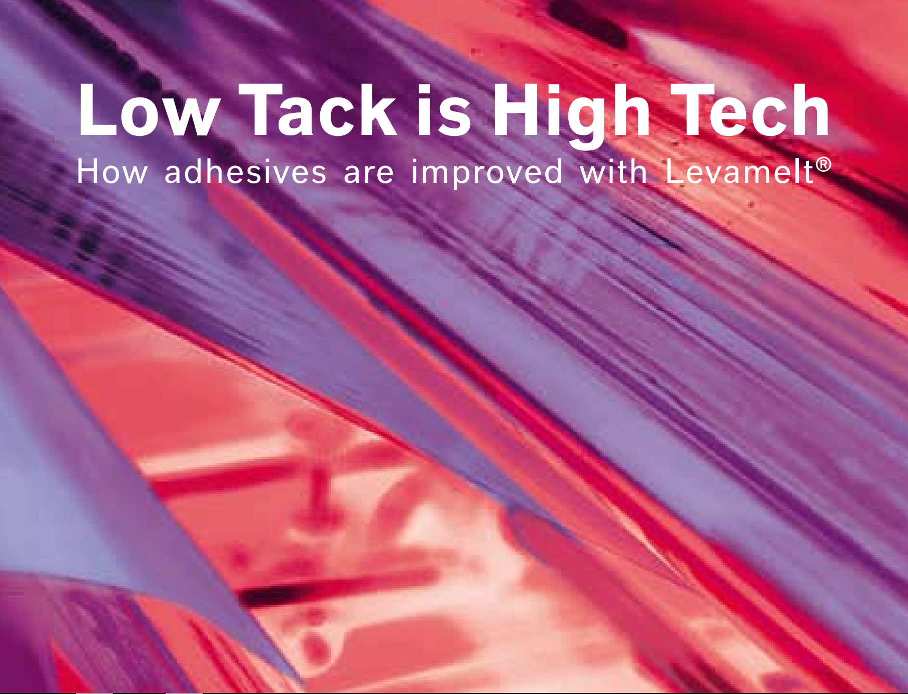
Low Tack is High Tech

How adhesives are improved with Levamelt®



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How adhesives are improved

Hardly anything is possible today in engineering without adhesives. They are even competing with rivets and screws. Cars and airplanes are now built with the smart joining technology of "bonding." But the success of adhesives stands and falls with the development of appropriate raw materials tailored to their substrates in the best way possible. Rubber and glass are as different as night and day in this regard.

Engineers have developed ultra-strong adhesives that hold even steel girders together, but now there is increasing demand for products that are intended to bond only temporarily and can then be removed without leaving any residue behind. These days, anyone can make adhesives stick. The challenges now faced by chemists tend to be found on the other end of the adhesion scale — in letting go again. "Low Tack is High Tech": this slogan summarizes the latest research efforts of LANXESS in this field.

LANXESS Bonding Agents

What the experts are working on

When it comes to adhesives, you're in good hands with Michael Herrmann. Not because his desks is buckling under the weight of adhesive strip dispensers and their drawers are overflowing with tubes of glue. But instead because the chemist knows a good deal about the materials and forces that make things all over the world bond, stick, and adhere. Herrmann is adhesive experts at LANXESS. He is the "LANXESS bonding agents" as it were. Here, we're talking not about the adhesives themselves, but the people who work with them.

Compared to all the things that adhesives accomplish today, however, Herrmann's responsibility seems rather modest. His job is to develop adhesives for labels and films that can be detached again after they are stuck on. "But that only seems to be an easy job," says Herrmann, the molecule juggler. Indeed, the unhappy remains of billions of adhesive labels on cars, lamp posts, knapsacks and refrigerators are proof that it is anything but easy to get rid of old

stickers. Removing tattoos is sometimes easier. “At the same time, the demand for stickers that can be removed without residue is constantly growing,” says Herrmann. “There is great interest in this in the consumer goods industry, for example, to protect displays or other sensitive surfaces against scratches and fingerprints on the way to the customer.”

This is becoming increasingly important, because beautiful, glossy surfaces make even everyday products interesting again for customers. Retailers and advertising experts are also urgently calling for innovative, “gentle” adhesives: “Naturally, labels that announce special sales shouldn’t leave any traces on the merchandise or the advertising medium,” says Herrmann. Developing the right adhesives for this is indeed anything but easy. “There’s now no shortage of ultra-strong adhesives,” says Herrmann. “The trick is now to develop adhesives that don’t hold forever but instead bond only when and as long as necessary.”

“Low Tack is High Tech” is the slogan embraced by LANXESS – long a premium supplier of high-performance raw materials for the adhesives industry – in its search for tailored, “just-for-now” adhe-

sives. And rightly so. “There are several reasons why some stickers are difficult to remove after being used,” says Michael Herrmann. “For one thing, the adhesive properties of some polymers change with time. There are adhesives that bond significantly better after years than at the beginning.”

In addition, substances can sometimes migrate from the adhesive layer into the substrate and change it, in which case one is sometimes left with ugly spots on the knapsack, although the sticker is long gone. “But the most important reason for ugly residues is that, in the past, adhesive films often used adhesives that were supposed to be ‘universal’ – usable somehow on every surface but not optimally formulated for any of them. But we now know that there is no such thing as a universal glue,” says Herrmann. “The reckoning comes at the latest when the sticker is removed again.”

And it so happens that an adhesive that can easily be removed from steel, for example, can stick to plastic surfaces like a barnacle on an old ship’s hull. In extreme cases, there is then only one thing to do: take out the scraper and scrape away – and, if worst comes to worst, ruin the sensitive surface beneath at the same time. “This

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effect is caused by a property that we call surface energy or surface tension," says Herrmann.

Surface tension? As it happens, the data for surface tension can be looked up in tables: for Teflon®, it's very low, for polypropylene somewhat higher, polycarbonate higher still, and metals like iron or copper have a surface tension almost a hundred times greater. The phenomenon behind this concept can be described in tangled formulas and demonstrated with diagrams. In greatly simplified terms, one can also say: substances that have similar surface tensions bond very well to one another and those with differing surface tensions not so well. "Birds of a feather flock together," says Herrmann.

Those who prefer a less debased explanation are free to seek the cause of this effect in the "polarity" of the surfaces. Oils are non-polar; water is polar. This is why one can easily mix olive oil and sunflower oil but not oil and water. The more "oil-like" a surface behaves – this is the case with synthetics like polypropylene, for example – the less polar it is. The more water-like – for example glass and metals – the more polar.

The Levamelt® family

Building blocks ensure flexibility

"The trick is quite simply to develop an adhesive raw material that is polar or non-polar, as needed, so that one can tailor it to the substrate surface as well as possible," says Herrmann. And LANXESS has precisely such a material in its product range: Levamelt®.

Strictly speaking, Levamelt® consists not of one raw material but of several. "The special feature is that we intentionally assemble the material from two molecular components: one is polar, the other non-polar. LANXESS is the only manufacturer in the world able to operate an innovative production process enabling both of these components to be mixed in almost any proportions."
The results are polymers – rubbers – that come out of the reactor polar or non-polar as needed. Or with surface tensions somewhere in between the two. And they can be mixed – in any proportions and even with other raw materials for adhesives. "In this way we can develop adhesives with polarities matched exactly to the surfaces to which they are to adhere," says Herrmann.

There's another side-effect too. Due to the different contents of polar components, the different types of Levamelt® also have different glass transition temperatures. The term really does mean what it says. The less polar the material is, the less brittle it is too. That's why corresponding types of Levamelt® remain flexible at low temperatures, paving the way for freezer labels and winter-proof car stickers. And talking about winter-proof: as Levamelt®, on top of everything else, is made up of especially robust molecules which are largely resistant to the attacks of UV light and aggressive gases, it's also resistant to aging. Months exposed to wind and weather hardly affect it. Stability is guaranteed.

But if it's almost entirely a question of polarity, why not use completely different adhesives from the word go? Acrylates, for example, are also polar, natural rubber is non-polar. "Because the work is much easier when only one family of materials is involved. The processing steps from adhesive raw material to the adhesive itself are essentially the same for all types of Levamelt®. We see our Levamelt® product family as almost a type of building-block system for adhesives."

This system of building blocks is currently catching on across a broad front in the sector – and Levamelt® is growing strongly with it. “Made-to-measure polarity doesn’t just mean maximum adhesion – it can also offer the opposite. If the polarity of a raw material for an adhesive is chosen so that the adhesion to the substrate is low, then you have exactly what industry is looking for – adhesives that only hold as long as is wanted,” explains Herrmann. For example, Levamelt® can be used to manufacture an adhesive foil that will stick to fresh car paints, yet can be removed without problems as soon as the transport along the dusty highway has ended at the showroom. “It’s also noticeable here that manufacturing adhesives on the basis of Levamelt® frequently doesn’t require plasticizers, which could damage the paint.”

Also possible are sticking plasters that can be removed without screams. Or stickers that adhere to plastic and metal surfaces, resist wind and weather over weeks, and still can be removed without difficulty, as if they were just resting there.

Another advantage for the manufacturers of such foils is that Levamelt® is a genuine synthetic rubber, and so can be processed

like any other foil material. “That makes the production of the stickers very much easier,” says Herrmann. “Instead of first producing a foil that then has to be coated with the adhesive in a difficult process, Levamelt® is just another of the many materials fed into a plant for manufacturing perfectly ordinary multi-layer foils.

To stick polar types of Levamelt® in particular to non-polar substrate materials such as polypropylene, the adhesives experts must, however, utilize an intermediate layer of another material that binds adhesive and substrate together. “Technically that’s not a problem” says Herrmann. “Packaging foils of up to nine layers have long been the norm. One more layer doesn’t make any difference.” On the contrary, the structure of substrate, intermediate and adhesive is also responsible for the fact that such foils can be wound into rolls – if Levamelt® adhered directly to the substrate, the user wouldn’t be able to pull the foil off the roll.

Classic self-adhesive tapes solve this problem by coating the back of the foil with a layer that repels the adhesive – which is not exactly the cheapest technological solution.

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The latest coup from the LANXESS adhesives experts is in collaboration with the development partner Sattler/Siegling: it's an ultra-robust printable and fiber-reinforced foil that can not only be easily peeled off plastic surfaces once the job has been done, but can also be reused, again and again. "If the adhesive layer gets dirty, it can simply be wiped clean with a damp rag," explains Herrmann.

Lemonade on offer once a month? That's no problem – Get out the stickers, wash them off again later and back into the store until the next time. It can be that easy. And it's sustainable too.

Will it stick?

What sticks? And why?

Dateline Stone Age: the long hunt is over, the deer speared, and the camp smells of roast meat and cooking smoke. The feast is over, but the hunters are still sitting together, and looking at their tools. Things have been lost and damaged before and during the hunt – the ax is broken, new arrows are needed, and the women are bringing broken pots. That would be no problem today, just get out the tube of glue and you're done. But 40,000 years ago?

"Of course, we really know very little about the technologies our ancestors used to make and maintain their tools," says Michael Herrmann, a chemist at LANXESS. "But they did know more than many people today believe. For example, when they wanted to join the two parts of an ax together, they were capable of a lot more than just winding and tying vines or hemp around it, like you see in the comics." In fact, our forefathers already had some remarkable technologies in their toolkit. For example, adhesives.

The stone-age adhesive was birch pitch. A black, viscous fluid that is produced by heating birch bark in a closed container. Exactly how the stone-age chemists manufactured their adhesive is still the subject of discussion among contemporary experts. But it worked. That is shown by the numerous black traces, for example on arrowheads and tools.

And as far as their choice of materials is concerned, the stone-age people were also not as primitive as is often thought. Joining using adhesives is still high technology today. In 2003, no less than 9.2 million tons of adhesive were used. “These products are all around us,” says Herrmann. He looks around his office in Leverkusen “The carpet is glued. Shoe soles, books, the different layers of the foil in the milk carton – they’re all glued. And more: the wallpaper, parts of the coffee machine, the TV, the windows, the laminate floor, the scratchproof surface of the desk – practically everything is held together with adhesives. The mortar in our walls is also a type of adhesive. Even organs don’t have to be sutured nowadays, as adhesives – albeit very special ones – have also made their way into the operating theater.

Parts of car bodies too – and even aircraft tails – are held together by adhesives. Ultra-light sandwich materials – which haven't been restricted to NASA voyages for a long time – would be unthinkable without them. "The advantages of today's adhesives are considerable," says Herrmann. "We can use them to join securely not only completely different materials – including those that are almost impossible to hold together with screws or rivets – such as metals and insulating materials. But we have also the additional advantage that adhesively joined components are better able to resist certain types of stress."

For example, adhesives versus rivets. Pulling on two pieces of sheet metal which are riveted to one another results in the force working point-like on the bolts. The force is concentrated over an area of a few square millimeters – and sooner or later, something gives. The first bolt breaks, the force on those remaining increases suddenly, and snap – that's it. But it's a different story when the parts are also glued. "In components joined using adhesives, the forces are distributed over the entire surface," explains Herrmann. And if you use adhesives intelligently, you can save a few rivets too.

Spot welds can also be replaced by the intelligent use of adhesives. That's why the welding robots in the car industry have less to do nowadays than they used to. Moreover, the combination of rivets and adhesive also protects components against material failure due to high shear stresses, i.e. loads that run parallel to the direction of adhesion in the component. Rivets alone have never stood a chance in this kind of situation.

However, no-one nowadays is smearing birch pitch on the surfaces to be joined. They're not even necessarily using the adhesives that came into use in the middle ages – animal glue, fish glue, potato starch or gelatin and so on. Even though today, around 18% of all adhesives used are based on natural materials. The remaining proportions are made up of a whole zoo of synthetic materials. Because one raw material alone is not enough.

The reason is: "As different as the substrates may be, the adhesives must, of course, be just as different," explains Herrmann. "The fried egg will stick to an iron pan, for example, but not to one coated with Teflon®."

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The science behind it all

How the adhesive molecules work

No-one would sit down in a Jumbo jet with a tail stuck together using handicraft glue. On the other hand, a high-technology adhesive developed to permanently bond glass to steel would be rather overqualified for sticking together the wrapping on the Christmas presents. As well as being far too expensive.

What makes the job of an adhesives expert so tricky is that lots of things have come along since the stone age. Yet the toolbox of modern raw materials for adhesives certainly hasn't been filled to overflowing. Only around a dozen plastics have established themselves as technically meaningful – from workhorses like poly-acrylates and synthetic rubbers to exotics such as silicones and so-called polysulfides. But they all work in much the same way. "The important thing about a glue is that it sticks. It also has to demonstrate good internal strength," says Herrmann. Specialists refer to these two vital properties as adhesion – sticking power – and cohesion – the ability to hold together.

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After all, what use is a material that sticks like chewing gum, but breaks in the middle as soon as it is subjected to a load? To put it another way, if you're gluing wood, it makes sense to use an adhesive that's stronger than rice paper.

Many materials have the inner strengths required for these applications. "The range from which we can choose is, however, further limited by the fact that we have to be able to apply these substances," says Herrmann. "Even if they bind unbreakably after adhesion, they must at least be viscous liquids when we want to apply them."

Anyone who has tried to stick something onto a surface has a restricted range of possibilities. Two, in fact, the first one is physical. Take long, thread-shaped molecules that get tangled up in the countless irregularities that can be seen, even on smooth surfaces, under the microscope – the Velcro principle. Hot-melt glues, for example, rely on this principle. They are composed of plastics that are solid at normal temperatures and liquefy at relatively low temperatures.

Instead of melting the adhesive, you can, of course, dissolve the important long molecules in liquids – solvents, or even water. The result is the same. Once the solvent has dried, the previously mobile molecules are left stranded on the microscopically fine peaks of the substrate. Voilà – it sticks.

Natural adhesives too, function by getting tangled up. Animal glue, for example, contains long protein molecules that catch on surface details. In potato starch, the long chain molecules are carbohydrates.

The second gluing method is the chemical. You take molecules that react directly with those of the surface. Most materials have points on their surfaces which are hungry for reaction partners – so they are ideal points of attachment for so-called reactive adhesives. That's how polyurethanes and some superglues work. They form permanent bonds with the surfaces, regardless of whether they be glass, metal, or wood.

Other adhesives attach to the substrate by means of electrostatic forces – more like fluff to a feather duster – but because even a

milligram of adhesive contains many billions of molecules, the result adds up to a force of considerable strength and a solid join. That's how even water can get sticky. If two panes of glass are laid one on top of the other, it's easy enough to lift off the top one. But if you put just a few drops of water between them, the panes will stick to one another as if they were nailed. The only way to separate them is to slide one off the other.

However, what sounds inspirational at first hearing runs into significant obstacles in practice. Because the problems, as ever, lie in the details. First of all, the universal adhesive just doesn't exist. Solvent-based adhesives make a sorry mess of polystyrene tiles, for example, if the wrong tube is used.

And liquid adhesive doesn't help at all when the substrate is too absorbent. In such a case, exactly the right viscosity is needed. Brittle glues wouldn't last long on an elastic base – over time even the strongest adhesive power wouldn't help here. And there's no sense in sticking labels on deep-frozen goods if the adhesive embrittles at low temperatures.

“Furthermore, adhesives experts have long distinguished between immediate and long-term adhesion. For example, it can be the case that an adhesive is immovably attached after a couple of days, yet immediately after application, has no more adhesive strength than sticky tape on a wool pullover. The adhesive must be optimally designed for the substrates and the task of joining,” explains Herrmann.

Tailored for the substrate. The chemist’s job is not only to look for polymers that distinguish themselves with good scores in both the areas of adhesion and cohesion, but also to bring these into a form that is easy to process and prepare them for their job with all kinds of additives. Extremely brittle adhesives, for example, can be made softer by mixing mineral oil with them. Or too fluid adhesives can, in contrast, have fillers added to make them more viscous. And superglues that take a while to build up their adhesive strength can have so-called tackifiers added. These are substances that stick immediately like flypaper and bridge the time until the “real” adhesive has hardened.

But all that is just a part of the story. “You always have to keep a

whole lot in mind," says Herrmann, "because there's always plenty that can go wrong." If the adhesive is intended for exterior use, for example, it must be resistant to UV light. Otherwise it will become brittle, like some adhesive strips that let the notes drop from the fridge door like leaves in the fall.

"The researcher's spirit is always needed here," says Michael Herrmann. Even when gluing is an ancient technique, it's still a high technology.

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Everything about Levamelt®

For detailed information about the possibilities and advantages of Levamelt®, please contact

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