Especially for MID-devices, the shadowing effects due to the geometry of the substrate have to be considered during radiation soldering, too. A more balanced heat deposition over the moulded interconnect device during soldering can be obtained with forced convection soldering. However, overheating can occur on specific parts of the substrate to a minor degree too, which can lead to damage of the PCB. Because of the defined boiling temperature of the medium during vapour phase soldering, an excessive temperature load on the substrate caused by different thermal masses of the components can be avoided. Restrictions in the context of MID relate to the need for condensate drain off. Either the geometry of the electronic device has to fit the requirements or a drain for the condensate has to be integrated into the surface of the substrate.

Substrates made of thermoplastics can be processed in the reflow soldering process in principle, but limitations can result from the specific properties of the substrate materials like melting temperature or adhesion of the metallization. The solderless electrical press fit connection technology can be an alternative if thermal stability is the limiting factor. A reliable press fit connection can only be realized if the PCB and press fit pin are optimally matched.

Reel-to-reel production line for flexible printed circuits

The benefits of producing FPC from reel-to-reel are high throughput and extensive automation possibilities of the single process steps. If standard high-performance systems from planar substrate manufacturing can be used with little modification, optimized machine capability can be achieved compared to specially built equipment which leads to higher manufacturing quality at lower production costs.

Solder paste printing, component placement and reflow soldering are the three main process steps in electronics production. The main problems for manufacturing “endless” flexible substrates are posed, because usually the first and second processes are discontinuous (this means that the foil is stationary during processing) whereas during reflow soldering the substrate is continuously moved through zones with different temperatures inside the oven. Owing to this fact, two problems arise: in order to combine the stationary and continuous processes a loop-buffer before the soldering process could be used, but this would increase the risk of component fall off in the loop between the placement machine and the reflow oven as a result of the component weight. Additionally, the foil with the components on it has to be moved continuously by the transportation system in heated condition through the oven. Owing to the low thermal stability of some thermoplastic foils and the mechanical load applied on the flexible substrate, irreversible strain could occur. Because of the aforementioned problems and the thereby uncontrollable boundary conditions, the concept of a reel-to-reel manufacturing-line without buffers and a stationary soldering oven has been realized at the FAPS-Institute together with the industrial partner SEHO Systems GmbH.

Qualification of the metallization of moulded interconnect devices

In the following section some results from research into the manufacturing of thermoplastics printed circuit boards are given. The intention of the research was the qualification of three different materials (PBT, PPS and LCP) for the use as substrate materials for fine pitch components. The components used were flip chips with a pitch of $250\ \mu\text{m}$ that required structures on the substrate of $100\ \mu\text{m}$ line width.

The structuring was done in two different ways: 3D-mask structuring and subtractive laser structuring, whereas the best results were achieved with the laser structuring. The base metallization was copper with a surface finish of Ni/Au to protect the copper from oxidation.

The first step for the qualification of the three materials was to identify the warpage of the substrate in its initial state. Since, the diameter of the solder balls was $150\text{ }\mu\text{m}$, too much warpage could lead to open connections between some of the solder balls and the substrate during soldering. The test was done using laser triangulation and the measured data was compared to the guidelines given in IPC-D-300. The warpage was within the limits for all of the three materials in initial state.

The adhesive strength of the metallization is of great importance for the reliability of electronic device, since the different CTEs of the substrate materials and the metallization lead to high mechanical stresses between the two components. The adhesive strength of the metallization on the three substrates was analyzed with standardized peel and pull tests according to IEC 326 and DIN EN 582. The test was performed before the surface finish was applied to the copper metallization. The results are shown in Figure 4. The metallization on LCP showed very low adhesive strength, for both the peel and the pull test. This is influenced by the anisotropic mechanical properties of LCP, because of the self-energizing adjustment of the molecules during solidification. Another indication for this behaviour was the cohesion fracture near the surface of the substrate which can be shown in Figure 4. The measured values for PBT are noticeably better. A cohesion fracture in the substrate material can also be seen. Breaking of the copper structure during peel test was often the failure mechanism for PPS. Nevertheless, the measured values were the highest compared to the other two materials. The pull strength tests for PPS also showed very good results. Optical inspection of the fracture showed an adhesion fracture between the stamp and the metallization caused by a failure of the glue.

After characterization of the metallization in its initial state, a surface finish was then applied. The next process steps were the application of the solder paste, the assembly of the components and soldering with leaded and lead-free solders. To analyze the thermal stability of the materials (LCP, PBT

and PPS), the warpage after lead-free soldering using a critical saddle (or soak) profile was determined. Both twisting and warpage were measured, on the one hand, along a line and, on the other hand, over the whole surface of the substrate at the area of the flip chip (Figure 5). The acceptable values for twisting and warpage are defined in IPC-TM-650 and the results are shown in Figure 5. It is very important that the warpage is smaller than the ball diameter of the flip chip ($150\text{ }\mu\text{m}$), in order to ensure that the connection between the component and the substrate is secured. No twisting could be detected for PPS and the warpage ($25\text{ }\mu\text{m}$ and accordingly 0.46 per cent) was clearly lower than the size of the ball diameter. Minimal twisting was determined for LCP, but the warpage was again not critical ($40\text{ }\mu\text{m}$ and accordingly 0.74 per cent). The twisting of PBT was clearly noticeable and the linear warpage ($150\text{ }\mu\text{m}$ and accordingly 2.78 per cent) was equal to the diameter of the solder ball, which means that a connection cannot be achieved. For this reason, only the PBT substrate did not meet the required standards.

The adhesive strength of the metallization was tested again after soldering and accelerated aging (Figure 6). This was done by temperature shock cycling between -40 and $+80^{\circ}\text{C}$ with a holding time of 15 min. With this test, the long-term stability of the substrates and the solder connection can be analyzed. For all substrate materials, no influence of the soldering profile (for leaded and lead-free solders) on the adhesive strength of the metallization in initial state, after 500 and 1,000 cycles was detected. The peel test of PPS showed constantly good values. Especially for lead-free solders, PBT showed the lowest peel strength after 1,000 cycles. Much larger differences between the different thermoplastics could be detected for the pull strength. PPS clearly showed the best results, with a failure occurrence between the stamp and the metallization (adhesion fracture). This means that the adhesive strength was better overall than the measured values. The values for LCP and PBT lie on the same level and are equal to the test before soldering.

Conclusion

The very limited installation space that cannot be used to full capacity with standard components for electronics production

Figure 4 Adhesive strength of the metallization on selected thermoplastics

Figure 5 Twisting and warping of the surface of the substrate in the area of the flip chip **Figure 6** Adhesive strength after soldering and thermal shock cycling

is often the barrier for further miniaturization. Therefore, substrates are required that can be customized for the needs of the designer of electronic devices. One possible concept for these purposes are MID that are able to combine electrical and mechanical functions whilst also allowing freedom in design. Because of their usually three dimensional shape, the process steps in electronics production have to be modified to fulfil the requirements of the MID-technology regarding processes like solder application, component assembly and soldering. Nowadays, solutions for all process steps are available. Depending on the thermoplastic material used, the connection technology has to be chosen carefully. With the use of high-temperature thermoplastics, even lead-free soldering is not a problem. Generally, the thermoplastics utilized affect the possible forming and structuring processes and, therefore, important properties such as adhesion of the metallization and the design rules. Owing to the large variety of manufacturing processes, solutions for many applications are available.

Another solution is the use of FPC. As for rigid thermoplastics, the thermal stability of the materials offer possible manufacturing solutions for electronic devices as well. FPCs have the additional advantage that the solder application, the component assembly and the reflow process are possible on standard SMT machines with only slight adjustments necessary. With the described reel-to-reel-production line, there is a very efficient way of producing electronic devices made of FPC on-hand.

References

- Feldmann, K. and Gausemeier, J. (2006), *Integrative Entwicklung räumlicher elektronischer Baugruppen*, Carl Hanser Verlag, München.
- Feldmann, K., Krimi, B. and Boiger, M. (2001), "Bestückungssysteme für räumliche Schaltungsträger", in Feldmann, K. and Geiger, M. (Eds), *Produktionssysteme in der Elektronik*, Meisenbach Verlag, Bamberg, pp. 267-303.

- Feldmann, K., Bigl, T. and Wölflick, P. (2002), "Improving MID-potentials by optimized product design and stable manufacturing processes", paper presented at 5th International Congress Molded Interconnect Devices 2002, Erlangen, 25-26 September 2002, pp. 1-13.
- Forschungsvereinigung Räumliche Elektronische Baugruppen 3-D MID (2004), *3D-MID Technologie Räumliche elektronische Baugruppen Herstellungsverfahren, Gebrauchsanforderungen, Materialkennwerte*, Carl Hanser Verlag, Munich.
- Wölflick, P. and Feldmann, K. (2003), "Processes and production systems for MID", *Proceedings – Beyond 3D MID Workshop, Tampere University of Technology, Vantaa/Finland, 5 September 2003*.

Further reading

- Bigl, T. and Feldmann, K. (2006), "Variantenreiche Verarbeitung flexibler Schaltungsträger. Konzepte zur automatisierten Handhabung und Herstellung flexibler elektronischer Baugruppen", *wt Werkstattstechnik-Online 9-2006*, Springer-VDI-Verlag, Düsseldorf, pp. 618-22.
- Brocka, Z., Schmachtenberg, E., Schüßler, F. and Feldmann, K. (2006), "Cross-linking of engineering thermoplastics films for the use as flexible printed circuits", *Proceedings of 7th International Congress Molded Interconnect Devices, Fürth, 27-28 September 2006*.
- Enser, W. (2005), "Neue Formen permanenter und lösbarer elektrischer Kontaktierungen für mechatronische Baugruppen", doctoral thesis, University of Erlangen-Nuremberg, University of Erlangen-Nuremberg, Bamberg.
- Feldmann, K. and Brand, A. (1994), "Analytical and experimental research on assembly systems for molded interconnect devices (3D-MID)", *CIRP Annals*, Vol. 43 No. 1.
- Feldmann, K., Bigl, T. and Zolleiß, B. (2005), "Innovative assembly concepts with reel-to-reel transfer for flexible printed circuits", *WGP Annals*, Vol. XII/2 No. 853.
- Feldmann, K., Schüßler, F. and Wölflick, P. (2004), "MID and foil – technologies for flexible circuit carriers", *Proceedings of 6th International Congress Molded Interconnect Devices, Erlangen, 22-23 September 2004*.
- Feldmann, K., Wölflick, P. and Boiger, M. (2005), *Verarbeitung von flexiblen Schaltungsträgern: Material und Prozesse, Produktion von Leiterplatten und Systemen*, No. 2/2005, Eugen G. Leuze Verlag, Bad Saulgau.

- Michels, J.S., Gausemeier, J., Peitz, T. and Bigl, T. (2004), "BMBF funded project: INERELA integrative development of three-dimensional electronic devices", *Proceedings 6th International Congress Molded Interconnect Devices, 22-23 September 2004*, pp. 251-61.
- Schüßler, F. and Bigl, T. (2005), "Reel-to-Reel-System zur hocheffizienten Produktion von Folienschaltungen", *Proceedings FAPS TT Fachseminar zur Elektronikproduktion, Folienschaltungen – Innovative Produktgestaltung und Prozesse, Nuremberg, 6 Dezember 2005*.

About the authors

Florian Schuessler, was born in 1977 and studied production engineering at the University of Erlangen-Nuremberg. Since, 2004, he has worked as a Scientific Assistant to Professor Feldmann at the Institute for Manufacturing Automation and Production Systems (FAPS). His graduation work dealt with the subjects of highly miniaturized and highly stressed electronic devices as well as the use of thermoplastics as flexible and rigid substrate materials. Florian Schuessler is the corresponding author and can be contacted at: florian.schuessler@faps.uni-erlangen.de

Klaus Feldmann, born in 1943, studied production engineering at the Technical University of Berlin. He earned his doctorate at the Institute of Professor Spur on his scientific research on design optimisation of automated lathes. After some years of working as an R&D Manager in the fields of automation and assembly technology in Erlangen and as a production manager at a plant in Amberg, he became Head of the Institute for Manufacturing Automation and Production Systems (FAPS) at the University of Erlangen in 1982. He is Chairman of the Research Association, "Molded Interconnect Devices – 3D-MID" and is an active member of national and international science communities.

Thomas Bigl, born in 1970, studied mechanical engineering at the University of Erlangen-Nuremberg. Since, 2001 he has worked as a Scientific Assistant at the Institute for Manufacturing Automation and Production Systems (FAPS) of Professor Feldmann. His current research topics deal with automated manufacturing lines for flexible substrate materials, printed electronics, process optimizations in surface-mount-technology and innovative concepts for quality assurance of area-array-packages.