Reducing Environmental Footprint with Bio-based Epoxy Resins

Composites in Automotive – Bangkok 2017
4th July 2017

EPICEROL®

Sustainability begins at the source

Epicerol® is manufactured by Advanced Biochemical (Thailand) Co. Ltd., or ABT

- ABT is owned by **Vinythai Public Company Limited**, a leading chlor-alkali and PVC producer

VINYTHAI
AGC Group

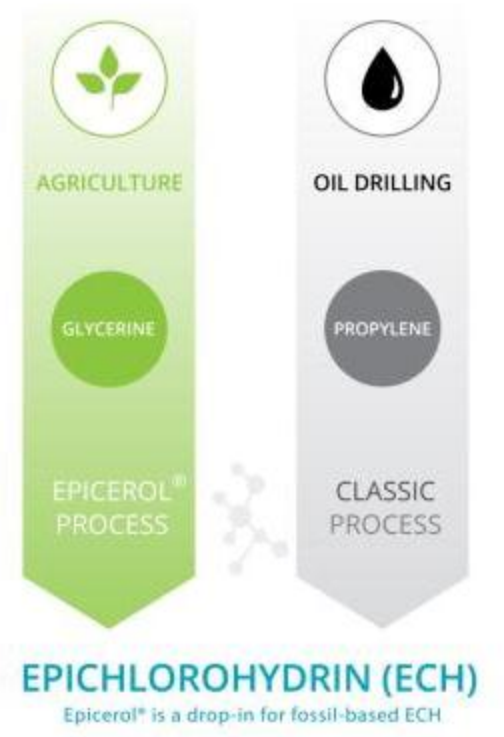
VINYTHAI SHAREHOLDING STRUCTURE	
AGC	*58.9%*
ptt GLOBAL CHEMICAL	*24.9%*
ตลาดหลักทรัพย์แห่งประเทศไทย The Stock Exchange of Thailand	*16.2%*

- ABT operates **the world-scale Epicerol® plant** (100 KT/y) in Map Ta Phut industrial estate, since February 2012

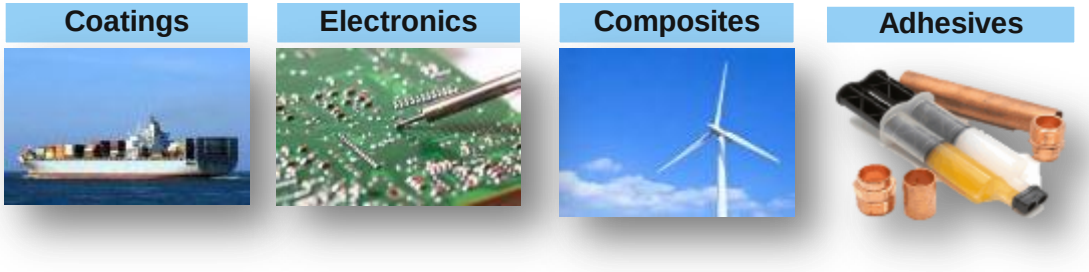
- ABT has been certified by **Roundtable on Sustainable Biomaterials (RSB)**

CERTIFIED BY RSB
Roundtable on Sustainable Biomaterials
www.rsb.org

Epicerol®: Bio-based Epichlorohydrin (ECH) competitive drop-in for propylene-based ECH

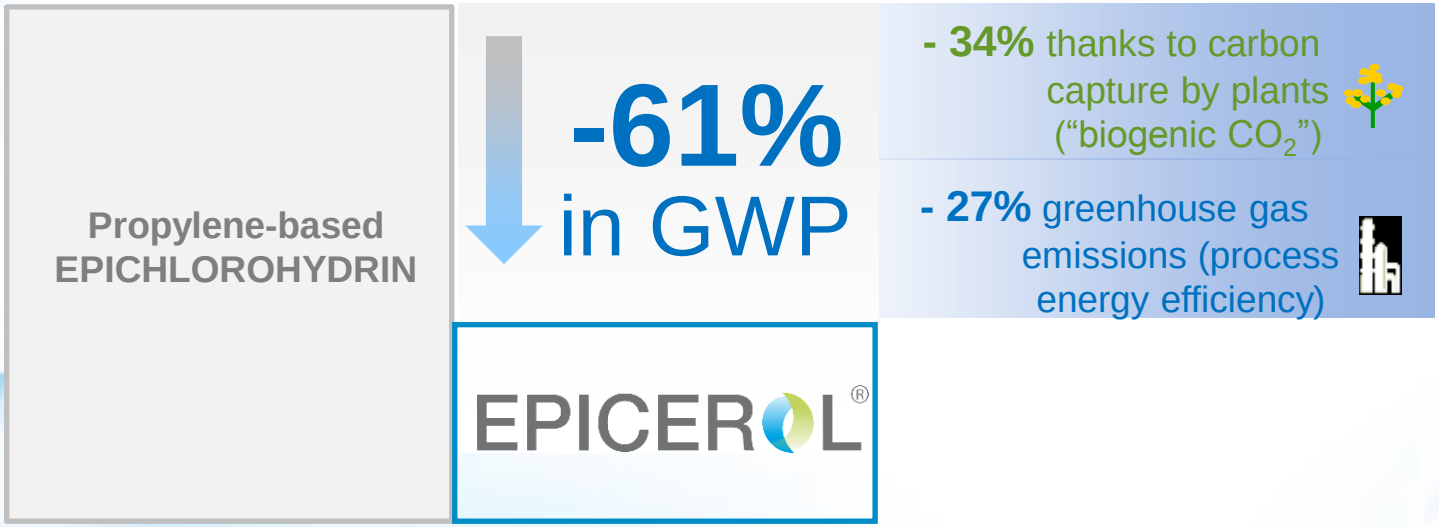


- **Epicerol® is bio-based epichlorohydrin produced using *an innovative and patented technology,* based on *natural and renewable glycerine* instead of propylene, a fossil fuel derivative**
- **Glycerol is a *by-product of biodiesel and oleochemicals*, manufactured through the transformation of vegetable oils**
- **Epichlorohydrin is a *chemical intermediate* mainly consumed in the production of *epoxy resins* for:**



- **Other epichlorohydrin derivatives include *surfactants for home & personal care, water treatment and paper chemicals***

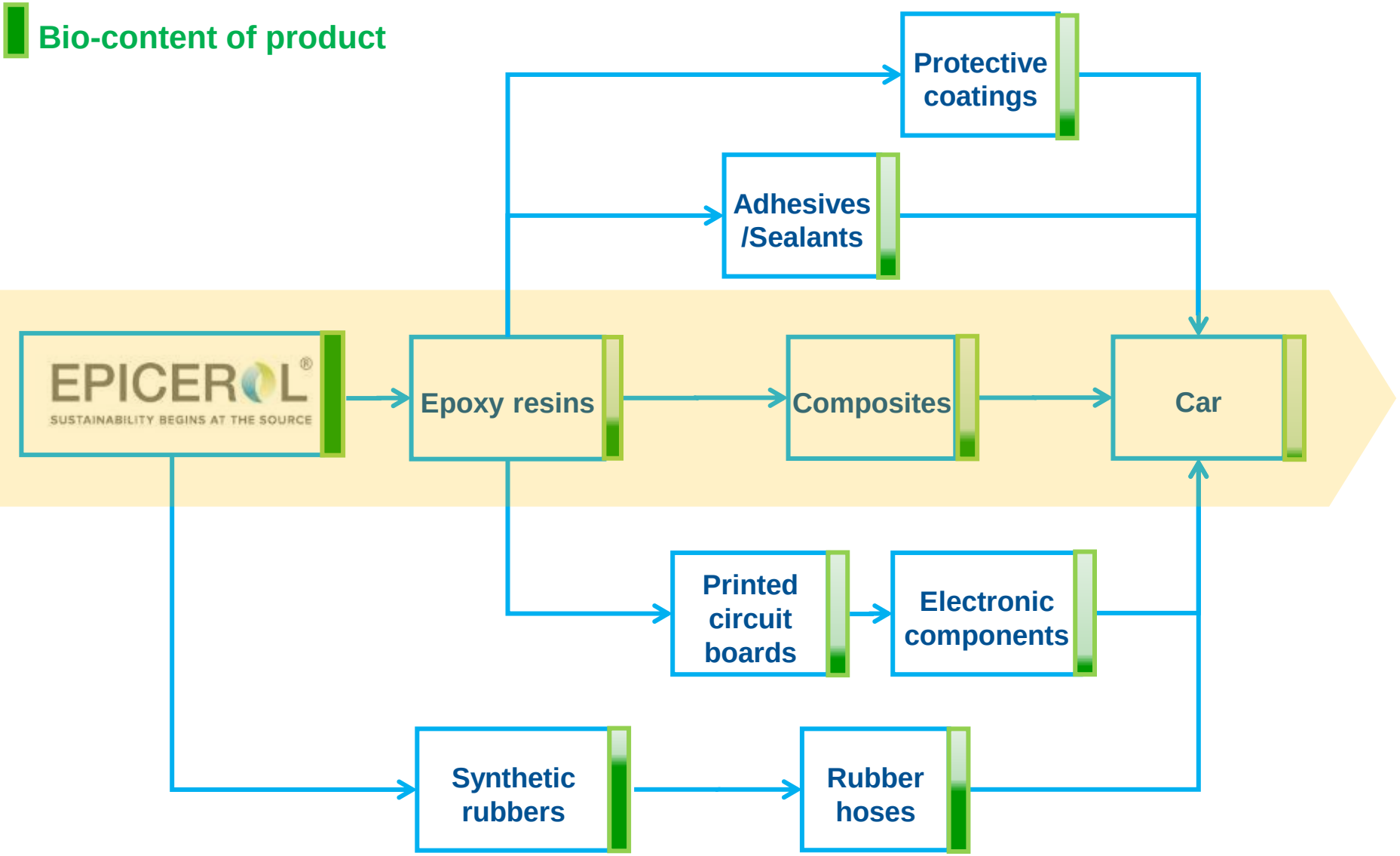
Epicerol® helps downstream users
reach their environmental goals



For each kg Epicerol® consumed (vs. oil-based ECH)
carbon footprint is reduced by 2.56 kg CO_2 eq.*

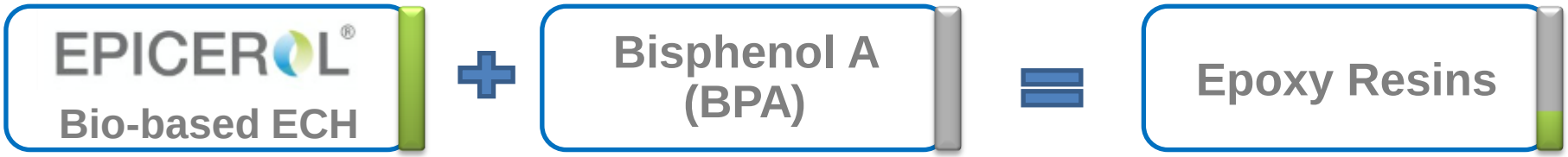
*** Defined as the global warming potential (GWP) from cradle to gate incl. biogenic CO_2 capture**

Epicerol® Value Chain in the Automotive Industry



Potential of Bio-based Epoxy Resins

*** ABT welcome for co-development**

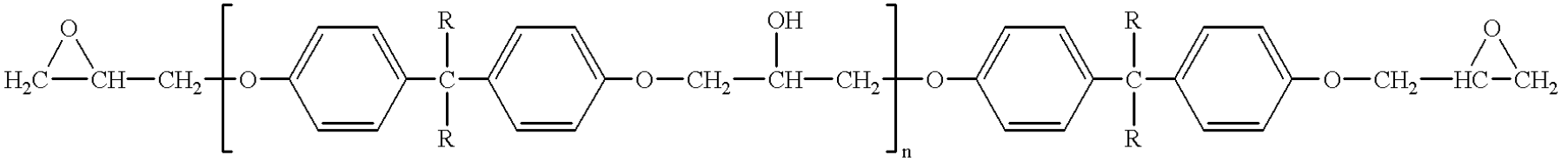


Bio-based content can be increased up to 100% by substituting BPA with renewable sources:

- **Cardanol-based**: renewable aromatics extracted from cashew nutshell
- **Lignin-based**: lignocelluloses in plant's cell wall, it is one of the most promising alternatives for BPA
- **Rosin-based**: naturally found in pines and conifers, extracted by distillation of tall oil, a by-product of the Kraft pulp process
- **Isosorbide-based**: derived from corn, and commercially available
- **Itaconic acid** (fermentation of glucose), **Gallic acid** (derived from plants) and others

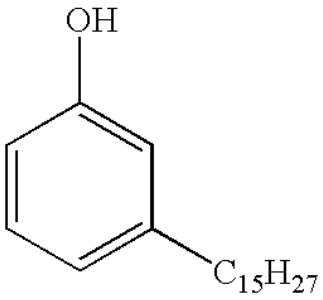
Bio-based Epoxy Resins for Composites

Bisphenol-type epoxy resins

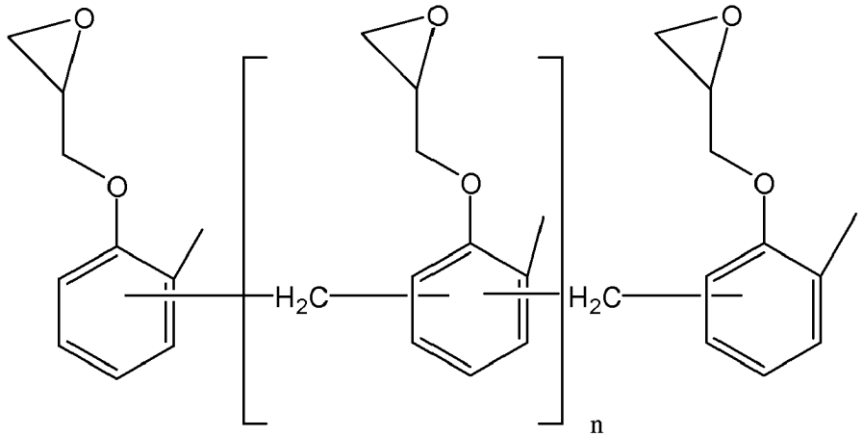


Available as partly bio-based (derived from Epicerol®)
Achievable 100% bio-based substitutes (Epicerol® + BP substitutes)

Novolac-type epoxy resins:



Cardanol
(a cashew nutshell liquid (CNSL) derivative)



Available as bio-based substitutes
(e.g. Epicerol® + cardanol derivatives)

Bio-based Epoxy Resins with Carbon Fiber

The Punch One Solar Car was produced using carbon fiber prepregs impregnated with bio-based epoxy resins to develop carbon fiber composite material for car body with 18% bio-content.

Core components of the epoxy resin system (**45% bio-based**)

- Cardolite NX-4001 (novolac derived from CNSL)
- Liquid epoxy resin derived from Epicerol®

PUNCH POWERTRAIN SOLAR TEAM

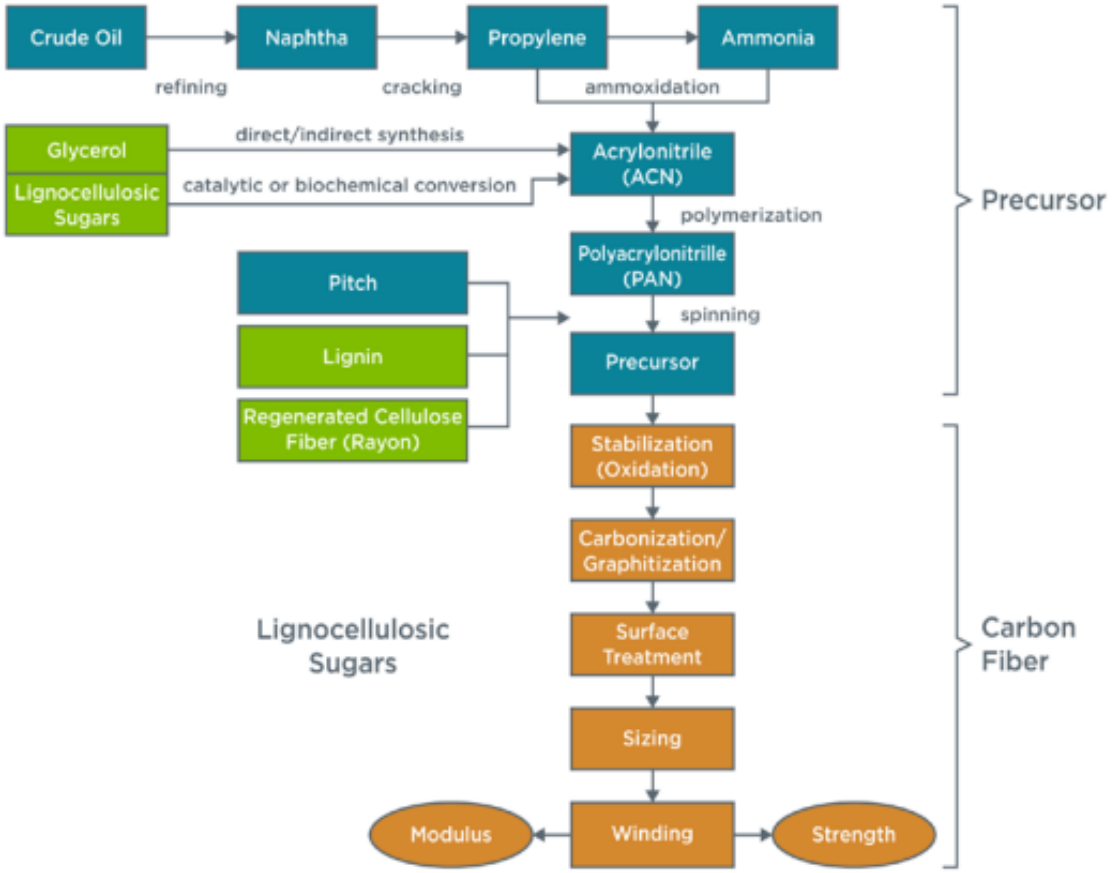
SHD composites

Cardolite

EPICEROL®

Bio-based Epoxy Resins with Bio-based Carbon Fiber (R&D state)

- There are few studies on bio-based carbon fiber
- Lignin-based carbon fiber offers too low modulus & strength to meet structural applications requirements
- Carbon fiber from **Lignocellulosic sugars** offers a "drop-in" bio-ACN
- Biomass-based Carbon Fiber has high potential demand from its cost and sustainability perspectives



Bio-based Epoxy Resins with Natural Fiber

I. Plant-based Fiber : Flax, Jute, Hemp, Wood, …

Advantages

- Renewable resource that absorbs CO_2 during growth
- Low energy consumption in manufacturing process
- Up to 40% lighter weight than glass fiber
- Good damping property (less vibration), especially for flax fiber

Disadvantages

- Quality variations
- High moisture absorption (*weakens the bonding between the polymer matrix and fiber)
- Low thermal stability of the raw fibers

Uses

- Used together with other fibers to improve mechanical properties
- Interior parts of vehicles due to its good thermal and acoustic insulation properties

Bio-based Epoxy Resins with Natural Fiber (continued)

II. Mineral – Based Fiber : Basalt

Advantages

- Renewable resource
- High temperature resistant
- **Best alternative for glass fiber** due to similar properties
- Recyclable; LCA results much better than glass and carbon fibers

Disadvantages

- Higher density (weight) compared to carbon fiber

Uses

- Exterior parts of vehicle
- Aerodynamic parts: i.e. side mirror of vehicles

World's First Car Made from Bio-composites debuts in 2017

- The students of Eindhoven University of Technology have made it reality! The car is called Lina, made from flax-based bio-composites
- The complete chassis, the body of the car and the interior are all made of bio-based materials
- The bodywork is also flax-based
- The car is electric-powered and has a total weight of 300 kilograms (661 pounds).

The car has also been certified by the Netherlands Vehicle Authority as roadworthy and is viable to carry four people. Currently, the team aspires to research the production process and test the market.

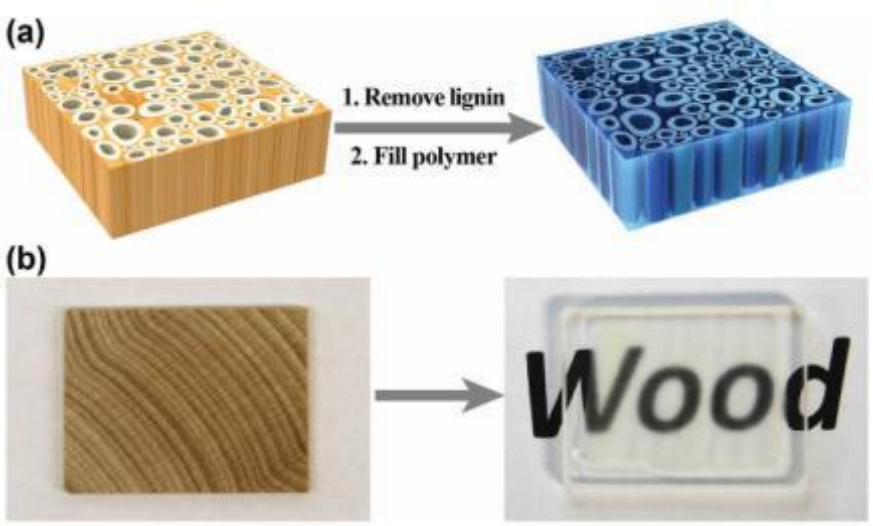
Source: http://onlinepitstop.com/lina-bio-composite-car/

Transparent Wood Composites

- A wood composite with a **transparency of up to 85%** by removing lignin from the wood cells (with NaOH, Na_2SO_3 and H_2O_2), and then filled with a liquid epoxy resin & its hardener

- The composite has **3x lower thermal conductivity** and is **much more ductile** than glass

- Ability to **absorb impact energy (solar cell application)**



Source: Advanced Materials, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim

- The transparent wood composites can be used in structural parts of automotive such as **glass replacement** where it gives **maximum use of sunlight** & **efficient thermal insulation**

- The transparent wood composite is developed and patented by ***Department of Materials Science and Engineering, University of Maryland***

Answering Automotive Trends with Bio-based Epoxy Resins Composites

Carbon fiber in Bio-based Epoxy Resins matrix offer the best compromise among **Fuel Efficiency** (weight reduction), **Corrosion Resistance** and **Mechanical Strength**.

Minimizing the Environmental Footprint of vehicles by combining **Bio-based Epoxy Resins** with Natural Fibers such as **Flax, Hemp, Jute and Basalt**

Meeting demand in **Design Freedom** and **Flexibility Requirement** especially for non-fossil drivetrain systems like **Electric, Hydrogen, and Hybrid Vehicles**.

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THANK YOU