BIO-BASED COMPOSITES FROM PLANT OILS AND KERATIN FIBERS FOR PRINTED CIRCUIT APPLICATIONS

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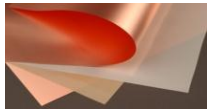
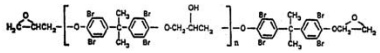
INTRODUCTION AND OBJECTIVES

- Basic materials for printed circuit boards (PCB) has a market of $42.5 billion per year[1]



http://www.rogerscorporation.com/acm/pcpindex_2.htm

- Common FR-4 materials for PCB: brominated epoxy reinforced with e-glass fibers

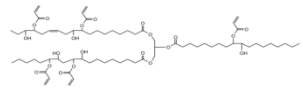


Brominated flame retardants (BFRs)

- BFRs are neurotoxic and carcinogenic
- Manufacturing of e-glass fibers requires a lot of energy

- Using greener bio-based renewable materials to replace petroleum-based epoxy
- Using natural fibers to replace e-glass fibers
- Maintaining performance
- Lowering the price

MATERIALS



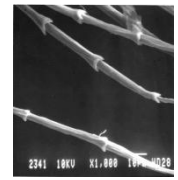
Acrylated epoxidized plant oils

However, the properties of bio-based resins need to be improved for printed circuit boards (PCB)

Low Tg: ~70 °C (with 30wt.% styrene)
Low mechanical strength
Flammable

Possible reasons: Low rigidity, high free volume, low cross-linking density

Chicken feather fibers:
Low density
High surface area
Good mechanical properties



[2]

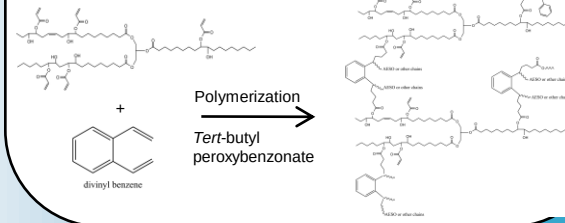
IMPROVEMENT OF RESIN PROPERTIES

Theoretical basis: Wool's Twinkling Fractal Theory[3,4]

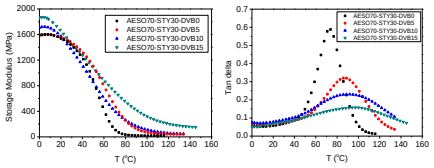
$$T_g(\nu) = T_g^0 + \frac{T_g^0 M_{ox}}{\rho(1-p_c)}\nu \qquad T_g^0 \sim \frac{2D_0}{9k}$$

ρ: density of the material k: Boltzlmann constant v : cross-linking density
D_0: inter-atomic cohesive energy
M_{ox} : molecular weight per backbone atom of the cross-linking structure
$p_c \approx 0.5$: the thermal vector percolation threshold when the glassy modulus approaches zero
T_g^o : T_g of the linear polymer extrapolated to v = 0

Increasing cross-linking density increases Tg

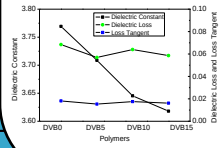


PROPERTIES OF POLYMERS



Storage modulus of DVB cross-linked AESO

Tan δ indicates higher Tg with higher DVB contents



$$\text{loss tangent} = \frac{\text{dielectric loss}}{\text{dielectric constant}}$$

Dielectric constant of DVB cross-linked polymer (1MHz, room temperature)

GENERAL PROPERTIES OF BIO-COMPOSITES FOR PCB

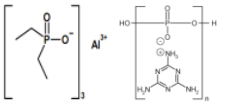
Characteristics		Unit	ACRES	Standard FR-4[5]
Resistance	Volume	MΩcm	6.7±0.2e8	2.6e7
	Surface	MΩ	5.45±0.08e8	1.3e7
Permittivity		(1MHz)	3.6-3.8	4.58
Loss tangent		(1MHz)	0.015-0.018	0.018
Flammability		-	Fail	UL94V0/1
Peel		N/m	1100 (0.5oz)	1900 (1oz)
Tg		℃	110-120	125
Flexural		MPa	234±32	83-415[6]
CTE (x, y)		ppm /℃	<20	15~18

BIO-PCB PROTOTYPE

The first printed circuit board made from chicken feathers!

http://www.sundancechannel.com/films/500320117

HALOGEN-FREE FLAME RETARDANTS



Clariant Exolit OP 930

Ciba Melapure 200

Without flame retardants

With flame retardants (25wt%)

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5 http://www.npc.com.tw/emd-new/di1/share/c4-01-3.htm
6 IPC 4101B