inseto	**HOW TO CHOOSE THE RIGHT ADHESIVE**	
	ADVANCED TECHNOLOGY FOR RESEARCH & INDUSTRY	**KNOWLEDGE BASE FACT SHEET**

- SCOPE: There are many factors that go into choosing the right adhesive for a particular application. This document offers guidelines on how to proceed with this sometimes tricky process.

Quite often, the last thing to be considered in a new project is the adhesive. After all, how difficult can it be to glue two things together??? If it was really that simple, this document would not exist, and unemployment figures would increase (but probably not dramatically – there aren't too many people who make a living from selling "glue" (legally, that is)).

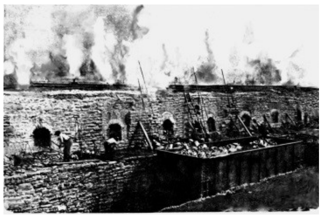
The factors that influence the choice of an adhesive can be broken up into three categories:

Pre-Cure

Cure

Post-Cure

Some factors could fit into more than one category, equally there will be some debate as to which category a property belongs!



It is usually a matter of eliminating possibilities to see what is left – for example, to bond two very large items, a heat-cured adhesive will not usually be chosen. Think of the oven size required to bond the various components that make up the wing of an airplane…

Pre-Cure

In no particular order, here are some factors that should be considered at the pre-cure stage when choosing an adhesive:

Surfaces are bonded, not materials – an adhesive bonds to the surface! So is the surface plated? Does it oxidise easily, like copper?

Some materials should be avoided at all costs, e.g. PTFE (aka Teflon), most Polyethylenes (PE) - there is a reason adhesive bottles are made from PE!

Corona

If it is not possible to choose a material that is easy to bond to, then consideration must be given to pre-treatment. This can range from simple batch plasma cleaning to expensive in-line plasma ovens. Other possibilities include flaming, corona treatment, and sand-blasting.

Cleanliness – do the surfaces need to be cleaned? Always a vital consideration, and highly recommended by Inseto.

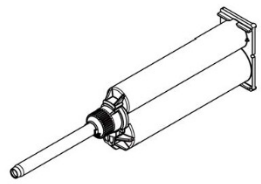
Storage of the adhesive a) at the customer's facility, and b) in a cleanroom (not always needed) – recommended adhesive storage temperatures range from RT (~23º) all the way down to -40ºC. At the lower extreme, an industrial freezer is required, so lots of £££ need to be spent. Adhesives that need -18ºC storage can be stored in commercially available freezers, so all Purchasing Managers will be happier with this choice!

Adhesives that need to be stored below 0ºC require specialised transport, packed in large Styrofoam boxes containing ~ 10Kgs of dry ice. There are only two courier companies willing to transport these, so transport costs can be very high.

Conditioning time – any adhesive stored in a fridge or freezer will need to be thawed to room temperature before it can be used.. The technical data sheet will advise this conditioning time, but do **<u>not</u>**, under any circumstances, force the thawing, for example, by placing the adhesive container on a radiator! This will induce moisture into the adhesive, and cause a lot of problems both during and after cure.

Processing time, or pot life – this can vary widely from adhesive to adhesive. Generally Inseto offers adhesives with working a life of 48 hours to 12 months!

Mixing – if a two-part adhesive is chosen, the resin will need to be mixed homogeneously with the hardener. For small to medium volume applications, this can be achieved by purchasing the adhesive in a “twin-pack” – it looks a little bit like the barrels of a shotgun! For high volume applications, the adhesive will be supplied in large (10L / 20L) containers, and expensive, specialised mixing equipment is required to dispense from these.



Viscosity – too low, and the adhesive can’t be controlled; too high, and it won’t move after leaving the container. Horses for courses…Also, care needs to be taken when choosing an adhesive based solely on its viscosity. Look at the small print on the data sheet to see how the viscosity has been measured. Unless the test method is identical to another adhesive that might be under consideration, any comparison is invalid.

Flowing behaviour – this is not defined in **any** data sheet! It’s very difficult to quantity, but it can have a big effect on processing. Basically, what happens to the applied adhesive as the ambient temperature increases?

Application of the adhesive – manual or automatic? This is usually determined by the quantity to be assembled. For small volumes, a manual process is usually sufficient. For larger volumes, repeatability is key, so an automatic process is usually required.

The next factor is the method of application – dispense, jet, stamp, screen / stencil print, spray, brush? Each has its own advantages and disadvantages, and sometimes the nature of the adhesive will rule some in / out. For example, moisture sensitive adhesives should only be dispensed.

Finally in this section, it is important to consider how the waste, or unused adhesive, can be disposed. The easiest way is to somehow cure what is left in the container and then dispose of it in normal household waste – a cured adhesive is a plastic! But there will always be some unused adhesive that must be disposed, and engaging the services of a specialist disposal company can be expensive.

Cure

An adhesive is cured by one or more of the following methods: heat, light, moisture (sometimes mistakenly called air curing – it’s actually the moisture in the air that causes the adhesive to cure), mixing a resin and hardener, or, in the case of anaerobic adhesives, the absence of oxygen **and** the presence of metal.

Sometimes the cycle time dictates which adhesive is chosen. For example, the automotive industry and the mobile phone industry both require a large number of parts to be made in the shortest possible timeframe. So if one part needs to be assembled every 5 seconds, an adhesive that needs 30 minutes to cure will not be used – think of the size of the oven that would require!!!

Sometimes the materials being bonded dictate the adhesive. It is not possible (under normal circumstances) to bond two opaque parts together using a light-cured adhesive – how does the light get to the adhesive??? When bonding to Polycarbonate, it is usually not possible to use a UV adhesive, as most grades of Polycarbonate block UV light (the trick in this instance is to use an adhesive that also contains a VISIBLE light photoinitiator). In addition, some plastics can’t withstand a high level of heat, so the adhesive needs to be cured at 60ºC - 80ºC maximum.

High intensity light is generally the fastest way to cure an adhesive. Cure times range from 1 second to 60 seconds, depending on the adhesive. The downside is material cost – due to the high cost of photoinitiators, this type of adhesive tends to be expensive. Having said that, the process cost, which is considerably more important than material cost as it is a true reflection of the cost of manufacture, is ALWAYS lower for light-cured adhesives, if the volumes are high enough.

The slowest curing mechanism is moisture. The cure rate for these adhesives is 2mm every 24 hours, so, depending on the geometry of the parts being bonded, the actual cure time can be days! Some, but not all, moisture cured adhesive can have their cure rate accelerated by adding heat, or increasing the moisture content in the ambient atmosphere.

Between these two extremes lie heat-cured, cold-cured, and anaerobic-cured adhesives. Usually, anaerobic curing is the fastest of these, anywhere between 15 seconds and 5 minutes. Heat-cured adhesives will usually cure anywhere between 60ºC and 180ºC, while cold-cured adhesives cure at room temperature after mixing. The cure schedule for most cold-cured adhesives can be accelerated by using heat – as a general rule-of-thumb for epoxies, every 10ºC rise in temperature reduces the cure time by half. The reverse is also true, so be careful when curing cold-cured adhesives in the wintertime when some ambient temperatures can drop below 20ºC.

When using a heat-cured adhesive, remember to include the heating-up time for the assembly. If a technical data sheet states that an adhesive cures at 120ºC for 30 minutes, curing only starts when the adhesive reaches 120ºC. This is especially critical when bonding metal, as it can act as a heat sink and remove heat from the adhesive.

One final point concerning the curing of heat-cured adhesives: Be very careful of curing at the bottom edge of the process window. For example, if a data sheet gives a minimum cure temperature of 80C, it is usually for a good reason – below this, the adhesive just will not cure, no matter how long it remains in the oven. If the oven is set to 80ºC, it is almost 100% guaranteed that not all areas within the oven are actually at this temperature. So if the parts to be bonded are placed in one of these areas, the adhesive will **<u>never</u>** cure. It is better to set the oven to cure at 82ºC - 84ºC to ensure that the adhesive cures.

Post Cure

There is potentially a very long list of "things" that the cured adhesive must provide. It is worth noting that despite the technical values that appear on a data sheet, these usually apply only to the adhesive, and the adhesive will behave very differently when it is bonding two parts together. The complete assembly must be tested by the customer to ensure reliability. After all, one customer's aluminium might be a very different (grade of) aluminium than another customer is using.

Here are some of these "things", again in no particular order!

Bond strength – this is usually one of the first factors considered when choosing an adhesive! How strong must the join be? Most customers will reply "as strong as possible"… There are two elements to "bond strength": cohesive bond strength, and adhesive bond strength.

Adhesive bond strength is defined as the bond strength of the adhesive to the materials being bonded. **<u>In every case</u>**, this has to be tested in the specific application under discussion. No two materials give the same bond strength, so an adhesive that bonds well to stainless steel might be terrible with aluminium. Even within a generic material such as Polycarbonate, care needs to be taken. There are in excess of 100 grades of Polycarbonate available, and each will probably bond differently! Generally, the technical data sheet will point in the right direction, so it's a very good starting point, but **<u>only</u>** a starting point.

Cohesive bond strength is more straightforward, it is the inherent strength of the adhesive, and is independent of the materials that it is bonding. It will be specified on the data sheet, and is measured simply by curing a test coupon of the adhesive and then pulling it apart until it breaks! The force required to break it is the strength of the adhesive, called the tensile shear strength (sometime just the tensile strength).

Flexibility – there are different ways to indicate the flexibility of an adhesive: elongation, Young's Modulus, sometimes shore hardness. Elongation is the easiest to both measure and visualise – it is calculated in the same test that determines the tensile strength of the adhesive. The percentage that the test coupon has strength when it breaks is the elongation, also specified in the data sheet – simple!

Temperature resistance – this will usually be specified on a data sheet, and depending on the application, will be more or less important to each customer. For those working in the military, aerospace and automotive fields, the temperature range of interest will be from -40ºC or -55ºC to +125ºC or +150ºC. For commercial applications, it will be much narrower, usually from -20ºC to +80ºC.

For tests such as temperature cycling and thermal shock, no data sheet will state "our adhesives survive" these tests. The temperature rating specified on the data sheet is a very good guideline (for example, an adhesive that is only rated to 80ºC should not be considered for an application that must work up to 120ºC…), but it not an absolute guarantee. Again, the complete assembly must be tested to ensure these requirements are met.

Chemical resistance – there are so many different chemicals that could possibly come in contact with the bonded assembly that it is absolutely impossible to test for all of them. Most application areas will have their own set of chemicals that the adhesive must survive. For example, in the automotive industry, this set usually consists of petrol, diesel, AdBlue, engine oil, brake fluid acetone, and maybe DI water. However, the mobile phone industry will have a completely different set of fluids, coffee, alcohol and water being the most frequent!

As a general guideline when choosing an adhesive for an application that needs a high chemical resistance, keep away from flexible adhesives. These tend to have a less rigid molecular chain once cured, so it is easier for chemicals to penetrate the adhesive and attack the bond. Hard, rigid adhesives generally offer the best chemical resistance.

Applications that will see changes in temperature over their lifetime need to consider how the adhesive expands and contracts with these temperature changes. Two very important characteristics of the adhesive need to be consider here – the glass transition temperature (Tg) of the adhesive, and the coefficient of thermal expansion (CTE) of the adhesive. These are directly related to each other.

The Tg is defined as the temperature at which the mechanical and physical properties of the adhesive start to change. Below the Tg, the adhesive network is in a solidified, relatively immobile condition. Above the Tg, the polymer chains of the adhesive may move slightly relative to each other, independent of the degree of cross-linking (i.e. curing). This may cause the adhesive to "soften" slightly above the Tg, but the degree of softening varies according to the adhesive.

In an ideal world, the chosen adhesive should have a Tg in excess of the operating temperature of the end application. As the Tg is exceeded, the adhesive softens, even if it is only very slightly. As the operating temperature comes back down below the Tg, the adhesive will harden slightly. Doing this thousands of times during the lifetime of the application will induce stress into the adhesive, causing the join to fail more quickly than it should.

CTE is defined as how the size of an object changes with changes in temperature, and is usually expressed in parts per million (ppm). Technical data sheets should contain two CTE values – $\alpha 1$ for the CTE below the Tg, and $\alpha 2$ for the CTE above the Tg. They will nearly always be significantly different values!

When bonding similar materials together, e.g. glass to glass, CTE is not an issue as both materials will expand and contract at the same rate. However, when bonding dissimilar materials such as glass and aluminium, the trick is to choose an adhesive with a CTE that is somewhere in between the CTE's of the glass and the aluminium – around 4ppm for glass and 23ppm for aluminium. While it may not sound much, this can be a huge difference for large pieces.

Summary

As evidenced above, there are A LOT of things to take into account when choosing an adhesive! Like most things in life, there will be a compromise between some of these. It's usually a good idea to create a list of "must have" properties, and "nice to have" properties – it can add clarity to the choosing process. Good luck!

For more detailed information on any of these topics, e-mail enquiries@inseto.co.uk