DELO Specialist Article

Adjusted RFID system solutions in focus

Mühlbauer, Intune and DELO start joint research project

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The market for contactless labels has passed through the trough and out the other side – RFID is gaining momentum again: In 2007 144 million RFID tags were sold in the EU alone. According to a current study of the EU project „Building Radio Frequency Identification for the Global Environment“, it is expected to be already be 90 billion in 15 years. IDTechEx's analysts identified more than 3,000 RFID projects worldwide in the past year. The market volume gained in this line of business was already worth US$ 5 billion in which China had the greatest share with more than 40 percent. The reason for this trend is that all IC cards are equipped with RFID in the scope of the national ID program. Through this alone, RFID has experienced an enormous upturn. Moreover, it was possible to reduce the production costs for labels and readers through increased industrialization of this technology. As a result, RFID applications are spreading out even further in the diverse value chains – trend upwards. Already for 2016, the global RFID market is predicted to reach a potential of more than EUR 20 billion.

In particular, the industry is discovering new applications for radio labels: Extensive development and field tests are carried out in nearly any sector. In the health care system, in production lines and in the management of packaging units RFID has already been and is currently being implemented. For example, Daimler uses RFID tags in its truck factory Wörth where every truck housing gets a digital identity. The RFID labels transmit their data wireless to a computer system. The advantage of this procedure is that the factory manager knows at any time where and in which lacquering station each driving cab is.

In the future the major focus in industrial applications will concentrate on labels and packaging solutions, where especially the demand for cost-saving and efficient production methods of smart labels – a label with semiconductor chip and antenna – is in the center of attention. One essential step in the production of radio labels is the bonding of the chip to the tag antenna (see illustration 1).

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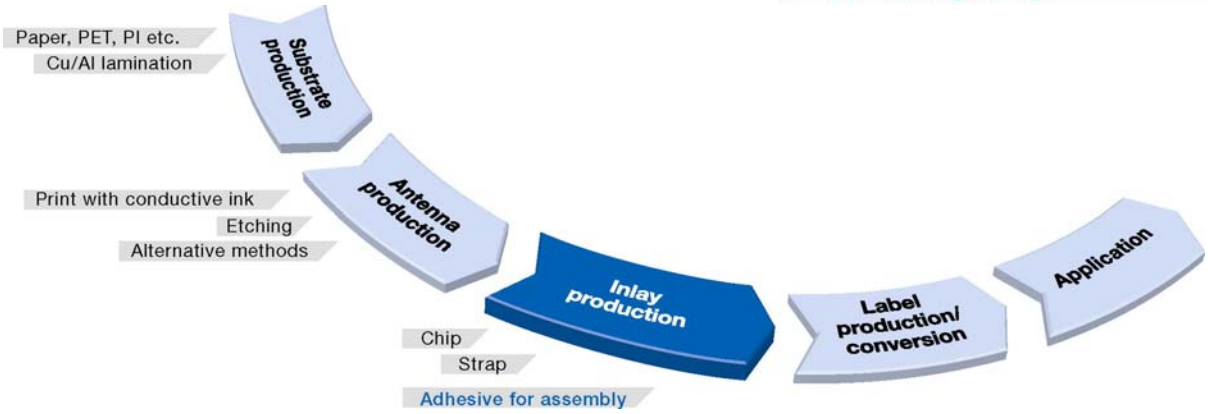

Illustration 1:
RFID value chain

In order to allow easy, cost-saving and fast contacting of chips to different substrates, the flip-chip technology is used for smart labels. The structured, active side of the semiconductor chip used is equipped with so-called “bumps”. For contacting, the chip refined with bumps is pressed into the metalization layer with its active side facing the antenna substrate. The adhesive, which was preliminarily applied in the area of the active surfaces, can be cured by means of a heated plunger (thermode) during placement of the flip-chip. Therefore, mechanical fixing and electrical contacting are performed in only one process step. Moreover, the contact surfaces are protected against environmental influenced as a result of embedding them in adhesive.

Research Project of Intune and DELO, supported by Mühlbauer

The compatibility of all components, like antennas, adhesives and machines, in inlay production is especially important – all components must be reliably adapted to each other. Therefore Intune Circuits, a Finnish manufacturer of RFID antennas, and DELO Industrial Adhesives as market leader in customized industrial adhesives started a research project, supported by Mühlbauer AG as market leader in smart label production lines.

The objective was to investigate for a “turn-key”-solution in the manufacturing of smart label inlay and to provide complete and harmonized solutions in the RFID value chain. The study focused on the compatibility of the aluminium antennas developed by Intune with DELO’s adhesives as well as the processability of both operating materials on the Mühlbauer machine.

Intune has worked in close cooperation with laminate raw material manufacturers, inlay producers and machine suppliers to develop an optimal aluminium substrate for RFID applications. A high-quality antenna substrate plays an important part in inlay production as, otherwise, difficulties may arise in combination with the chip adhesives and the necessary curing processes.

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The substrate used for the tests is the standard product ´102 aluminium UHF antenna web´. The laminate design is based on a heat-stabilized 50 µm PET film with a temperature- and chemical-resistant laminating adhesive and a high-purity 9 µm aluminium alloy.

Illustration 2:
Smart inlay

In particular, the chemical compatibility between the antenna laminating adhesive and the IC attachment adhesive (ACP or NCP) is important. Only a suitable material combination can ensure that the chip is permanently and reliably bonded to the antenna. Besides chemical adjustment, the antenna's dimensional stability must be guaranteed. During adhesive curing, the antennas are exposed to clearly increased temperatures of approx. 200 °C. Consequently, voids may occur below the chip, which may influence the reliability of the inlay. On the other hand, the exact dimensionality of the antennas may be impaired by shrinking processes during temperature influence. Amongst others, this has effects on the processing of the inlay to a label and the fully automated production process of flip-chip bonding itself. The positioning precision decisive for microelectronic production processes can result in significant misadjustments through an expansion of the antenna web and, thus, to waste rates. Moreover, the final quality of the antenna is also dependent on the purity of the metal alloy and the precision of the etching process. Especially, the latter is necessary to generate antenna structures with a high resolution which can be precisely processed in high-volume reel-to-reel processes.

DELO developed the tested adhesives especially for flip-chip bondings in the RFID sector. On the one hand, it must be possible to apply the adhesives without any difficulties and cure them fast on the respective production system to allow for an effective production. The DELO-MONOPOX MK055 is an adhesive which has proven to be efficient for this kind of application. This heat-curing epoxy is a one-component, unfilled product – also called NCP (non-conductive paste) – which cures, for example, at 190 °C in 8 seconds. In addition, further products were tested which were specifically modified for aluminium antenna metalizations. The DELO-MONOPOX AC265 is a one-component, heat-curing ACP (anisotropic conductive paste) and is based on the DELO-MONOPOX MK055. NiAu particles with a size of 2.5 µm are added as filler to establish anisotropic conductivity. The DELO-MONOPOX AC VE 42878 was tested, as well: This adhesive is an accelerated ACP and cures about 20 to 25 percent faster than MK055-based modifications. This product is also filled with 2.5 µm NiAu particles.

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Two different semiconductor chips were used in the laboratory tests. In combination with ACP adhesives, a semiconductor chip dimensioning 1 x 1 x 0.3 mm with 4 plated NiAu bumps (100 µm x 100 µm each) per chip was used. In combination with NCP adhesives, a semiconductor chip dimensioning 1.5 x 1.5 x 0.15 mm with 4 plated Pd bumps (70 µm x 70 µm each) per chip was used. The chips used were furnished with test structures so that the reliability of the bonded connection could be observed in different aging tests by means of resistance measurings.

The inlays were manually set up in DELO's laboratories. The chip was placed into the waffle pack and picked from there by the vacuum tool of the die bonder ´Fineplacer PICO´ of company FineTech. The adhesive was applied to the antenna through manual pin transfer. Afterwards, the chip was aligned on the substrate and placed in position. A laboratory thermode station (type TTS 300) of company Mühlbauer was used for adhesive curing. With the high-reliability laboratory bonding station for the curing of flip-chip adhesives, bonding in production processes of RFID applications can be optimally simulated. The machine has a top and a bottom thermode with independent temperature control. As the substrate shrunk at temperatures above 180 °C during the curing testes, a temperature of 180 °C was specified as maximal curing temperature (see chart 1). After curing and prior to the mechanical and climatic tests, the specimens were stored at room temperature (20 – 25 °C) for 24 h.

Adhesives	Top thermode/°C	Bottom thermode/°C	Curing time/s	Bond force/N
DELO-MONOPOX MK055	180	170	10	3
DELO-MONOPOX AC265	180	170	10	2
DELO-MONOPOX AC VE42878	180	170	8	2

Chart 1:
Curing parameters

Detailed tests in DELO's laboratories

In order to evaluate the behavior of PET-Al substrates of Intune in combination with NCP and ACP adhesives of DELO, different laboratory tests were carried out at DELO: One of these tests was the die shear test with which the mechanical strength is examined.

In this test, the force with which a bonded chip is sheared off of an antenna is determined. 10 chips were used per die shear test and adhesive. For this purpose, the inlays were fixed to a rigid surface (polycarbonate bars) by means of a cyanoacrylate (superglue). This measure minimizes the deformation of the PET material considerably leading to a reduction of the peel forces applied. Therefore, the results of the shear test are more reproducible and more reliable.

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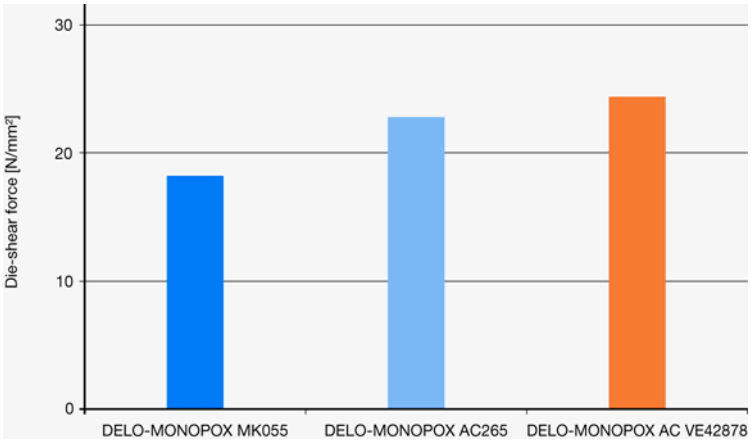

Illustration 3:
Die shear force of DELO´s adhesices on PET/AL-substrate of Intune

As demonstrated in illustration 3, the DELO-MONOPOX MK055 shows slightly lower shear strengths in the die shear test than the other adhesives. However, it must be considered that in case of this product a larger semiconductor chip was used. That means that the residual peel effect is slightly more intensive which apparently results in slightly lower values. However, compared to other RFID substrates available on the market, the shear strengths achieved can be considered as being excellent: According to DELO's internal benchmarks, 10 N/mm² are presupposed as a standard for products in single-use applications (e. g., tickets) and 15 N/mm² for applications with elevated requirements (e. g., passports). Both criteria were met in the tests with all substrate-adhesive combinations. The high strengths reached ensure excellent mechanical anchoring of the chip on the antenna and, thus, constitute the basis for presumably successful temperature and humidity storage tests.

The lifetime of a bonded connection is simulated by various climatic tests. The inlays were stored at 85 °C and 85 % rel. humidity for up to 504 h and subjected to temperature shock cycles between -40 °C and +85 °C. Therefore, further qualification tests at the customer are recommendable as the performance is always dependent on the materials used (chip, substrates, production conditions and parameters).

Temperature changes are also decisive in use as RFID applications in goods and delivery traffic must work reliably under various environmental conditions. The temperature shock test comprising of several cycles between -40 °C and +85 °C has proven to be efficient.

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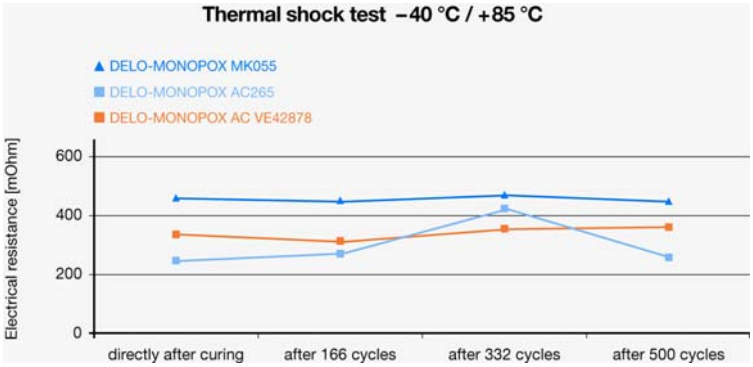

Illustration 4:
Electrical resistance in temperature shock tests -40 °C / +85 °C.

Illustration 4 describes the behavior of the inlay's electrical resistance during the shock cycles performed. Both adhesive variants, the MK055 as NCP adhesive and the ACPs DELO-MONOPOX AC265 and AC VE 42878, showed a very stable behavior on an accordingly low electrical resistance level. The constant level over the numbers of cycles is essential for evaluation. The peak after 332 cycles of AC265 can be traced back to a failure of the component due to the manual setup.

Moreover, the substrates were subjected to a so-called 85/85 climate test (illustration 5). Storage at 85 °C and 86 % relative humidity has turned out to be the most critical reliability test as adhesive properties, like low humidity absorption, high adhesion, low tendency to subsurface migration on the relevant substrate and high strengths are in particular demand. The resistances were measured after a storage time of 168 h, 336 h and 504 h.

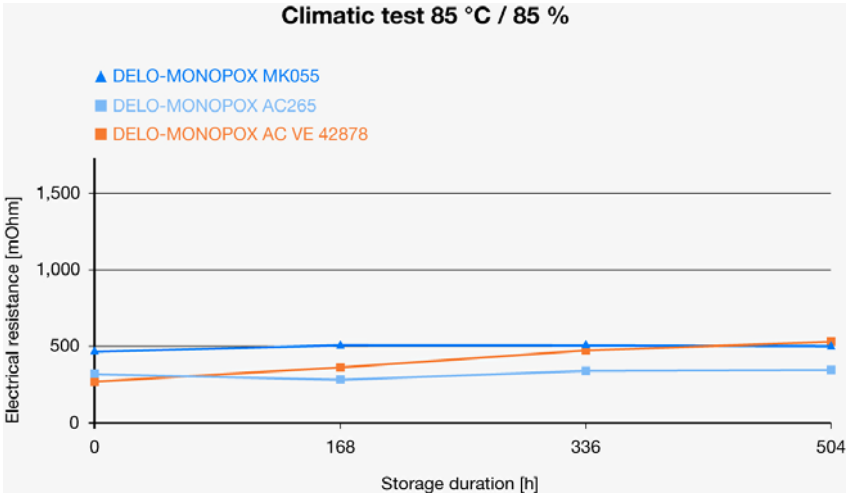

Illustration 5:
85/85 climate test

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In particular, the ACPs DELO-MONOPOX AC265 and AC VE 42878 did very well: DELO-MONOPOX AC265 did not show any essential changes in the electrical resistance even after storage under 85/85 conditions for 504 h. This is also the case with the product MK055 which is the basis for the adhesive used for chips with palladium bumps. The slight increase in resistance of AC VE 42878 is presumably caused by its accelerated chemical reaction behavior compared to the AC265. The adhesive passes through the polymerization reaction faster and the stage of physical and chemical interaction to the antenna is shorter, whereas the sensitivity to physical effects due to the humid environment is more distinctive. Nevertheless, the adhesive's performance can be considered as being very stable.

Behavior of substrate and adhesive in the production tests

The processing of the antennas, which are also called tape in reel form, with DELO adhesive was tested and assessed on an RFID production machine of company Mühlbauer.

Temperature of top thermode	180 °C
Temperature of bottom thermode	180 °C
Thermode force	0.5 N
Thermode type	low force
Curing time	10 sec
Used adhesive	DELO-MONOPOX AC265
Used IC	EPC 1.19
Equipment	Mühlbauer FCM Light

Chart 2:
Production parameters

Basically, processing of the tape by means of the Mühlbauer FCM Light system was trouble-free. Only the vacuum plate of the dispensing station had to be adjusted to improve the light reflected to the camera (vision system for positioning). This difficulty could be solved by using a white vacuum plate. Therefore, the antenna structure could be resolved in a sufficiently contrasty manner to ensure reproducible adhesive dispensing controlled by image recognition even at maximal throughputs. After adhesive curing at 180 °C / 180 °C in the final bonder for 10 seconds, the center of the tape was slightly deformed due to thermal influence.

Test results showed good compatibility

The laboratory tests did not show any interactions of the ACP adhesive tested with the materials used. However, the tests demonstrated that the PET film shrinks at temperatures above 180 °C. The die shear tests in the laboratory experiments resulted in values of 18 – 24 N/mm². According to experiences with substrates of other manufacturers, the die shear

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forces reached can be considered as being very high compared to other RFID substrates available on the market.

DELO's internal benchmarks are 10 N/mm² for products in single-use applications (e. g., tickets) and 15 N/mm² for applications with increased requirements (e. g., passports). Both criteria were met in the tests.

The epoxy-based resins DELO-MONOPOX MK055 (NCP) and DELO-MONOPOX AC265 (ACP; 2.5 µm Ni/Au particles) as well as the accelerated AC VE42878 (2.5 µm Ni/Au-particles) demonstrated a consistent behavior of the electrical resistance after storage at -40°C/ 85°C for 500 cycles after storage at 85°C/ 85 % r. h. for 504 cycles. Both tests indicated that small and hard particles, i. e., 2.5 µm NiAu particles, are best suitable to penetrate through the aluminium oxide layers.

The examinations and tests prove an excellent performance of the adhesives on Intune's PET and Al substrates compared to substrates of other manufacturers. The production tests showed an easy processing of the tapes on the Mühlbauer FCM Light system. However, before using the material combination described, the results must be checked again and further tests must be carried out as the basic test do not replace a full qualification by the end user.

All in all, the following conclusion can be drawn in view of the tests performed: RFID tags processed with Mühlbauer's FMC Light system, Intune's substrates and DELO's standard adhesives DELO-MONOPOX MK055 (NCP) and DELO-MONOPOX AC265 (ACP) delivered and excellent performance. As "plug-and-play" solution, the partners can together offer an optimized system solution for the customer due to their special know-how. The customer benefits from the tailor-made solution immensely: Fast-curing adhesives, high-quality antenna substrates and machines which can be ideally integrated into production lines and are tailored to the products provide for an efficient production: Already now, extremely short cycle times and the production of 15,000 – 20,000 units per hour are possible.

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