New lignin based material to replace fossil plastics and adhesives

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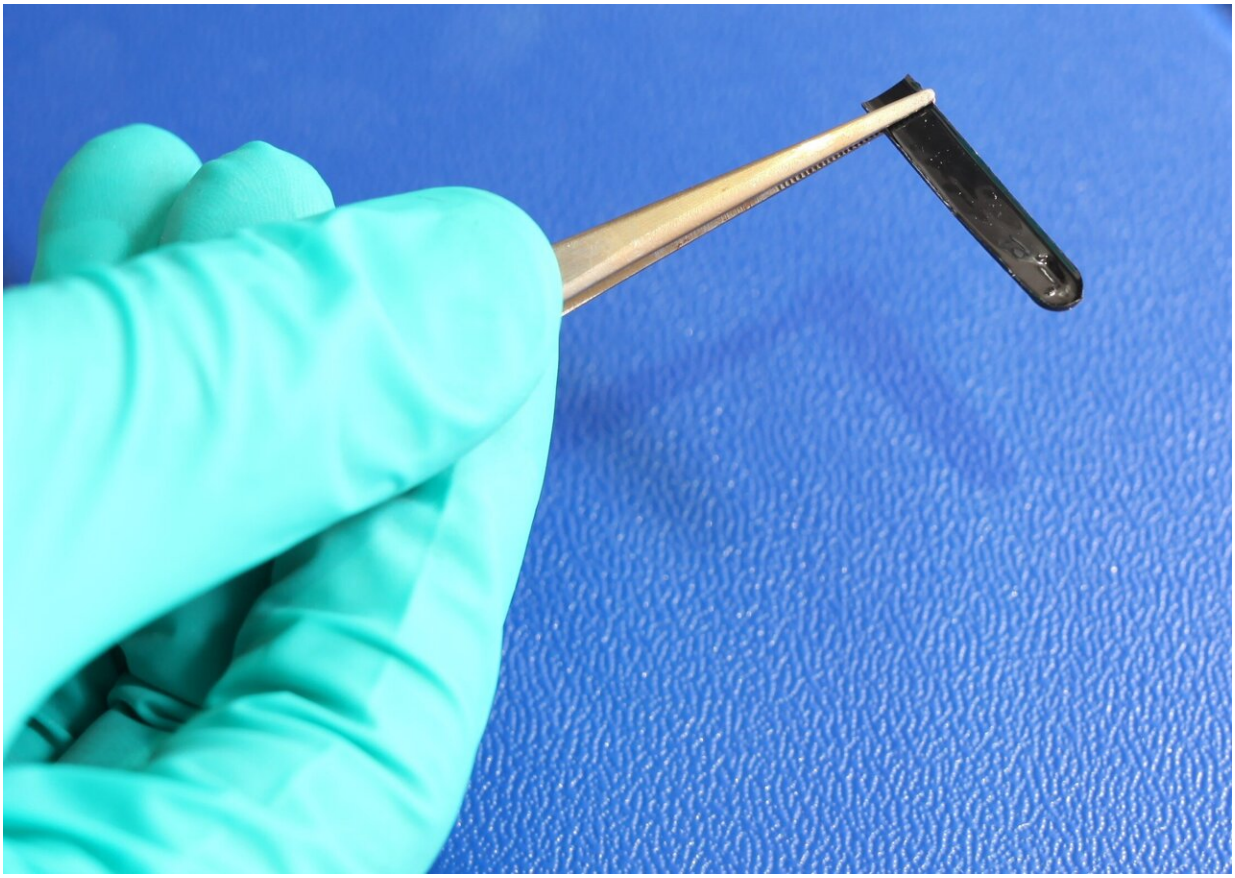

The new lignin based material. Credit: Mika Sipponen

Researchers at Stockholm University have developed a resource-efficient method to produce new lignin-based materials that can be

thermally reprocessed and used to substitute thermosetting resins and adhesives.

Modern societies need to find alternatives to materials that are derived from fossil oil and gas resources. In parallel, there is an urgent need to develop enabling technologies for a transition to a sustainable circular economy. For example, thermosetting resins offer robust performance in today's demanding applications, but unfortunately these synthetic plastics cannot be readily recycled.

Researchers at Stockholm University have developed a resource-efficient method to produce a material that behaves like thermosets but can be thermally reprocessed. The team used lignin as the renewable raw material in a catalyst-free reaction with a non-toxic chemical derived from ethylene glycol. Lignin is a by-product from the pulp and paper industry, where it is mainly burned to recover chemicals and heat. However, there is a strong push to use lignin as a building block for new value-added materials that serve as carbon stocks during their lifetime.

"We were amazed by the performance of the new materials, and one of the striking aspects of our results is the simplicity and material-efficiency of the synthetic process. In contrast to earlier examples we do not need any chemical modification or fractionation of the lignin but can simply cook it with the cross-linker in a one-pot reaction," Dr. Adrian Moreno at Stockholm University and one of the researchers behind the study, clarifies. The result is a black and plastic-like material that could be casted to various shapes using conventional technology such as injection molding.

The new lignin-based materials can be used several times, which is central to future's circular materials. To demonstrate this, the researchers measured mechanical strength of the pristine material as such and again from the same material that was reprocesses from the fractured sample.

The mechanical strength was comparable to that of engineered plastics and remained unchanged after the reprocessing.

Showing the new lignin based material. Credit: Mika Sipponen

From single use to recoverable adhesives

The scientists also discovered that the material performance could be tailored from hard and brittle to soft and tough simply by changing the amount of lignin used in the formulation. "The ability to tune the material properties opens many opportunities to commercial applications. For example, the formulation containing 50 percent of

lignin by weight is an excellent adhesive for several types of soft and hard materials," says Mohammad Morsali, Ph.D. student at Stockholm University and one of the authors of the article. "It is possible to recover the adhesive or simply detach the material and glue it again at mild temperatures comparable to those that are used in the kitchen oven."

Lignin is one of the nature's wonder materials that only recently has attracted attention as a candidate for advanced materials. "This is an excellent demonstration of the possibilities that lignin holds as a valuable feedstock. The material that we developed is perfectly in line with the current move towards sustainable circular materials. Owing to its design consisting of so-called dynamic covalent bonds, the material can be formed over and over again by relatively mild heating," Assistant Professor Mika Sipponen explains.

The research has been published in *ACS Applied Materials & Interfaces*.

More information: Adrian Moreno et al, Catalyst-Free Synthesis of Lignin Vitrimers with Tunable Mechanical Properties: Circular Polymers and Recoverable Adhesives, *ACS Applied Materials & Interfaces* (2021). DOI: 10.1021/acsami.1c17412

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