SETTING UP THE DIE ATTACH PROCESS

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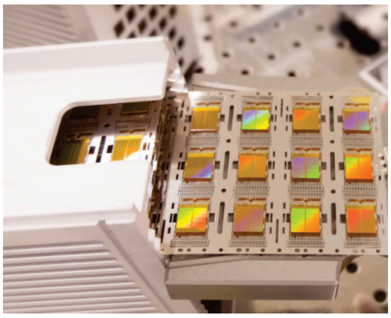
- SCOPE: An introduction to the die attach process, and factors to be taken into consideration when setting up or reviewing this process.

When setting up a die attach process, some of the factors that need to be taken into account are:

- Die Type & Size
- Die and Substrate Materials
- Substrate Bondability
- Joining Agent
- Application Method
- Cure / Reflow Method

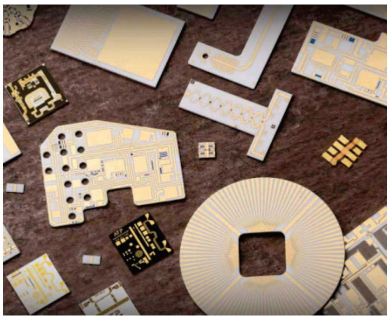
Die Type & Size:



There are only two options for die type: flat or bumped. If the die is flat, the next consideration is to decide if electrical conductivity is required. If so, then the choice is between using a conductive epoxy, a solder, or a silver sinter material (usually used mostly in high power applications). If electrical conductivity is not necessary, an adhesive will be used. Generally, the adhesive will be either an epoxy or an acrylate (for compliancy when the die is large).

If the die is bumped (for examples, BGA or Flip Chip), then it is usually a choice between an Anisotropic Conductive Adhesive (ACA) or soldering the bumped die to the substrate and then applying an Underfill (for more detailed information on Inseto's ACA materials, please visit **HERE**). Using an ACA requires precise alignment of the die as the ACA is applied to the substrate prior to attaching the die, so the die and substrate pads must be aligned just prior to placement. Underfills are applied after attaching the die to the substrate, so there is no need for alignment, but the downside is that there is an extra process involved (reflowing the solder balls to attach the die, and then curing the Underfill material after it has been applied).

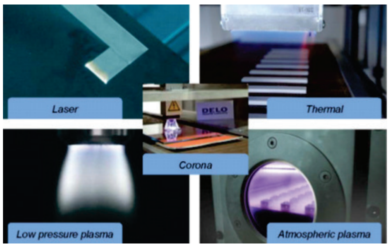
Die & Substrate Materials:



The die material, in the majority of applications, will be silicon, but other materials are also used, such as GaAs, InP, and GaN. These compound semiconductor materials tend to require more heat dissipation than silicon, so non-conductive adhesives tend not be used in these applications.

On the other hand, there is a wide range of substrate materials to choose from - ceramic (alumina, AlN, BeO, Quartz, etc.), FR4 (too many variations to mention), softboard (Duroid, epoxy tape, PI flex, etc.), and traditional semiconductor leadframes. Quite often the deciding factor will be influenced by other criteria: cost, reliability, availability, etc.

Substrate Bondability:



In general, the surface of the die does not require any form of preparation in order to achieve good adhesion. However, it can be a very different story when it comes to the substrate material! As a broad category, it is straightforward when bonding to ceramics. For FR4 and softboard materials, there is a wide range of surface finishes, not all of which are easy to bond to (cost can be a big factor when choosing substrate material, and it's not always a case of "the cheaper the better", because that can lead to extreme variability in surface finish). In that case, some form of pre-treatment / cleaning may be necessary. Options include laser ablation, low-pressure plasma, atmospheric plasma, and corona treatment, and for cleaning the choice is between aqueous or solvent cleaning. Each has its advantages and disadvantages, ranging from process cost (i.e. time) to equipment cost, and whether the pre-treatment can be an in-line one, or on a batch-by-batch basis.

It's also worth noting that cleanliness is critical for any form of joining process, whether it's adhesive bonding, soldering, or silver sintering. If pre-treatment is necessary, then it can also be a requirement for another cleaning process after the pre-treatment process, for example when laser ablating.

Joining Agent:

As stated above, the first consideration is to decide if electrical conductivity is necessary. If so, then the choices are solder, conductive adhesive, or silver sintering. Best results are achieved with solder or silver sintering. The electrical conductivity of an adhesive will never be as good as that of solder or silver sintering, simply due to the fact that adhesives when cured become plastic, and this will reduce the electrical conductivity because plastic is a poor conductor of electricity, even if the bond line thickness is very fine.

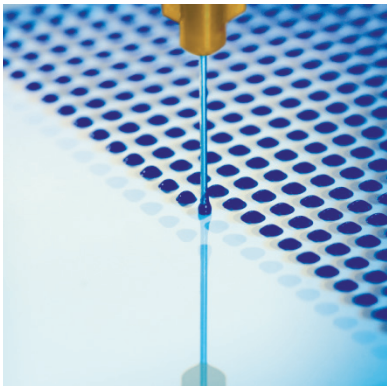
Solder has been used for many decades to make the electrical connection between the die and the substrate - it is a well-established process! However, solder is available in solid form as preforms, ribbon and wire, or suspended in a liquid form as paste. Solder preforms can be supplied in bulk (glass vials), in Waffle Packs, or on Tape-on-Reel. The latter two are used in automated processes, but they come at an additional cost of putting the preforms into the pack / reel. Solder ribbon is very useful for R&D and prototype assembly - it saves on the cost of a stamping tool - but the ribbon must be cut to size before being applied. Solder wire is used mainly in power applications, and requires some type of feeder mechanism to apply and melt just the right amount of solder onto the die attach area. Solder paste contains a flux to improve the wettability of the solder, and this has to be removed after solder reflow, another process to be carried out, with the additional cost it brings (time and equipment).

To make an adhesive electrically conductive requires a conductive filler (as mentioned earlier, adhesives by themselves do not conduct electricity, they are inert plastics once cured). The filler is usually silver (particles, flakes, or spheres in some rare cases), although gold has also been used in the past - before the price of gold increased substantially some years ago! While not as electrically conductive as solder, conductive adhesives tend to be less expensive than solder and can normally be cured at lower temperatures than solder, thereby imparting less stress into the materials being bonded.

Silver sintering is a relatively new process, used mainly to bond high-power semiconductors, so reliability data is limited at the moment. It's based on a solid-state diffusion process where silver particles are fused to each other and to the metalisation on the die and the substrate. Therefore it can only be used when the surfaces of the materials being joined are metalised (and free of oxides - pre-treatment?). It is generally a temperature and pressure (~ 10 MPa) process, although some pressure-less materials are currently under evaluation. Sintering temperatures are comparable to, or lower than, typical SAC-reflow temperatures. Similar to solvent-based materials, silver sinter materials require a drying stage prior to the final firing process.

Where electrical conductivity is not a requirement, then the only choice is adhesive bonding! The question then becomes, is thermal conductivity (but electrical isolation) a requirement? If so, then a thermally conductive filler material is added to the adhesive instead of silver. Generally these fillers are alumina, aluminium nitride, or boron nitride (despite the fact that in sheet form alumina is significantly less thermally conductive than aluminium nitride, this difference is significantly negated in particle form). If thermal conductivity is not a requirement, then a special filler in not needed. There is an extensive range of non-conductive die attach adhesives on the market, so other factors such as cure time, ease-of-application, MOQ and container size will influence the decision on which adhesive to choose. For more information on Inseto's range of die attach adhesive, please visit **HERE**.

Application Method:

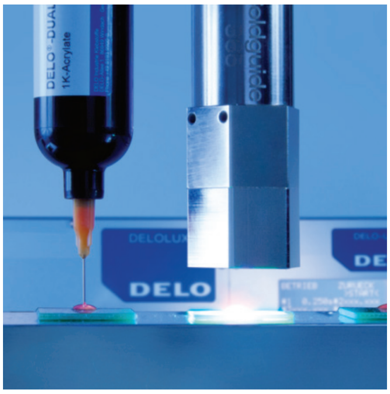


This will be heavily influenced by the joining agent, and the substrates being joined. Solder preforms (and cut ribbon) are either placed by hand (R&D, prototyping) or by die bonders, also known as pick-and-place machines, for high volume production. The cost of die bonders is dictated by the required UPH and repeatable placement accuracy. Solder paste is either dispensed or screen / stencil printed, depending on the size and topography of the substrate.

Adhesives will be either dispensed, jetted, stamped, or screen / stencil printed. Sometimes the nature of the adhesive will dictate the application method - some viscous adhesives are easier to print than to dispense, while less viscous ones are more difficult to print as they are very difficult to control between the act of printing and the actual component placement process (especially for applications with a large number of components on a substrate). Adhesives that contain abrasive fillers, while it is definitely possible to jet them, will cause damage to the jetter, necessitating the replacement of very expensive equipment after short periods of operation. Finally, adhesives that are susceptible to moisture cannot be stamped or printed, unless in a controlled atmosphere, as it is possible for them to be exposed to moisture for extended periods of time.

Silver sintered materials are applied in paste form, or as pre-dried films. The pastes are screen / stencil printed, a well-established process in use for many years, while the films contain a special sintering inhibitor that must be dried off.

Cure / Reflow Method:



Solder, no matter what form it is supplied as, will be reflowed in order to get it to join the two substrate materials together. Reflow means that heat is applied to raise the temperature of the solder to its melting point in order to get it to soften, dwelling at that temperature for a specific period of time to form the bond, and then cooling the assembled parts down to room temperature for the next stage of the process. Regarding the melting step, solders will either be eutectic alloys, or have a melting temperature range. Eutectic alloys go from solid to liquid instantaneously at a given temperature (for example, 80%Au 20%Sn turns liquid at 280°C - it is solid at 279°C!), and so are desirable from a control and consistency point of view. Alloys with a melting point range (and this accounts for most alloys) can be difficult to control - for example, 70%Pb 27%Sn 3%Ag (granted, not a commonly-used alloy!) melts between 179°C and 312°C, which will mean significant variation between batches. For more detailed information on Inseto's range of solder alloys, please visit **HERE**. Reflowing solder paste has an added wrinkle in that a relatively lengthy dwell time is required during the ramp-up process in order to dry off the flux contained in the paste. This is especially true for applications that contain a large thermal mass - it takes even longer for all the components to reach the desired temperature.

Curing die attach adhesives generally falls into two categories - using heat just like when soldering (but at lower temperatures) or using UV light (or sometimes a combination of the two!). This is true whether the adhesive is electrically conductive, thermally conductive, or neither! Curing by heat seems relatively straightforward: put the joined parts in an oven for a defined period of time, with the oven set to a defined temperature. However, it's not quite as simple as that. If a technical data sheet says that an adhesive must be cured at say 100°C for 30 minutes, this does not include the time it takes for the adhesive to get to 100°C. So taking the assembled parts out of the oven after 30 minutes means that the adhesive will NOT be fully cured. This is especially important if one or both parts are metal - because most metals conduct heat very well, it will take even longer for the adhesive to reach the desired temperature.

Care also needs to be taken to ensure that the parts actually reach the desired temperature. Heat uniformity in an oven can vary, with some "hot" and "cold" spots present. For example, if the oven is set to 100°C, there will probably be areas in the oven where the actual temperature is 102°C, and some where it is 98°C (or even lower). So if a data sheet specifies a minimum cure temperature of 100°C, and the parts being bonded are in an area of the oven that is only at 98°C, the adhesive will **never** cure, even if the parts are left in the oven for hours! So it's highly recommended that curing is not carried out at the lower end of the process window. Using thermocouples when setting up the process for heat curing is strongly advised. (This is also true for the soldering process.)

Curing with UV also needs some careful deliberation to get the process right. The first consideration is the type of lamp. In general, there are two types of lamp used to cure a UV adhesive: older style mercury bulb lamps and newer style LED lamps. The mercury bulb lamps cost less (and sometimes a lot less) than LED lamps, but the cost of ownership is much higher! Once a mercury bulb lamp is switched on at the beginning of a shift, it must remain on for the whole shift (8 hours typically), even if it's not actually curing adhesive the whole time. This is because it has a cooling down period, once switched off, of 15 to 20 minutes, before it can be switched back on. Because these bulbs only have a lifetime of ~ 1,000 hours, they need to be replaced frequently, at cost of many hundreds of pounds. LED lamps do not have this problem, they cure on-demand so during an 8-hour shift, they may actually only be in operation for a fraction of that time. And because they have a lifetime of > 10,000 hours, on-going operational costs are significantly lower.

The other consideration concerns the wavelength of light that the adhesive needs to cure. "UV light" is a catch-all phrase that can actually be broken down into actual UV light and Visible light. UV lies below 380 / 400nm on the electromagnetic spectrum, while Visible light lies above 400nm (400nm is the generally accepted cut-off point between UV and visible light). So care needs to be taken to ensure that the lamp is tailored to the adhesive. Most adhesives will contain photoinitiators that allow curing to be done both by UV light and by VIS light, but this is not always the case. For more detailed information on Inseto's range of UV lamps, please visit **HERE**.