MATCHING TO MATERIALS

A basic understanding of how adhesives work is necessary to obtain the best results. Most adhesion failures can be traced to:

- Mismatch between the adhesive and the materials to be affixed
- For long-lasting applications, the mismatch between adhesive type and environmental conditions
- The mismatch between the adhesive type and the forces the bond will be subjected to during its life.
- Lack of surface preparation

This is why the selection of adhesive or sealant is so critical to success. In case of adhesive failure, observing the type of failure can help address the underlying causes: if the adhesive leaves traces on both sides of the bond (cohesive failure), the adhesive type or the curing conditions may not have been adequate. Conversely, if the adhesive leaves traces on one of the surfaces but not the other, it could have been because the adhesive is not adapted to that surface, or to unsuitable surface preparation.

To understand how adhesives work it is necessary to consider the forces that constitute the bond between the adhesive and the substrate surface and the forces that ensure that the adhesive has the necessary cohesion to hold parts together. In practice, adhesives or sealants compositions may use a combination of adhesion and cohesion forces to achieve their properties.

The other parameter to consider is the wetting properties of the adhesive.

Main types of adhesion

a. Chemical adhesion

If potentially reactive groups are present at the surface of the material, very strong covalent bonds can be formed. This is the reason why silane adhesion promoters are used in adhesives or coatings for glass or mineral surfaces rich in hydroxyl groups which chemically react with the silanes. Epoxy adhesives also contain reactive groups which can form covalent bonds with hydroxyl or acid groups on surfaces.

Ionic bonds are nearly as strong as covalent bonds and were used for example in second generation dental adhesives. The presence of organic acid groups from polyesters in an adhesive formulation will help adhesion to metals by formation of metallic salts on the surface. Unfortunately, ionic bonds are sensitive to water and for that reason these types of adhesives were abandoned in later dental adhesives generations.

The third type of chemical adhesion is based on hydrogen bonding. It is generally weaker than either covalent or ionic bonding but can still yield excellent results. Successful

bonding is based on the availability of hydroxyl groups on the interface between the adhesive and the surface and nitrogen and/or oxygen atoms. Hydrogen bonds are plentiful in animal or vegetable-based adhesives, and this is why they strongly adhere to wood and paper surfaces. However, hydrogen bonds are weakened in the presence of humidity.

b. Physical adhesion

If the surfaces glued together are porous, adhesive materials can fill the voids and mechanically lock them together. Some textile adhesives are based on this mechanism.

Molecules can carry electrical charges, and this effect is used in dispersive adhesion when the adhesive carries a charge opposite the substrate. They are named van der Waals forces. Since they are effective only at close distances, they are mainly put to use in self-adhesive tapes or labels. The advantage is that they can be easily removed or re-used.

The merging of materials at the joint is called diffusive adhesion. It occurs when the molecules constituting both the adhesive, and the substrate are soluble in each other. This type of adhesion mechanism is used to glue many plastics together. An example is a hard (unplasticized) PVC adhesive based on a solvent (often a ketone such as cyclohexanone or methyl ethyl ketone - MEK - or tetrahydrofuran - THF -) that partially swells the plastic surface, allowing the polymer molecules to diffuse in each other. This is also called a solvent weld.

Surface Wetting

Successful adhesive bonding requires that the adhesive wets (or spreads on) the surfaces to be bonded. The wettability of a surface is determined by its surface energy (force per unit area) or surface tension (force per unit length). The ability of an adhesive to wet a surface depends on its surface tension and on the cohesive forces within the liquid which causes it to ball up.

Simply put, the surface tension of the liquid adhesive must be lower than the surface tension of the material.

Metals and glass have very high surface tensions (>290 dynes/cm) while most polymers (plastics) are characterized with low (31-47 dynes/cm) to very low surface tensions in the cases of silicone (21 dynes/cm) and Teflon™ (18 dynes/com). Given that water has a surface tension intermediate between metals and plastics (73 dynes/cm) the use of water as an adhesive solvent poses special challenges (see section on solvents). This specific issue can be addressed to some extent by the addition of surfactants which lower the surface tension.

Good wetting is achieved when the surface tension of the adhesive is lower than the surface tension of the surfaces to be bonded. It explains why it is so difficult to achieve good adhesion to low surface tension materials such as polyethylene, polypropylene, silicones and polytetrafluoroethylene (Teflon™). What is sometimes required is some form of surface preparation to increase the surface chemical activity.