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Bonding

Tips & Tricks no. 2

Adhesives must bond well to their substrates. A good bond demands good wetting of the materials.

The bonding of an adhesive depends on several mechanisms:

- Boundary surface adhesion because of the energetic behaviour on the boundary surfaces
- Mechanical locking (filling up cavities in the surface of the substrate)
- Diffusion of the adhesive molecule into the substrate and vice versa
- Chemical bonding between the molecules of the substrate and those of the adhesive
- Attraction of different surface charges between substrate and coating

In all cases the presence of non-adherent or weak interlayers (e.g. dust or water or the like) on the surface of the substrate is damaging. In addition, the greatest possible contact surface (e.g. by "roughening") is, of course, also useful. One important requirement for subsequent bonding is always the wetting of the substrate by the adhesive. Only where wetting is adequate is intimate, full-surface contact possible. This means that the substrate must possess the largest possible surface energy σ_s.

The boundary surface adhesion is high if the liquid and solid surfaces are eliminated by the formation of a common boundary surface with the greatest possible gain in energy, i.e., expressed in another way, that surfaces with high surface energy are eliminated:

$$\Delta G_{\min} = \sigma_{sl} - \sigma_l - \sigma_s = -2\left(\sqrt{\sigma_l^D \cdot \sigma_s^D} + \sqrt{\sigma_l^P \cdot \sigma_s^P}\right)$$

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A mechanical anchorage can only occur if the rough structures and cavities in the surface are filled by (penetrating/liquid) adhesive, i.e. that the liquid spreads on the surface (reduced contact angle). The spreading of the liquid adhesive also hinders the formation of air bubbles on the surface of rough structures which can act as crack-initiation points.

Mutual diffusion only takes place if the liquid spreads on the surface. If the liquid is repulsed at the macroscopic level there will also be no diffusion of the molecules.

Bonding as a result of electrostatic attraction is not to be sought after since this bonding is not stable in atmospheric air. Water binds to the polar groups which are then no longer available for electrostatic bonding.

The causes of chemical bonding can be (in order of increasing efficiency):

- Van-der-Waals-forces Dispersion forces (London-Forces, induced-dipole-induced-dipole-forces)
- Debye-forces(Dipole induced dipole)
- Keesom-forces (Direct dipole-dipole interaction)
- Hydrogen bonding and
- Direct chemical bonds. (there is generally no direct correlation with the surface energy).

Pre-treatment is normally necessary to optimise adhesion. In the case of substrates of plastics and metals, plasma pre-treatment with the plasma atmospheric corona discharge, which in many industrial plants can be integrated, is recommended industrially. The pre-treatment removes loosely-bonded foreign layers, forms polar groups on the surface and increases surface energy. Which of these mechanisms is individually most responsible for the improvement in adhesion requires a special investigation in each case.

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