

# Wood-derived advanced materials lead sustainable system of material utilization to the future

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Forestry and Forest Products Research Institute

# Forest in Japan

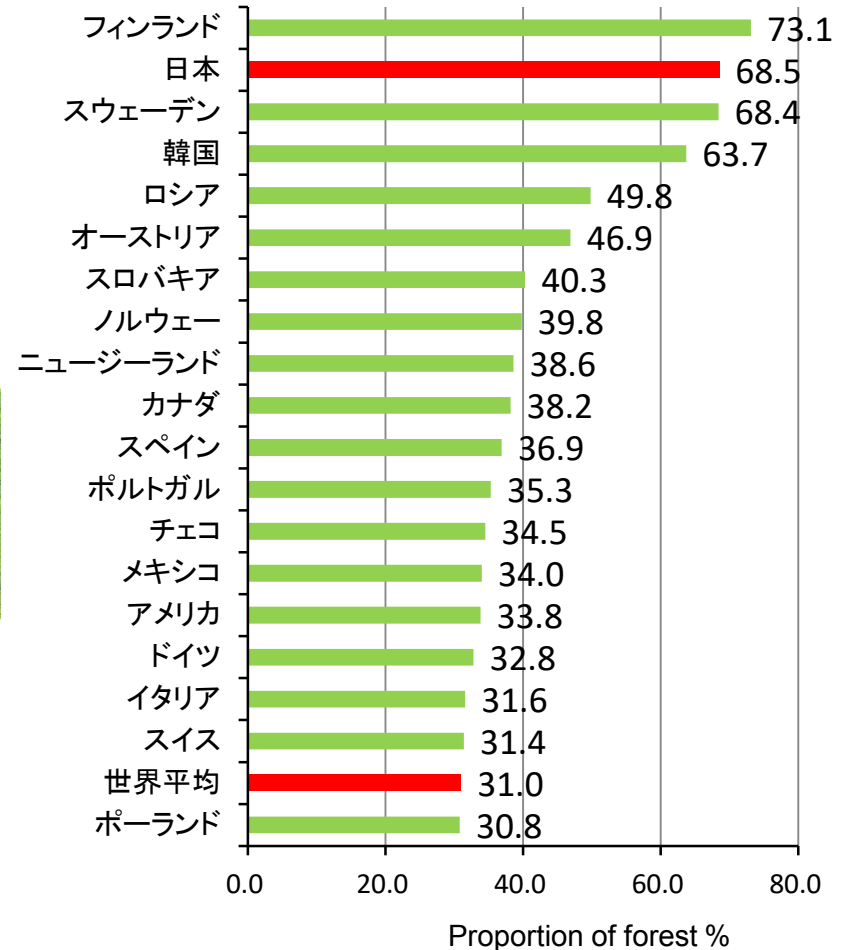
Land area : 378,000 km<sup>2</sup>

Forest in Japan : 250,000 km<sup>2</sup>



Forest covered about 70% of Japan land area.

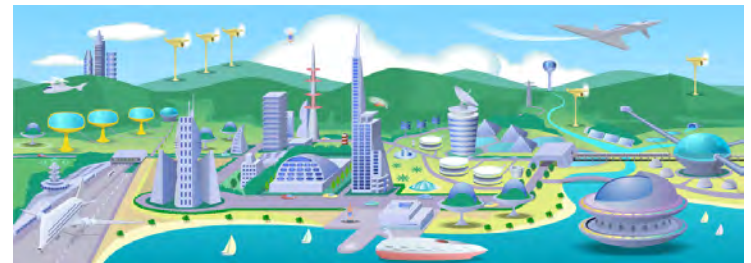
World total forest area: 40 million km<sup>2</sup>  
Proportion of forest: 31% (world average)



資料: Global Forest Resources Assessment 2015 (FAO)  
※面積の算出方法が異なるため、国交省の森林率とは差がある。

# Contents

- “Lignin” and “Glycol lignin”
- Glycol lignin based materials
- Concept of local production for local consumption in bio-based materials



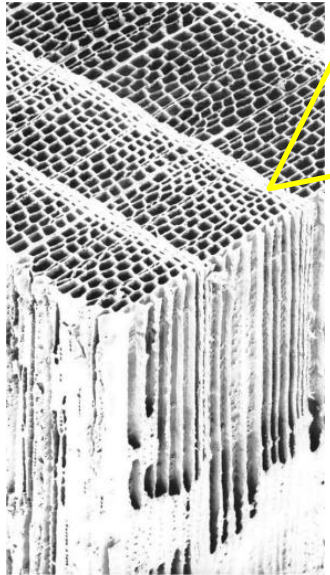
# Chemical structure of plant cell wall



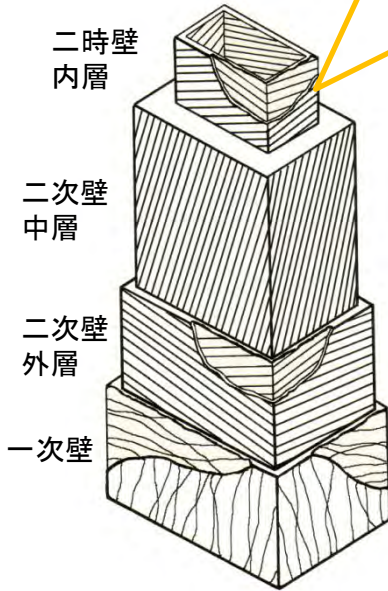
Tree



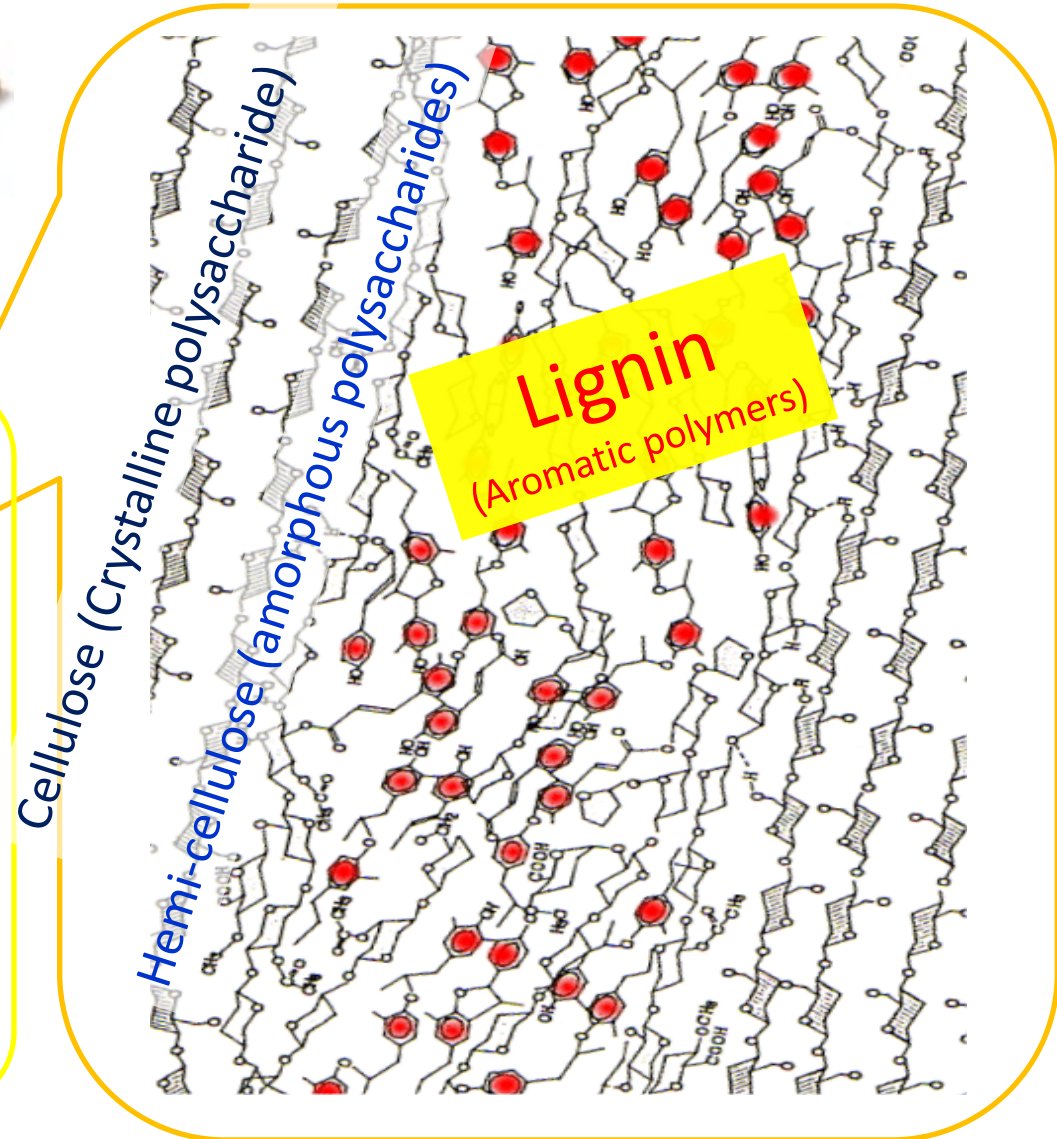
Wood



Japanese cedar, SEM

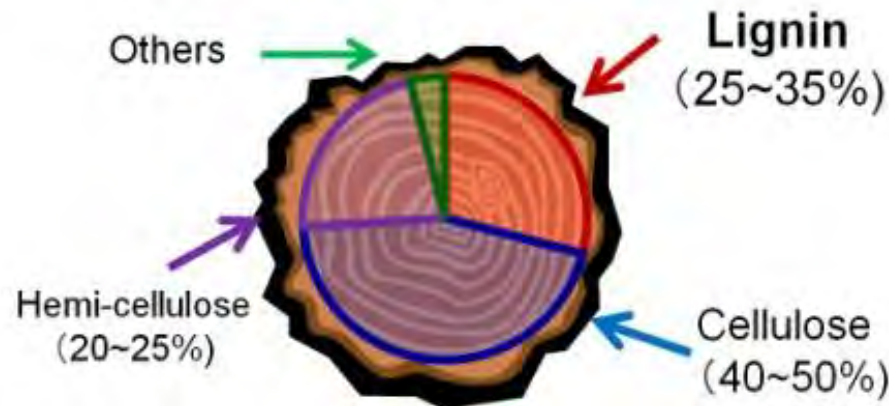


Model of cell wall of tracheid



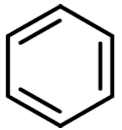
# What is lignin?

- Lignin is one of the main chemical components of wood.
- The word “lignin” itself comes from the Latin term “lignum”, which literally means wood.
- Based on the meaning of the original word, wood is wood precisely because it contains lignin.



# Lignin – Natural aromatic polymer-

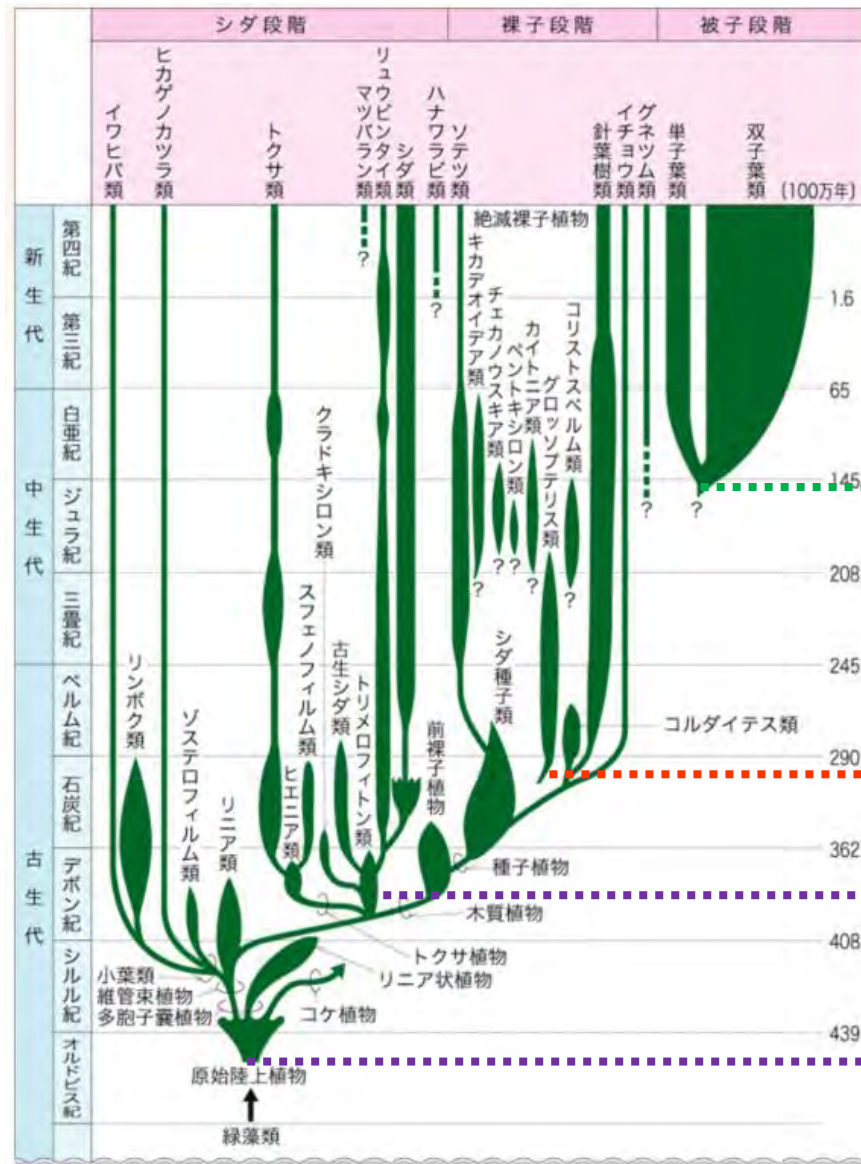
- Lignin is the most abundant naturally occurring aromatic polymer on earth.
  - Aromatic compound is a hydrocarbon containing one or more benzene rings that are characteristic of the benzene series of compounds.
  - Aromatic polymers, which wholly or partially include benzene rings and/or pseudoaromatic heterocycles, have been used in a wide field of high-performance or functional materials.



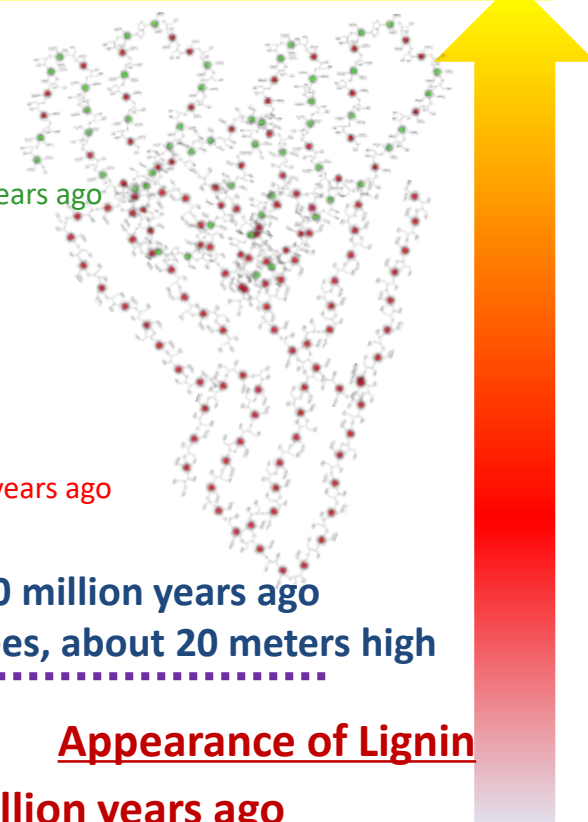
Lignin has a potential to be a source of high-performance materials such as heat-resisting plastics and high-strength plastics.

*Plus: Lignin is biodegradable*

# History of lignin, with evolution of land plants



Evolution of lignin with diversifying functions

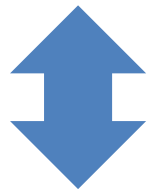


# Dilemma of lignin-based materials

## For trees, lignin is

- highly evolved high-performance material
- functional material to make tree form flexible and strong
- changing the form to adapt variety of growth condition

*consequently* Lignin is not uniform



Dilemma

Industrial materials should be uniform with a stable property



# Solution “Glycol lignin”

“Glycol Lignin” is a series of lignin-derived advanced industrial materials.

- lignin derivatives with unique chemical structure
- high-performance with excellent workability
- variation controlled to be a stable properties as an industrial material

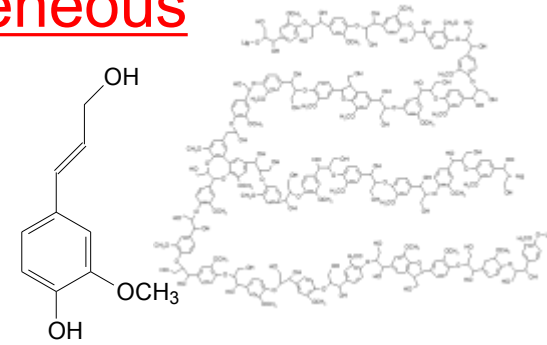


Two key points in the development of Glycol Lignin

# Key point 1. Selection of plant species

## Lignin in “Japanese cedar” is relatively homogeneous

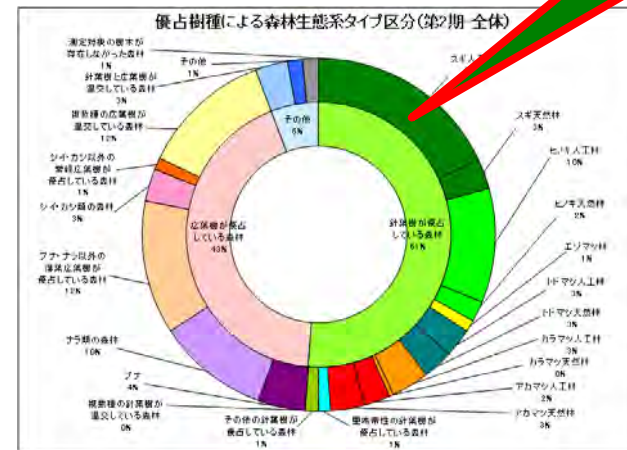
- ★ Japanese cedar is monotypic genus of cedar, single and endemic species of Japan
- ★ Since, Japanese cedar lignin is formed by single type of building block unit, structural variation is relatively small.
- ★ Japanese cedar is major and representative wood in Japanese forestry. Stable supply system is certain in Japan.



Chemical structure of Japanese cedar lignin unit (left) and a schematic structure of the lignin (right)

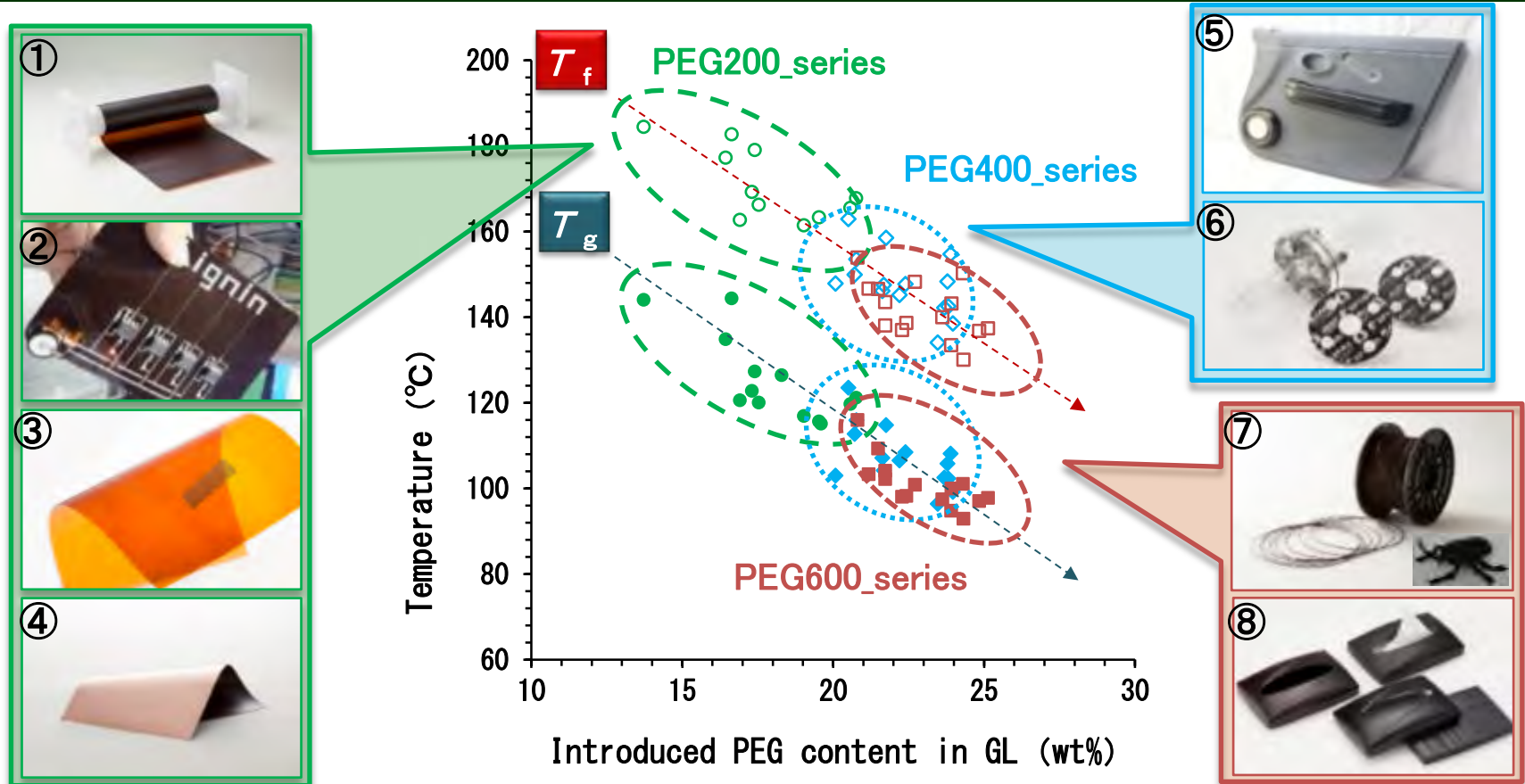
Japanese cedar 21%

The system using Japanese cedar wood will make a system using Japan domestic forest resources





# Freely controllable thermal property of Glycol Lignin by controlling process condition



Thermal properties of the glycol lignin as a function of introduced PEG content in the glycol lignin. ( $T_g$ : glass transition temperature,  $T_f$ : thermal flow temperature)

写真：改質リグニンを用いて開発された高付加価値製品

①改質リグニン-粘土ハイブリッド膜、②回路を搭載した改質リグニン電子基板、③タッチセンサー用改質リグニンフレキシブル基板、④銅箔塗改質リグニンハイブリッド膜（産総研）、⑤改質リグニン繊維強化材（自動車用ドアトリム）（株式会社宮城化成）、⑥改質リグニンガasket（ジャパンマテックス株式会社）、⑦3Dプリンター用改質リグニンフィラメントと3Dプリンター造形物（ネオマテリア株式会社）、⑧改質リグニン/パルプコンジット射出成型品（トクラス株式会社）

# Glycol Lignin based products

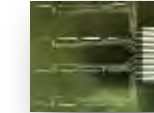
改質リグニン-粘土ハイブリッドフィルム



ロール生産技術の成功



銅箔塗工の成功



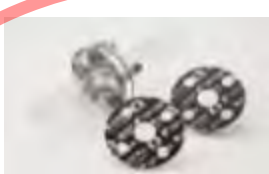
銅箔塗工型改質リグニンハイブリッドフィルムとその電子基板への展開



スマートメーターへの導入



アルミ箔塗工型改質リグニンハイブリッドフィルムとその放熱材への展開



改質リグニン配管シール材



改質リグニンコンポジット射出成型品



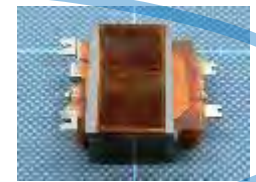
改質リグニン製の不燃材  
(公的認証取得済)



ヒーティングモジュールの開発



電着技術を開発



絶縁材料の開発



改質リグニン系コンクリート用化学混和剤



改質リグニン製3Dプリンター用基材



改質リグニン製自動車用内装材



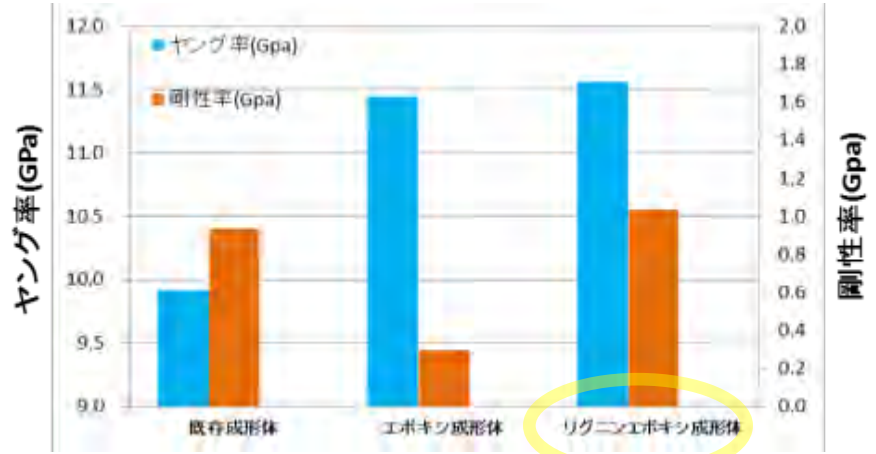
改質リグニン製自動車用外装材 (GFRP)



改質リグニン材を導入した自動車

# Ex.1 Glycol lignin based FRP for automobile

Invent a method of Glycol Lignin based molding resin for fiber reinforced plastics (FRP).



GL based FRP shows better performance in mechanical properties than widely used epoxy resin type of FRP.

Volatile Organic Compound (VOC) emission test

測定成分	不飽和ポリエステル (従来仕様品)	改質リグニン 使用
ホルムアルデヒド	26	0.06
アセトアルデヒド	9.1	0.05
トルエン	0.09	<0.08
エチルベンゼン	1.7	<0.08
キシレン	0.35	<0.24
スチレン	360	<0.08
テトラデカン	<0.08	<0.08
フタル酸ジ-n-ブチル	<0.08	<0.08
フタル酸ジ-2-ヘキシル	<0.08	<0.08

$360 \div 0.08 = 4500$   
 改質リグニンを用いたGFRPの場合は、不飽和ポリエステル樹脂を含浸させる従来品の4500分の一未満

試験方法:トヨタ法「サンプリングバッグ法による揮発成分測定方法」

GL based FRP shows excellent performance in the VOC test.

# Starting the practical vehicle test of exterior and interior Glycol Lignin based FRP

AIST, FFPRI, Miyagi-kasei Co., Ltd., Mitsuoka Motor Co., Ltd.

## World 1<sup>st</sup> motorcar using Glycol Lignin based FRP



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朝日新聞  
日本経済新聞  
日刊工業新聞社  
産経新聞  
時事通信社  
化学工業日報  
日刊木材新聞  
株式会社日本林業調査会(J-FIC)「林政ニュース」  
株式会社科学新聞社  
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フリーランス 遠藤正賢  
フリージャーナリスト

*Reported widely by more than 20 web news*



Asahi News Paper 10月24日



NIKKEI News 10月24日

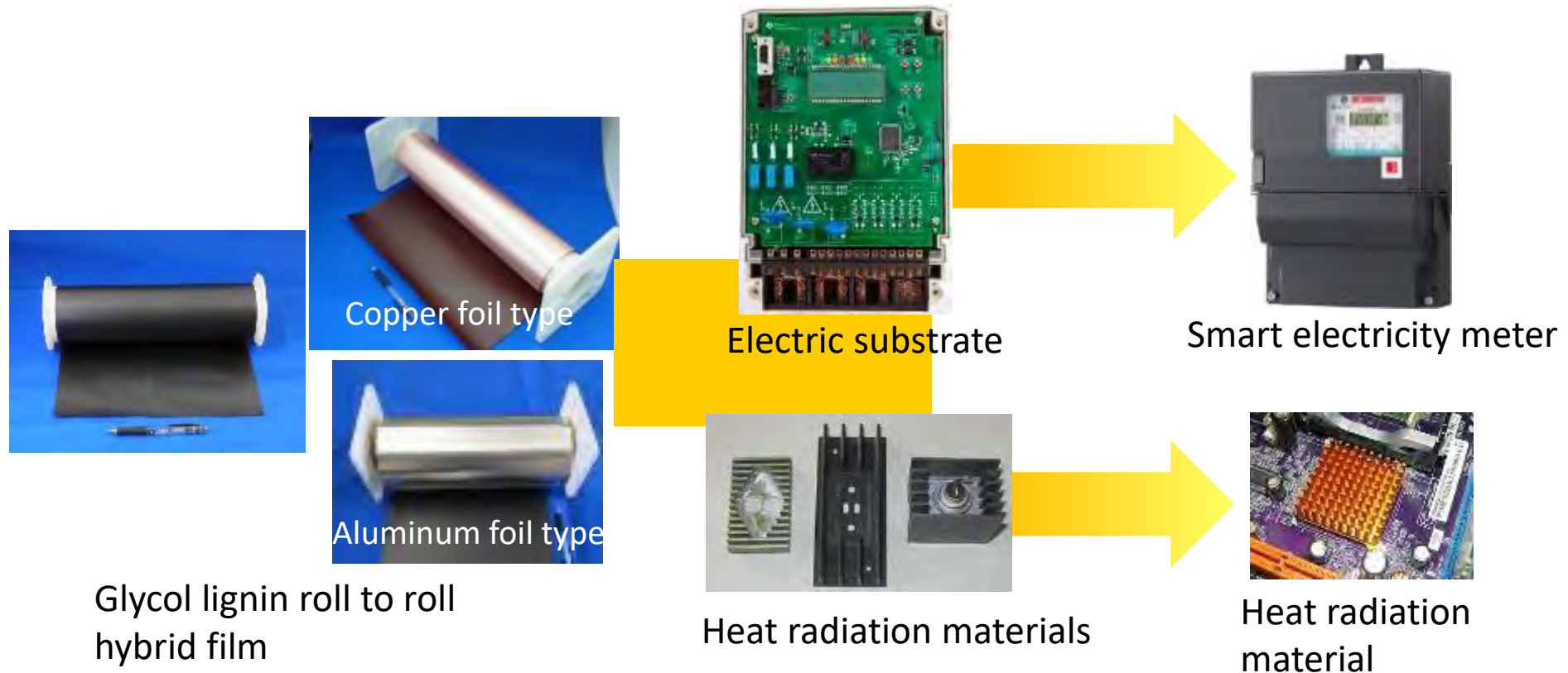


TV Tokyo news 10/23 11:00~

**Media reported widely**

# Ex. 2. Hybrid film for printed electronic devices

Flexible electric substrate film was prepared by Glycol lignin-Clay hybrid material



Development for printed electrics and heat radiation materials

Glycol lignin-Clay hybrid film shows better performance than commercial polyimide film in gas barrier property and dimension stability. The price becomes a one-third of the commercial polyimide film.



# Environmental adaptability

## Glycol lignin : Environmental friendly materials

- No harmful volatile organic compounds in the production process
- No accumulation in the environment (biodegradable)
- Favorable in environmental impact assessment (carbon neutral)



✓ No harmful volatile organic compounds

✓ Biodegradable  
✓ No microplastic marine pollution

# Glycol lignin production for the promotion of local industry



Example

Operation at a local sawmilling factory

Point

**Use wood waste only**  
(Not affect to the lumbering work)

改質リグニン製造ビジネス例

商品	現在の製材工場例	SIPシステム導入後の製材工場例	国内の同規模工場にSIPシステムが普及した場合の各生産量と売り上げ	
	売上 (百万円/年)	売上 (百万円/年)	生産量 (千トン/年)	売上 (百万円/年)
製材品		1,736	2,138	190,300

**Example: Sales increase by 65%**

\*派生物: プラスチック、紙、繊維、プラスチック



Creating new markets of 100 billion yen scale



Glycol Lignin based new products

New companies are entering the market one after another

*Creating new markets*



# Conclusion

- Two key points in the development of Glycol Lignin
  1. Focus on the Japanese cedar lignin that is relatively homogeneous.
  2. Modification with polyethylene glycol (PEG) to control thermal properties

Using Japanese cedar wood will make a system of using Japan domestic forest resources

- Many Glycol Lignin based products has been developed through composite technologies.
- Since glycol lignin is biodegradable, glycol lignin based products will not accumulate in the environment (No microplastic marine pollution).

# Sustainable system on domestic resources



Forest: 25 million ha  
(67 % of the land area)



Farmland: 6 million ha  
(12 % of the land area)

Land area, total: 38 million ha



Totally about 80% of the land is covered with biomass

Biomass superpower?

Glycol lignin will lead sustainable system of material utilization to the future

生物資源は近くにあります

都市

Methane hydrate in the ocean  
Lignin in the mountain

Need innovation !

# Thank you!

Tatsuhiko Yamada, Ph.D.



Website

<http://lignin.ffpri.affrc.go.jp/>

↓ YouTube

<https://www.youtube.com/channel/UCOF0JebKdA9fmH0MiCi4IUA>



国立研究開発法人 森林研究・整備機構  
**森林総合研究所**  
Forestry and Forest Products Research Institute

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