The science of adhesion

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Ref: FFT101024

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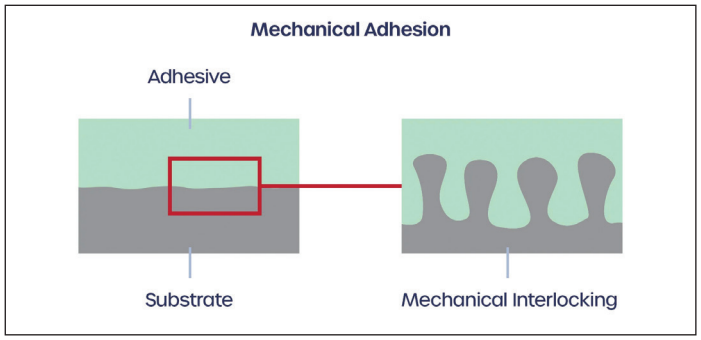
What is adhesion?

Adhesion is the bond between two different materials at the interface. In the context of adhesives, it is the bond between the adhesive itself and the substrate.

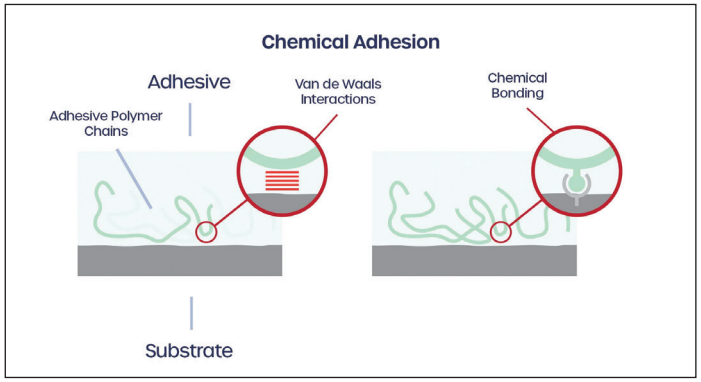
Multiple factors can impact adhesion - surface energy, contaminants and adhesive type all play a significant role in the strength of adhesion.

There are also several different types of adhesion. Mechanical adhesion is where materials are joined together by interlocking. Voids or pores are filled and the material 'hooks' itself onto the adherend. It isn't always an adhesive that forms mechanical bonds. Velcro and sewing are also examples of mechanical adhesion on a much larger scale.



Chemical adhesion is the strongest form of adhesion and it occurs when there is either an intramolecular or intermolecular interaction between the substrate and the adhesive. Intermolecular attractions are between one molecule and another.

Whereas intramolecular attractions are the forces within the molecule. In terms of strength intramolecular attractions are the strongest, but intermolecular attractions can be strong when there are a large number of them. The most common intramolecular bonds are ionic and covalent bonding. Examples of intermolecular interactions include hydrogen bonds and van der Waals.



There are other types of adhesion – electrostatic and diffusive adhesion. However, these are rarely associated with adhesives and bonding as we know it

Typically, the adhesives used to create a bonded joint will need to form a chemical bond. This type of adhesion is the strongest and most durable. Mechanical adhesion is also able to create strong durable joints. Dispersive adhesion is the aim for bonded joints that need to be removable.

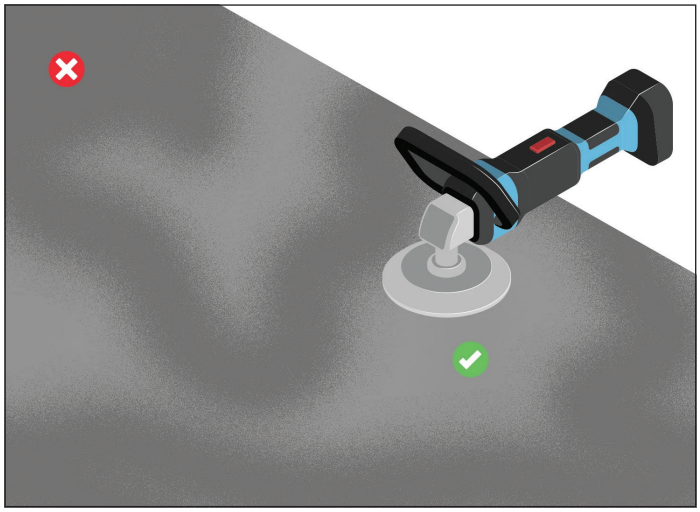
What affects adhesion between substrate and adhesive?

The correlation between adhesion and bonding is obvious. The stronger the adhesion, the stronger the bond; right? This isn't always the case. Strong adhesion doesn't necessarily mean a strong bond. Multiple factors decide a strong bond.

Nonetheless, a strong adhesion between the adhesive and the substrate will form the foundation of a strong bond and to get a strong chemical adhesion is more important still.

To begin with, the material's surface plays a big role in adhesion. Contamination can create a barrier between the adhesive and the substrate. It's important to remove any contamination to ensure a strong bond.

Abrasion can help remove contamination. It can also create pits and grooves on the surface to add an element of mechanical adhesion. But, as we explain in a separate article, abrasion isn't always consistent.



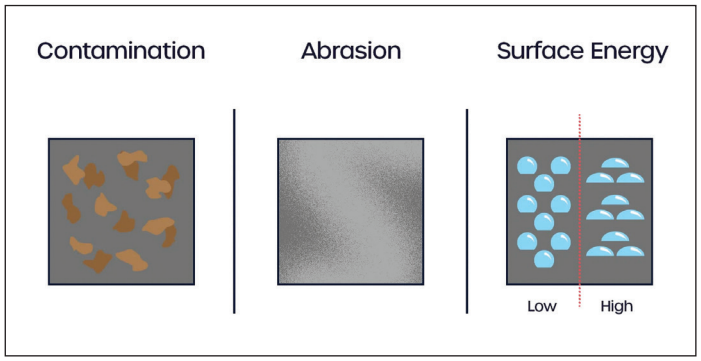
There are several other methods of surface preparation you can use to remove contamination. Abrasion is usually the 'go-to' method. Even if it isn't always the best. Regardless of contamination and abrasion, there's one thing that ultimately determines a material's ability to form a strong bond – surface energy.

Surface energy is what determines a material's tendency to attract or repel a liquid. Surface energy is measured in millijoules per square meter. Materials with lower surface energy repel liquid and make it difficult for the liquid to 'wet'. The 'wettability' of a surface describes how well a liquid spreads.

When the surface energy is low, it makes it very difficult for things to adhere to. It's ideal for items that you don't want things to stick to. It's not so ideal if you want to stick things to the material.

An adhesive needs to have a lower surface energy than the material so it can wet out and form an effective bond. Some plastic types have very low surface energy. PTFE (Teflon), polyethylene, and polypropylene are the most common plastics that have low surface energy.

In summary, three main things will affect the 'bondability' of a material; contamination, abrasion, and surface energy. The surface energy of the material will be the deciding factor. But don't forget the effect contamination and abrasion can have too.



How can good adhesion be ensured?

Now that the science behind adhesion is understood, it's time to analyse how good adhesion can be ensured. Understanding how adhesion works is a good start. Now, that knowledge needs to be applied when analysing an application. When it comes to selecting an adhesive, different adhesive chemistries will be compatible with different materials.

For example, epoxy adhesives bond very well to metal. Polyurethane adhesives will form strong bonds with wood. Acrylic adhesives have good adhesion to plastics. Some adhesives are also not compatible with certain materials. Most adhesives will struggle to bond low surface energy plastics. But apart from that, some methyl methacrylate or acrylic adhesives aren't compatible with wood due to the curing mechanism. It is also difficult to bond over the top of silicone or silicone-coated materials.

Whilst an educated guess can be made on whether an adhesive and substrate are compatible, there is never a guarantee. Testing each material is essential.

Testing material surfaces

It's also worth remembering that although some materials are generally easy to bond, different grades or different brands of metal will not have the same properties. This variation means you can't be complacent when using materials from different suppliers. When a material change is made, the adhesive must be compatible before you use it in production.

We've seen examples where a recreational vehicle manufacturer changed their supplier of GRP. They didn't test the adhesive on the new GRP. After all, isn't all GRP the same? The new grade of GRP had a very inconsistent surface. Although this didn't affect the performance of the GRP, it did affect the adhesion. In some areas, it formed a strong bond. In other areas, the GRP hadn't fully cured, leaving an incompatible surface for the adhesive. Simple surface preparation fixed the issue for the company. However, they learnt the lesson that not all materials are made equal.

Ultimately all the predictive methods in the world can be used, but the best way to ensure an adhesive and substrate are compatible is to test and there are several simple testing methods for checking the adhesion.

Will strong adhesion ensure a strong bond?

Strong adhesion is the foundation of a strong bond. But it won't guarantee that the bond will remain strong for long. The argument of adhesion vs cohesion is an important consideration at this point. From an adhesive and bonding perspective, adhesion is the strength of the bond between the adhesive and the material. Cohesion is the internal strength of the adhesive.

Both are equally important in a strong bond. But even if there is a strong adhesion with an adhesive that has high cohesive strength, it still isn't enough to guarantee a strong bond.

Other factors such as durability, impact resistance, and heat resistance are just a few factors to be considered. It's at this point that companies can get stuck. They aren't sure how to choose the right adhesive and don't know if the adhesive will survive in 'real life' conditions.

At Forgeway we've helped companies in this exact situation for over 25 years, finding the right adhesive following four simple steps. We know that the first step in finding the right adhesive is to ensure the materials are understood. Understanding the materials will help know whether it can form a strong adhesion, as well as the science behind adhesion. Strong adhesion will help form the foundations of a strong bond.