DEVELOPMENT OF SUSTAINABLE BIO COMPOSITES MADE OF ACACIA WOOD FOR ELECTRONIC APPLICATIONS

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PRESENTATION OUTLINE

- Introduction
- Natural fibre composites
- Flexible Energy Storage applications
- Commercial Electronics
- Biomedical Devices
- Novel intrinsically conductive polymers (ICPs)
- Conclusion
- References

INTRODUCTION

Primary problem

- Traditionally dielectric materials are made from inorganic substances
- Mica and Silicon dioxide
- Inorganic materials have higher thermal properties / temperature requirements leads to an extreme end of processing temperatures and brittle

Secondary problem

- Polymers are gaining wider use as dielectric materials due to easier processing, flexibility, able to tailor made for specific uses and better resistance to chemical attack
- Coefficient of thermal expansion is relatively larger than ceramic materials and susceptible to atmospheric and hydrolytic degradation
- Weak mechanical strength

Solution

- Natural fibers reinforced polymer matrix composites (synergism properties)

INTRODUCTION

Natural fibres of all kinds have been used for various applications

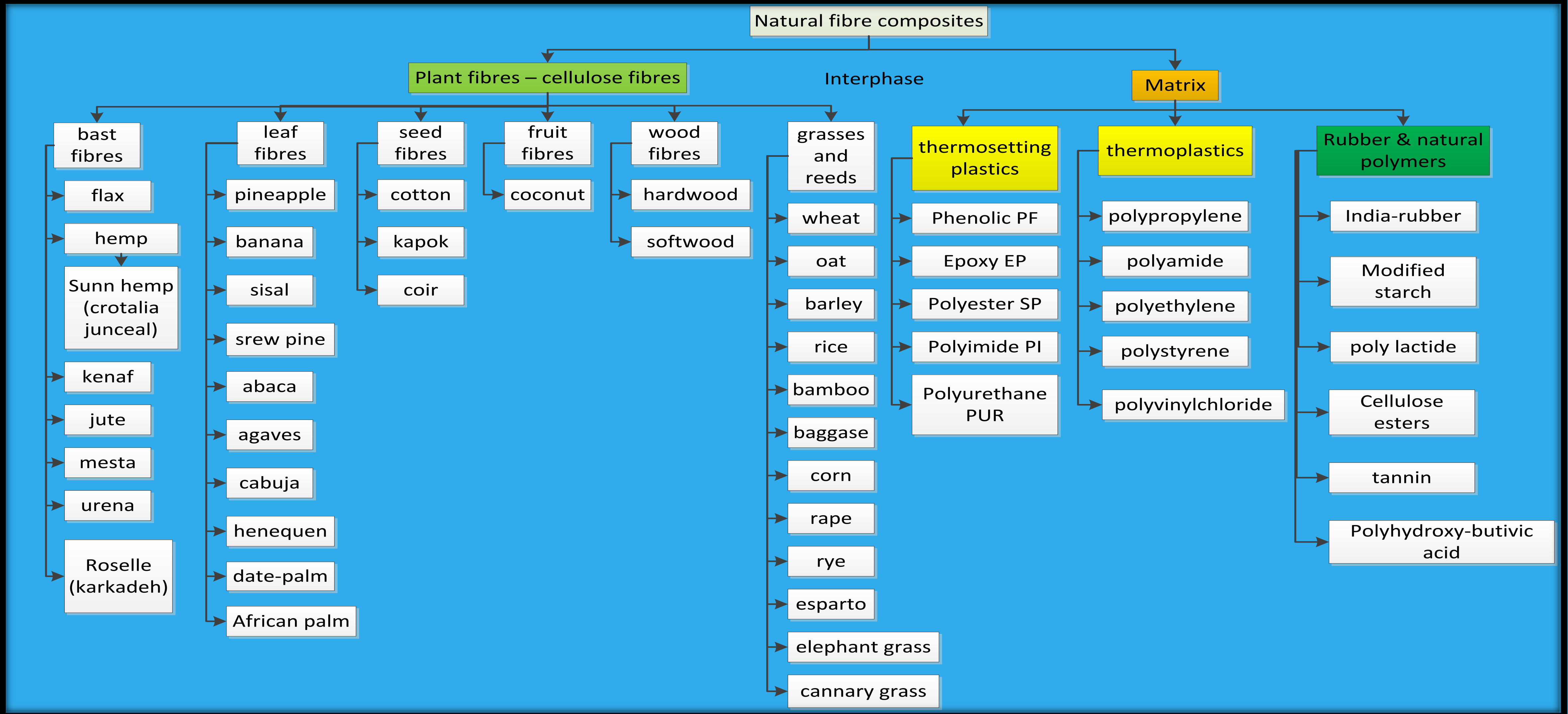
One of the applications in which natural fibre has been found useful is in dielectrics.

Dielectric materials serve huge insulations, energy storage, high breakdown materials for transmission, and many more applications.

Although, the use of conventional materials such as ceramics and other substrates as a dielectric has reached a point where the facets of sustainability have not properly met.

Hence, research on natural fibre reinforcements on the dielectric application has increased to improve or find a suitable alternative for ceramic-based composite materials.

NATURAL FIBRE COMPOSITES



METHODS

- Dielectric Mold

- Hydraulic Hot Press

MEASURING INSTRUMENT

The dielectric properties of the composite specimens were measured with an HP Impedance Analyzer E4980A.

Measurements using the Agilent E4980A precision LCR meter and the 16451B dielectric test fixture.

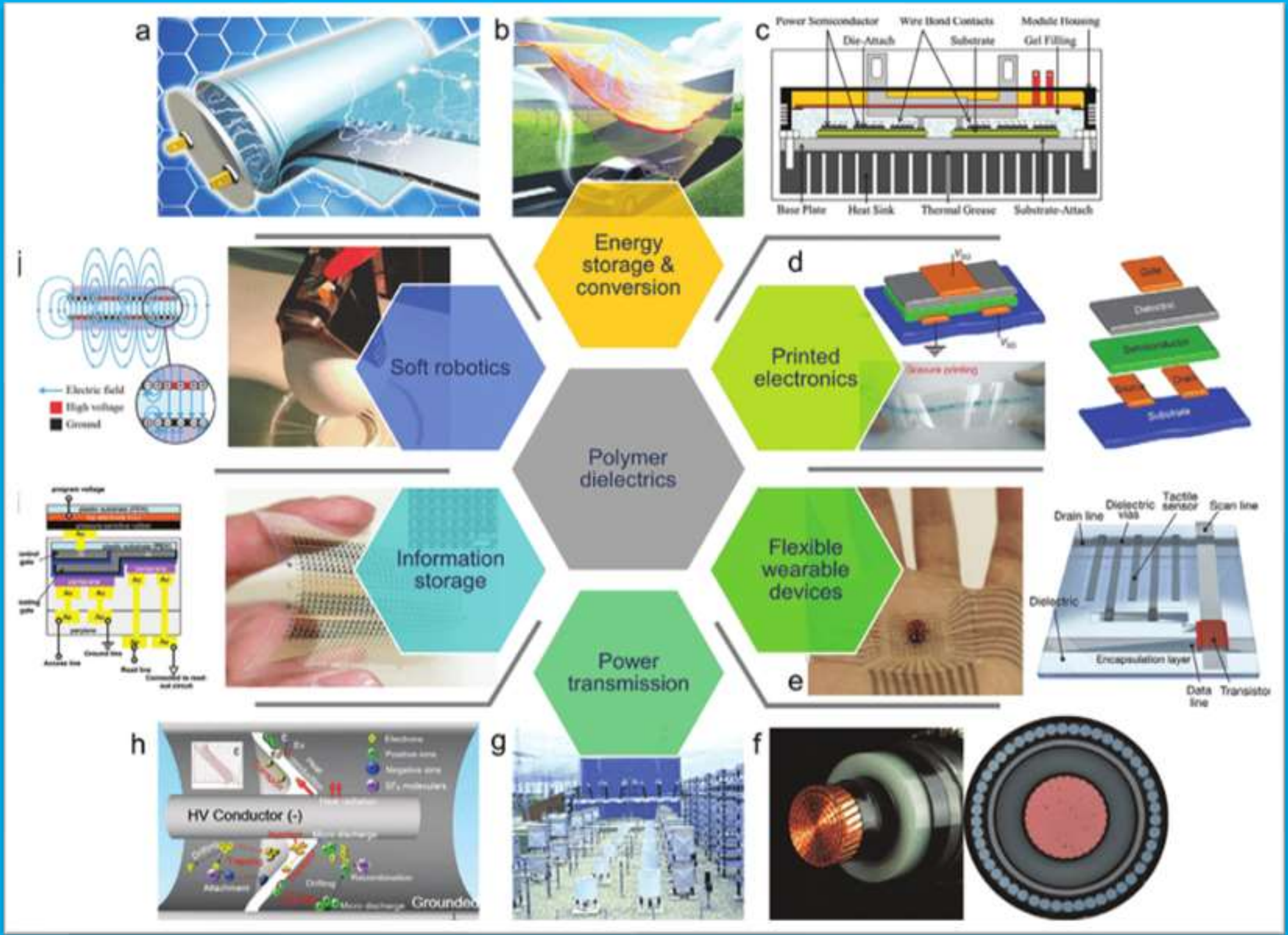
The LCR meter is capable of measuring up to a frequency of 2MHz. The disc shaped samples had a diameter of 50 mm and a thickness of about 5mm.

The specimens were analyzed using a contacting electrode method, which uses a rigid metal electrode.

The measurements were done at varying frequencies ranging from 1 kHz to 1 MHz in accordance with ASTM D-150-10 standard.

Agilent E4980A precision LCR meter and the 16451B dielectric test fixture

DIELECTRIC MATERIALS APPLICATION



DIELECTRIC APPLICATIONS OF NFRPCS

Natural fibres are great insulators which means that they can be polarized when they are subjected to high electric fields as it is known that there is multiple polarization process involved such as

- Atomic,
- Ionic,
- Spontaneous,
- Space-charge, and
- Dipole polarization.

Chemical treatments such as alkali, silane, acetylation, peroxide, chlorine, permanganate, and stearic acid are highly effective in increasing fiber surface roughness and introducing hydrophobicity one way or another other.

Other treatments which would give rise to better polarization (specifically space-charge/interfacial polarization) are isocyanate treatment and the Malenization process.

NATURAL FIBRES AND THEIR DIELECTRIC PROPERTIES

Natural Fiber	Dielectric Constant	Dielectric Loss	Relaxation Frequency	References
Jute	5.13	0.18	1 kHz	[21]–[23]
Flax	4.5 – 6.11	0.17	1 kHz	[19], [24], [25]
Hemp	13.55	0.33	500 Hz – 1 kHz	[21], [26]
Kenaf	1.7	<0.005	1 kHz	[27], [28]
Wood	7.1	0.35	1 kHz	[29]
Loofah	1.9 – 2.8	0.016	1 kHz	[30]
Cotton	3.18	0.025	500 Hz – 1 kHz	[31]
Bamboo	4.45	0.015	1 kHz	[26], [32], [33]
Bagasse	2.9	0.4	1 kHz	[9]
Silk	2.65	0.014	1 kHz	[34], [35]
Wool	2.00	0.06	2 MHz	[36]
Hair (animal/human)	1.8	0.89	1 MHz	[35]

FLEXIBLE ENERGY STORAGE DEVICES

Flexible energy storage devices range from various,

- Electronic textiles,
- Artificial electronic skins,
- Military wear, and
- Wearable electronics such as smartwatches and distributed sensors.

Flexible energy storage devices at the current research stage are to offer high performance, optimum operational safety, and environmentally safe.

These energy storage devices must possess insulating (dielectric) layers, which allows moderate levels of shielding, and since they are being used on human beings, they must possess a high energy-to-weight ratio as a dielectric.

This is where natural fiber reinforced polymer composites come to play, where their lightweight and optimum dielectric properties allow them to potentially be applied in these applications

COMMERCIAL ELECTRONICS

Apart from flexible energy storage devices, dielectric composites have always been a part of integrated circuits, batteries, and electrical breadboards for three decades of research.

However, the composite materials used are of ceramic and polymer combination, which does not permit sustainable material use and is not cost-effective.

Recent research has come up with solutions to amp up dielectric properties and provide biodegradability at the same time.

As a contender to ceramics and other non-ecologically friendly materials, natural fibers have come a long way in not only in reinforcement but increasing the operability of the newly fabricated product.

Currently, these composites are used as insulators, plugs used in households, connectors, cables, and printed circuit boards.

Some of the main observations from assessing the characteristics of these composites were fibers aligned with 90° orientation along the composite exhibited better dielectric properties due to increased dipole-dipole polarization.

BIOMEDICAL DEVICES

As new fabrication methods are emerging, like fused deposition modeling (FDM), there has been an increase in target-specific applications in biomedicine and pharmaceutical industries.

FDM can be combined with 3D printing to produce fiber-reinforced polymer composites.

FDM is very popular with polymers as the configurations of FDM fabrications allow an even finish on the product, and further machinability options are opened.

As a result, this methodology is combined with 3D printing, where natural fiber reinforced polymer composites are fabricated to focus on arrays of medical implants and devices made for assessing bone structures.

Heavy power-consuming devices have always had materials with high breakdown strengths where the material/composite protect other components of important use.

Although fiber-reinforced composite material is dielectric, it possesses relatively fewer breakdown strengths and required further research to fully utilize the niche in which these composites can be put to good use.

NOVEL INTRINSICALLY CONDUCTIVE POLYMERS (ICPS)

Intrinsically conducting polymers are a type of synthetical metals as they possess properties of electrical, magnetic, and optical phenomena, same as metals and semiconductors.

Their applications must have low cost-high performance and organic, which can be used in chemical detecting sensors.

Also, these dielectric composites reinforced by natural fibers have potential in bio-actuators, chemical, and electrochemical catalysts.

The idea here to incorporate natural fibers into polymer matrices is to arrange the structures of ICPs to introduce conductivity, and a dielectric composite makes it the right choice for these applications.

As a result, these plastics can conduct minute charges, making them suitable for switching devices and electromagnetic shielding for other electronic components.

From a commercial point of view, ICPs with natural fiber reinforcements can be put a definite shelf life for a considerable amount of time and requires periodic replacements.

CONCLUSIONS

From the perspectives of sustainability, eco-friendly, and safety matters, natural fiber reinforced polymer composites have great potential in use as a dielectric.

Some of the applications that have been seen here could be great examples to prove that this advancement from using conventional composites to novel dielectric composites is viable in future and technology-driven applications.

Although, if one were to critically analyze the exploitation of technology for improving the performance or qualities of NFRPCs, it requires tremendous efforts and research to move a fabricated composite to a finished product.

Looking at the commercial point of view, novel composites will always stay an integral part of society and business as time and technologies progress.

CONCLUSIONS

This allows stakeholders (manufacturing industry) and communities (engineering/research fellows) to flourish as there will always be new opportunities when NFRPCs are scrutinized for their properties.

A recurring challenge to this research community is to make a fully biodegradable polymer composite or manufacturing polymer derivatives from bio-based materials.

Furthermore, there are other facets of materials science where NFRPCs can diversify with opportunities in additive manufacturing technologies where more challenges lie ahead.

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THANKS