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Adhesives Target Hard-to-Bond Plastics

New two-part acrylic-based adhesive offers superior performance on polyolefin plastics.

By Christine Marotta, Mike Williams and Nicole Laput, Henkel Corp. -- Design News, July 20, 2010

Many modern plastics used for medical and other applications are formulated specifically for their resistance to specific chemical and environmental conditions. As a result, these substrates also tend to be difficult to chemically bond.

Bonding, however, remains the preferred joining method, particularly when dissimilar substrates are involved and/or solvent welding or mechanical fastening is not desired. Polyolefin plastics, such as polypropylene (PP) or polyethylene (PE), are the most common type of hard-to-bond plastics because of their low surface energy.

Cyanoacrylate, light-curing cyanoacrylate, hot melt and specially designed light-curing acrylic adhesives exhibit high bond strengths on typical difficult to bond substrates including PE, PP, acetal, fluoropolymers and TPVs. Source: Henkel

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Advances in adhesive chemistries and surface preparation techniques have given us the tools we need to achieve strong bonds to even the most difficult to bond polymer substrates.

Only a few industrial adhesives offer consistently high bond strengths on hard-to-bond plastics. Cyanoacrylate, light-curing cyanoacrylate, hot melt and occasionally light-curing acrylic adhesives have exhibited high bond strengths on typical difficult to bond substrates including PE, PP, acetal, fluoropolymers and elastomers called thermoplastic vulcanizates (TPVs).

Cyanoacrylate adhesives are polar, linear molecules that undergo an anionic polymerization reaction. A weak base, such as moisture, triggers the reaction causing the linear chains to form. The products are maintained in their liquid form through the addition of weak acids that act as stabilizers.

A wide variety of cyanoacrylate formulations (which form thermoplastic resins when cured) are available with varying viscosities, cure times, strength properties and temperature resistance.

Standard unfilled ethyl monomer-based cyanoacrylates typically exhibit low impact and peel strengths, low to moderate solvent resistance and maximum operating temperatures of 160 to 180 F. They are known for their ability to fixture in as little as three sec.

Rubber-modified cyanoacrylate formulations offer greatly improved peel and impact strengths over standard cyanoacrylates. The compounded rubber added to ethyl formulations does slightly increase fixture time to 30 sec to two minutes.

Blooming Issues

"Blooming" or "frosting" is the presence of a white haze around a bond line. A selection of cyanoacrylate adhesives offer monomers with a higher molecular weight and lower vapor pressure, which minimizes blooming/frosting. The change in monomer can affect the adhesive's cure speed, physical properties, and operating temperatures.

Thermally resistant ethyl cyanoacrylates can withstand continuous exposure to test temperatures up to 250 F. Available in both black and clear versions, these modified, toughened cyanoacrylate products also have increased fixture times.

Although light-curing acrylics do not offer the significant performance strength of cyanoacrylates on hard-to-bond substrates, they do offer moderate performance on several of the cited plastics including acetal and polyethylene.

Light-curing acrylics cure via a free radical reaction to form thermoset resins when exposed to light of the appropriate wavelength and intensity. Like cyanoacrylates, light-curing acrylic adhesives are available in a wide range of viscosities from low (~ 50 cP) to thixotropic gels. In addition, light-curing adhesives vary in final cured form from hard and glass-like to soft and flexible resins.

With these adhesives, light must reach the entire bond line in order to achieve full cure. Any adhesive remaining in shadowed areas will remain liquid. Light-curing acrylics fixture rapidly and cure in as little as 5 sec following light exposure. Because the final resins are thermoset plastics, light-curing acrylics offer enhanced thermal, chemical and environmental resistance over cyanoacrylate adhesives.

Surface Preparation

In order to enhance adhesion, materials designated as hard-to-bond require surface preparation prior to joining. Surface preparation methods for hard-to-bond plastics include both chemical and physical treatments designed to increase reactivity and roughness on the surface of the substrate. Common methods include plasma or corona treatment, flame treatment, chemical etching or surface priming.

Plasma treatment is used on a wide variety of substrates including polyolefins and polyester. A gas such as oxygen, argon, helium, or air is excited at low pressure, resulting in the production of free radicals. One of the major drawbacks with plasma treatment is its potentially short shelf life. Most substrates treated with plasma must be assembled within a very short period of time since the reactive surface is re-exposed to air and rapidly reverts back to its normal state.

Plasma treatment is frequently used with cyanoacrylate, light curing acrylic and light curing cyanoacrylate adhesive technologies. Since each plasma gas imparts different characteristics onto a substrate, end-users should consult their adhesive and substrate suppliers to determine the optimum gas for the materials used.

Similar to plasma treatment, corona discharge uses ionization of a gas to effect surface reactivity and roughness. Reactive groups such as carbonyls, hydroxyls, hydroperoxides, aldehydes, ethers or esters are introduced to the surface. Corona discharge has a limited shelf life and requires parts to be assembled in a limited time period. Corona discharge is commonly used on polyolefin substrates. Both plasma and corona treatment require an investment in capital equipment or outsourcing of treatment.

Chemical treatment methods such as chromic acid etching are often used on polyolefins and acetals. Like other surface treatment methods, chromic acid etching adds reactive species to a surface. Because it can be hazardous, chemical treatment is used on a limited basis to treat a variety of substrates prior to bonding with cyanoacrylate and light curing acrylic adhesives.

In flame treatment, various reactive groups such as hydroxyls, carbonyls and carboxyls are introduced to bonding surfaces through an oxidation reaction when the substrate is exposed to flame. In addition, flame treatment lowers the surface energy of the substrate surface, allowing for better wetting. Flame treatment is commonly used on polyolefins and polyacetals, and is most frequently used when bonding with cyanoacrylate adhesives.

Surface roughening results in mechanical interlocking sites and causes bond strength to increase dramatically. A surface roughness of approximately 63-125 micro-inches is often used as a guideline for assemblies that are to be bonded with adhesives. Surface roughening will significantly increase the bond strength of most adhesive technologies, and is highly recommended for both hard-to-bond and traditional substrates.

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