RESEARCH NEWS

Solvent-free adhesives

Eco-friendly formulations based on vegetable oils

There is an increasing demand for green products, but for them to be genuinely sustainable, manufacturers must also use adhesives and paints that are made of bio-based feedstocks. Advanced materials developed in Fraunhofer labs point the way forward.

Demand for organic products is booming. Factory farms and fields drenched in chemical cocktails hold little appeal for the many consumers who prefer to see free-ranging animals in verdant pastures, eat untreated fruit and vegetables and wear clothes made of organically grown, pesticide-free cotton. It is not enough, however, merely to replace plastic with natural materials such as wood or cork. For products to be genuinely sustainable, manufacturers must also use adhesives and paints that are made of bio-based raw materials.

Most legacy adhesives are made of petroleum-based thermosetting epoxy resins. These are synthetic resins that hold their shape once they have been heated. Monomers are the building blocks of epoxy resins. A curing agent or hardener causes the individual molecules to bind, creating a solid plastic that will not melt. Additives serve to fine-tune the properties to suit the given application. For example, pigments can be added to color the resin, and other additives are used for flameproofing or to make the plastic easier to process.

Vegetable oil epoxides with natural additives

Yet it is also possible to produce epoxy resins from environmentally friendly materials. One new approach is showing promise – vegetable oil epoxides, an organic version of conventional epoxy resins. They are sourced from vegetable oils containing a high proportion of unsaturated fatty acids. These fatty acids are epoxidized; that is, linked with a trivalent compound consisting of two carbon atoms and one oxygen atom. Combining these vegetable oil epoxides with hardeners produces remarkably resilient plastics. And with that, sustainable adhesives, coatings and even foam resins are looking to be viable options. But the chemical composition of raw materials extracted from the seeds of oleaginous plants may vary greatly. And that variance is a problem for manufacturers.

Editorial Notes
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Eco-friendly adhesives with ideal properties

Researchers at the Fraunhofer Institute for Microstructure of Materials and Systems IMWS set out to tackle this problem by probing the properties of newly developed biogenic resins. This is a penetrating analysis: "We are investigating these resins from the micro to the macro level," says Andreas Krombholz, group leader at IMWS. The first step is to determine how variations in the composition of the feedstock affects the resins. Once the IMWS team has solved that puzzle, they can start enhancing and adapting the resins to the given processing methods.

Fraunhofer scientists are also using vegetable oil epoxides to develop novel adhesives. All formulations for these adhesives from the Fraunhofer labs are solvent-free. The researchers are digging deeper to learn which fillers and additives can be used to deliver specific properties. High electrical conductivity, for example, comes in handy. If an adhesive layer is conductive, it can be heated from the inside out by applying an electrical voltage, thereby quickly and selectively curing it. Or an additive such as modified thyme oil could endow the adhesive with antibacterial properties.

Conversion from epoxidation to enzyme treatment

The use of vegetable oil epoxides increases the organic content of these adhesives to 86 percent, because the materials contain a high percentage of vegetable oil and the hardening agent is based on organic substances rather than petroleum derivatives. By comparison: to qualify as a sustainable material, at least 35 percent of its ingredients must be sourced from renewable sources. "Together with the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, we switched from epoxidation to a novel enzyme-based process. This means we can process vegetable oils without using petrochemicals. The treatment with enzymes takes place at 40 degrees Celsius rather than 100 degrees Celsius as in the past, so we are also conserving energy," adds Krombholz. The benefits do not end there. Industrial users in Europe had sourced the linseed oil for vegetable oil epoxides from Canada, which is not exactly eco-friendly considering the distance it has to travel. Fraunhofer scientists adapted the process to use an essential oil derived from the Moldavian dragonhead plant, grown organically in Germany, rather than imported linseed oil. This reduces the carbon footprint even further. On top of that, the researchers found an environmentally sound replacement for the previously highly toxic hardener.

Picture 1: Two metal parts joined using the new, sustainably produced adhesive. Behind them: three pots containing the ingredients of the adhesive – the liquid hardener (yellow), the paste hardener (white) and the lignin organic solvent (black).

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Picture 2: Powdered lignin and linseed. Behind them: three pots containing the ingredients of the adhesive – the liquid hardener (yellow), the paste hardener (white) and the lignin organic solvent (black).

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Picture 3: Assessing the measurement curve and determining the tensile shear strength.

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