Direct Bonding Definition

Direct Bonding is a means to directly connect an RFID wire antenna to a micro-sized chip without the need for bulky module housing and without additional soldering material.

Direct Bonding allows creation of smaller or thinner RFID-based products, which are more reliable, easier to process and even more cost effective than standard RFID products. While low frequency (LF) Direct Bonding is well known and has been proven for years, high frequency (HF) Direct Bonding for card and industrial applications has not been available on the market before. HID Global is leveraging its years of experience and expertise to extend this technology to HF applications to create ultra-thin or small products.
Two Decades of Direct Bonding Experience

In the low frequency area, Direct Bonding is a well-known technology used in producing ultra-thin or small products. Nearly 20 years ago, HID Global (formerly Sokymat) pioneered this technology and holds several patents. HID Global today produces over 60 million transponders per year, including Animal ID, automotive and more than 100 million RFID products for access control cards and keyfobs using LF Direct Bonding technology.

HID Global continues to develop innovations to the process and application of Direct Bonding.

The following picture illustrates an important innovation enabling the bonding of the latest chip generations of NXP (Hitag µ) and EM Microelectronic (EM 4200), which are extremely small - only 0.5 x 0.5 mm. HID Global's specially designed, automated production equipment makes it possible to hold a chip of this tiny size in position while welding two wires to it that are thinner than a hair.

![Figure 2: Direct Bonded NXP Hitag µ on left, compared to Hitag-S on right](image)

In order to weld the wires to the chip through LF Direct Bonding, special versions of the chip with customized bumps for connection are needed (see golden pads on the chips in Figure 1 above).

While this process is well established for LF environments, to date HF Direct Bonding has remained an industry-wide challenge. HID Global is the first company to successfully address this challenge due to its in-house expertise of building specialized production equipment.

The main challenges encountered by using Direct Bonding in the HF RFID field are:
- Thin antennas
- Thin chips
- Large (microcontroller) or very small chips (like memory chip) have to be carefully handled.

Advantages of Direct Bonding

Wide range of form factors

Depending on the application, the antenna is welded directly to a micro controller chip (0.5x0.5 mm or 3x3mm) instead of a module (~5x8 mm). This not only allows building smaller products such as
the Glass Tag Mini of ø1.4x8 mm, miniaturized disc shape Piccolino e-units or Logi Tag™ industrial tags, but also provides significant advantages for bigger products such as ISO cards or passports:

**Figure 3**: Direct Bonded MIFARE® Chip (left) compared to a traditional module (right)

**Excellent Printability of ISO Cards**
When it comes to embedding a module into an ISO card, the size and thickness of the module may cause the surface of the card to become uneven which is a problem when the card is later printed on a desktop printer. A Direct Bonded chip is so small and thin that the card surface remains perfectly flat to support printing after lamination with excellent results.

**Allows Ultra Thin Inlays**
When associated with a thin chip (today 75 µm, but thinner tomorrow), an inlay with a Direct Bonded chip can become as thin as 200 µm, whereas a standard inlay produced with a module is typically 330 µm thick. Today’s thinnest modules are already ~250 µm.

Inlay thickness is an important criterion for some applications, such as e-government applications, where organizations are requesting more and more security features on cards.

An ultra-thin polycarbonate (PC) inlay gives additional room to ID card manufacturers to apply additional PC security layers in their card construction.

**Improved Durability**
Due to the smaller surface occupied by the Direct Bonding connection, Direct Bonding is much less susceptible to bending and torsion than module technology. In addition, there are only two connection points to the chip, whereas with module technology there are in total six connection points, which imply three times as many potential failure points. The image below shows the external antenna connections to a module (1, 6) and internally within a module (2, 3, 4 and 5). Direct bonding would weld the external antennae (1, 6) directly to the chip (3, 4), removing the need for any other connections.

**Figure 4**: Antenna connections for module technology
Proven, Highly Reliable Copper Wire Antenna

Direct Bonding works with copper wire antenna technologies that are truly welded to the chip. This is the best solution in terms of RFID performance as well as robustness and long term reliability.

Today with more than 90% of RFID e-documents manufactured using copper wire antenna. The reliability of the copper wire antenna is proven.

Direct Bonding vs. Flip-Chip Technologies in HF Applications

When a module is not required in the development of ultra-thin products, some manufacturers use Flip Chip technologies as an alternative to Direct Bonding. The long term reliability of the Flip Chip connection remains to be proven. Although this may not be an issue for applications like single-use public transport ticketing, long term reliability is a key criteria for some applications such as e-government documents that require 10 or more years of lifespan.

The Flip Chip concept is not new; it was commercially introduced by IBM in the 1960’s for individual transistors and packaged diodes.

The traditional solder bump Flip Chip process may be considered as four sequential steps: (1) preparing the wafer for solder bumping, (2) forming or placing the solder bumps, (3) attaching the bumped die to the board, substrate or carrier and (4) completing the assembly with an adhesive under-fill.

Based on this concept, various companies have developed the Flip Chip for use in thousands of different applications in an effort to take advantage of the size and cost benefits offered by this assembly method. RFID applications are no exception to this approach and several companies have developed an “alternative” Flip Chip method. Due to the temperature limitation of the manufacturing process however, the traditional Flip Chip technology with solder bumps is not always a feasible approach and cannot be used in the packaging of contactless smart cards.

Solder bumps have been replaced by other material (primarily gold bumps) such that the Flip Chip connection is no longer considered a legitimate welding process. The Flip Chip technology may use different types of adhesive technologies such as ACF (Anisotropic Conductive Film), ACP (Anisotropic Conductive Paste) or NCP (Non Conductive Paste).

For all these Flip-Chip technologies, the chip is glued to the substrate and the electrical connection is completed by a “physical” and “rigid” contact instead of being welded, thus creating a less reliable and more breakable connection.

Flip Chip technology is also associated with different types of antennas such as printed antenna or etched antenna, but not to copper wire antenna.

The image below illustrates a typical Flip-Chip mounting via glue on a PET or Polycarbonate substrate and a printed or etched aluminum or copper antenna. The glue will float aside as the chip is pressed down to allow the contacts to touch the antenna.
HID Global is working with major chip vendors to constantly increasing the number of Direct Bonded HF technologies that is available for Genuine HID® products. The first technology for industrial use is called Vigo™ and has the following main characteristics.

- ISO 15693 / ISO18000-3 standard compliant at 13.56 MHz
- 64 bit UID and 1 Kbit, 1.6 Kbit or 2 Kbit user programmable memory
- 32 bit password protection for functionality and data
- Privacy mode option, when the privacy mode is enabled the tag remain silent until a login command is received
- 60 years data retention
- Direct bonding of chip to antenna

A range of small industrial products is available with this technology for use on- or off-metal. E.g. LogiTag 121, Glass Tag, Piccolino Tag or Brick Tag. Then image below shows an example of Vigo direct bonding that can for example either be used to create very small e-units or larger ones where the chip is very close to the antenna so that a big hole is possible in the tag e.g. to run a pipe through.

Figure 5: Flip-chip mounting via glue

**HID Global’s Vigo™ Technology**

Figure 6: ClearDisc Vigo™ with hole (left) and Piccolino Tag Vigo™ (middle)
**Conclusion**

When high quality is requested in applications, such as industrial or government eIDs applications, that demand many years of reliable function and excellent performance, Direct Bonding is the preferred choice.

HID Global pioneered and successfully established production of hundreds of millions of tags per year based on LF Direct Bonding technology. Now the experienced engineering and automation team at HID Global has enabled Direct Bonding for HF products.

The HF Direct Bonding capabilities enable HID Global’s customers across a wide range of business segments to match products to their needs, based on the latest technology.

HID Global currently supports LF and HF Direct Bonding for industrial tags and also for Government ID, ISO cards and prelaminates with a constantly increasing number of chip types.

For questions or availability information, please contact your HID Global sales representative.