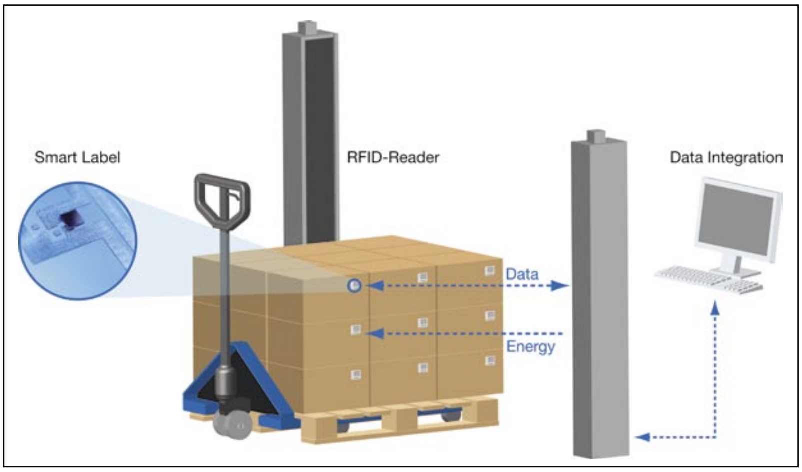
Integrated Smart Label Production Solutions

by Delo, Intune and Mühlbauer

The market for contactless labels has passed through the trough and out the other side – RFID is gaining momentum again: IDTechEx's analysts have identified more than 3,000 RFID projects worldwide in the past year. The market volume in this line of business is currently US$ 5 billion. China has the greatest share with more than 40 percent, due to its national ID program in which all ID cards are equipped with RFID. In addition to growing demand, production costs for RFID labels and readers are decreasing through increased industrialization. As a result, RFID applications are spreading even further in diverse value chains.

In the future, the major focus of industrial radio frequency identification (RFID) applications will be in labels and packaging solutions, especially in segments where the demand for cost-saving and efficient smart label production methods is at the centre of attention. Smart labels are implemented in particular in the logistics sector. Here, the products are furnished with a smart label, i.e. an antenna with a chip, which contains data about the goods, for example serial number, production date, etc. If tagged goods leave the production area, this can be recorded by an RFID reader so that the manufacturer knows at once which products are where (Figure 1). This information is passed on to a database which automatically records the data.

Figure 1 – Process chain



One essential step in the production of RFID labels is the bonding of the chip to the tag antenna (Figure 2). In order to facilitate easy, quick and cost-saving contacting of chips to different substrates, flip-chip technology is used. In this technique, the structured, active side of the semiconductor chip is equipped with so-called "bumps". For contacting, the chip is pressed onto the metallization layer with its active side facing the antenna substrate. The adhesive, which is preliminarily applied to the area of the active surfaces, can be cured by means of a heated plunger (thermode) during placement of the flip-chip (Figure 3). Therefore, mechanical fixing and electrical contacting can be performed in one process step. Moreover, the contact surfaces are protected against environmental influences by embedding them in adhesive.

Antenna, adhesive and equipment compatibility

The compatibility of all components, like antennas, adhesives and machines, in inlay production is particularly important. Therefore, Intune Circuits, a Finnish manufacturer of RFID antennas, and Delo Industrial Adhesives as market leader in customised industrial adhesives, started a research project, supported also by Mühlbauer as a market leader in smart label production lines. The objective was to investigate a "turn-key" solution for the manufacturing of smart label inlays. The study focused on the compatibility of the aluminium antennas developed by Intune with Delo's adhesives as well as the processability of both materials on Mühlbauer machines.

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

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

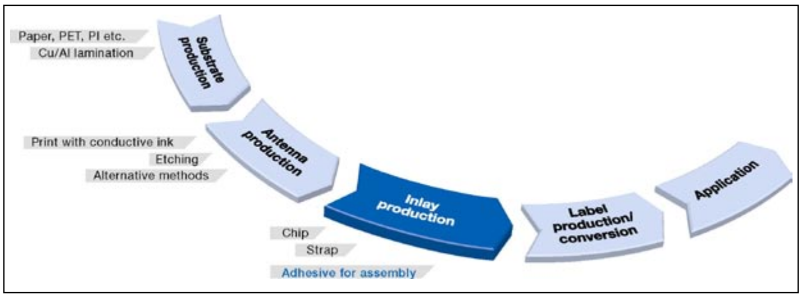


Figure 2 – RFID value chain

chemical adjustment, the antenna's dimensional stability must be guaranteed. During adhesive curing, the antennas are exposed to clearly higher temperatures of approximately 200°C. Consequently, voids may occur below the chip, which may influence the reliability of the inlay. On the other hand, the exact dimensions of the antennas may change due to shrinking during the high temperature processes. Amongst other influences, this has effects on the converting of the inlay into a label and the fully automated production process of flip-chip bonding itself. Expansion of the antenna web can reduce the positioning accuracy, so critical in microelectronic production processes, and result in significant misadjustments and, thus, lower yield rates. In addition, the final quality of the antenna is also dependent on the purity of the metal alloy and the precision of the etching process. In particular, the latter characteristic 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 bonding in the RFID sector. On one hand, it must be possible to apply the adhesives without any difficulties and cure them quickly on the manufacturing system in order to obtain an effective production solution. 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). In addition, further products were tested which were specifically modified for aluminium antenna metallizations. 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.

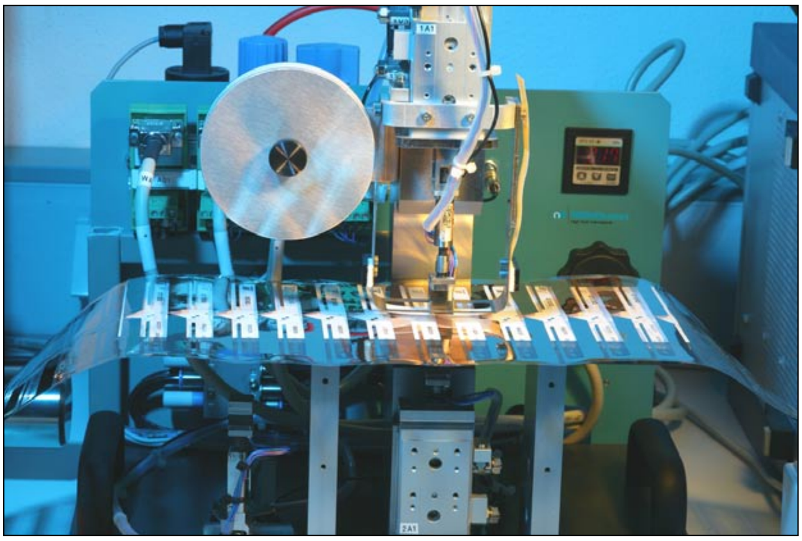
Two different semiconductor chips were used in the laboratory tests. In combination with ACP adhesives, a semiconductor chip measuring 1 x 1 x 0.3 mm with 4 plated NiAu bumps (100 µm x 100 µm each) was used. In combination with NCP adhesives, a semiconductor chip measuring 1.5 x 1.5 x 0.15 mm with 4 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 measurements.

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 a Fineplacer Pico die bonder from 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) from 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 tests, a temperature of 180°C was specified as the maximum curing temperature (Table 1). After curing and prior to the mechanical and climatic tests, the specimens were stored at room temperature for 24 h.

In-depth laboratory tests

In order to evaluate the behavior of the PET-Al substrates from Intune in combination with the NCP and ACP adhesives from Delo, different laboratory tests were carried out at

Figure 3 – In the thermode station, the chip is pressed onto the antenna and the adhesive is cured with heat



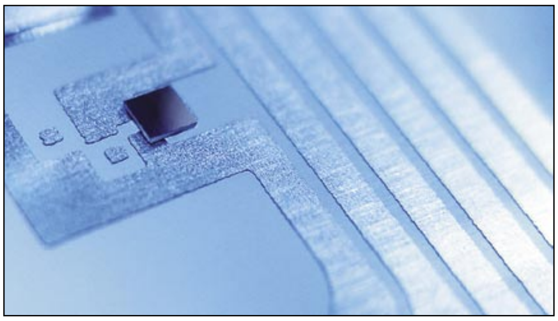


Figure 4 – Smart inlay

Delo. One of these tests was the die shear test.

In this test, the force needed to shear off the bonded chip of an antenna is determined. For this purpose, the inlays were fixed to a rigid surface by means of a cyanoacrylate. This measure minimises 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 reliable.

As demonstrated in Figure 5, the Delo-Monopox MK055 shows slightly lower shear strengths in the die shear test than the other adhesives. However, it must be considered that with this product, a larger semiconductor chip was used. That means that the residual peel effect is slightly more intense 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 excellent: according to Delo's internal benchmarks, 10 N/mm2 are taken as a standard for products in single-use applications (e. g. tickets) and 15 N/mm2 for applications with elevated requirements (e.g. electronic passports). Both criteria were met in the tests with all substrate-adhesive combinations.

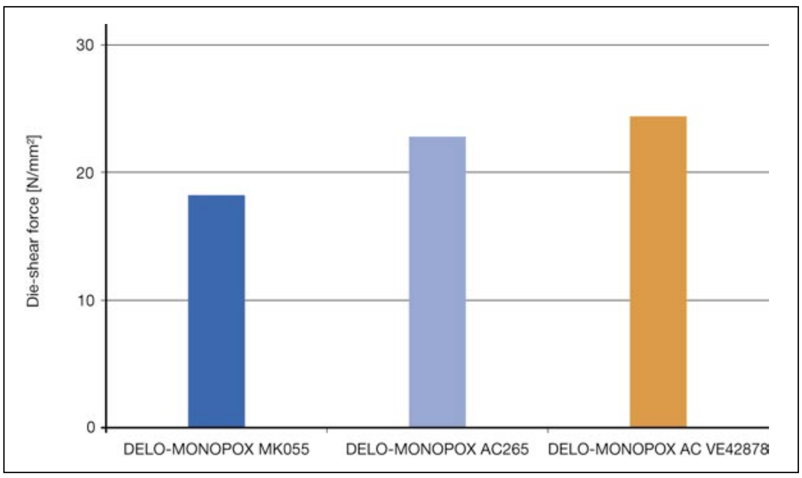
The high strengths reached ensure excellent mechanical anchoring of the chip on the antenna and presumably constitute the basis for successful temperature and humidity storage tests.

The lifetime of a bonded connection is simulated by various climate 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 customers' are recommended as the performance is always dependent on the materials used.

Operational temperature ranges are also critical, as RFID applications in logistics must work reliably under various environmental conditions. The temperature shock test comprising several cycles between -40°C and +85°C has proven to be efficient.

Figure 6 describes the behaviour of the inlay's electrical resistance during the temperature shock cycles. Both the MK055 as NCP adhesive and the AC265 and AC VE 42878 as ACP adhesives, showed a very stable behaviour at a 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.

Figure 5 – Die shear force of Delo's adhesives on Intune's PET/AL-substrate



Moreover, the substrates were subjected to a so-called 85/85 climate test. Storage at 85°C and 85% 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 storage times of 168 h, 336 h and 504 h. In particular, the ACPs AC265 and AC VE 42878 did very well. AC265 did not show any essential changes in the electrical resistance even after storage under 85/85 conditions for 504 h. This was also the case with 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 behaviour compared to the AC265. The adhesive passes through the polymerisation reaction faster and the stage of physical and chemical interaction with the antenna is shorter, whereas the sensitivity to physical effects due to the humid environment is more distinct. Nevertheless, the adhesive's performance can be considered as being very stable.

Production testing

The processing of the antennas in tape in reel form with Delo adhesive was tested and assessed on an RFID production machine from Mühlbauer. 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

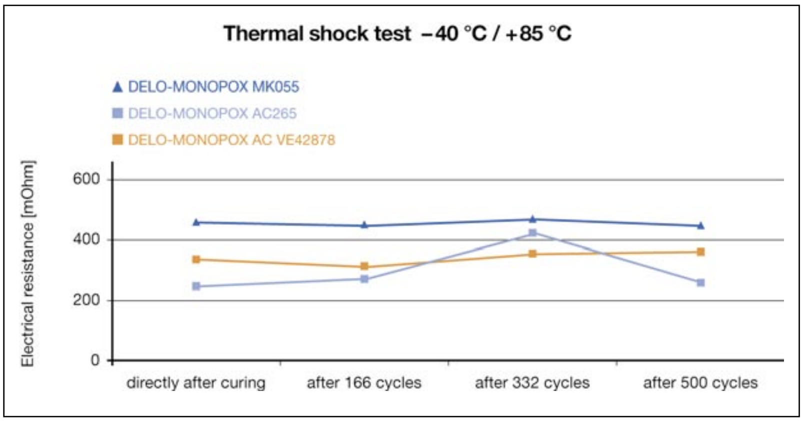


Figure 6 – Electrical resistance in temperature shock tests, -40°C / +85°C

camera (vision system for positioning). This difficulty was solved by using a white vacuum plate in order to resolve the antenna structure with sufficient contrast to ensure reproducible adhesive dispensing even at maximum throughput. After adhesive curing at 180°C / 180°C in the final bonder for 10 seconds, the centre of the tape was slightly deformed due to thermal influence.

Test results show good compatibility

The laboratory tests did not show any interactions of the ACP adhesive 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 gave values in the order of 18-24 N/mm². According to experiences with substrates from other manufacturers, the die shear forces reached can be considered as being very high. Delo's internal benchmarks are 10 N/mm² for products in single-use applications and 15 N/mm² for applications with increased requirements. Both criteria were met in the tests.

Table 1 – Curing parameters

Adhesive	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

The epoxy-based resins Delo-Monopox MK055 and Delo-Monopox AC265 as well as the accelerated AC VE42878 demonstrated a consistent behaviour of the electrical resistance after testing at -40°C/ 85°C for 500 cycles and 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 suited to penetrate through the aluminium oxide layers. The examinations and tests proved an excellent performance of the adhesives on Intune's PET and Al substrates. The production tests showed an easy processing of the tapes on the Mühlbauer FCM Light system.

In summary, RFID tags processed with Mühlbauer's FMC Light system, Intune's substrates and Delo's standard adhesives MK055 and AC265 delivered an excellent performance. As a "plug-and-play" solution, the partners can offer an optimised system solution for the customer due to their special know-how. The customer benefits from the tailor-made solution: fast-curing adhesives, high-quality antenna substrates and machines which can be ideally integrated into production lines and are tailored to the products provide efficient production. Already, extremely short cycle times and the production of 15,000 – 20,000 smart labels per hour are possible.

2011: The Year Of OLED Lighting?

Recent developments and announcements from major developers of organic electroluminescence (OLED) technology seem to be pointing towards the conclusion that 2011 will be the year where the first commercial OLED lighting applications will appear on the market.

Prototypes have been demonstrated by several companies by now, such as NEC, Osram OS, Matsushita Electric Works and Koizumi Lighting technology. General Electric have also demonstrated the ability to use printing technologies to manufacture OLED panels on a roll to roll process and its optimisation over the next few years will see the reductions in cost that are so inadvertently intertwined with the successful introduction of OLED products in the market. Konica Minolta is working closely with General Electric in the development of their lighting products.

Konica Minolta has also licensed UDC's proprietary phosphorescent OLED technology and is integrating it into their white OLED lighting products. The incorporation of the core competencies of the two companies into the final products will strengthen the competitiveness of the resulting products and lead to their accelerated commercialization.

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