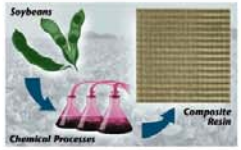
LOW DIELECTRIC CONSTANT MATERIALS FROM SOYBEAN OILS AND HOLLOW KERATIN FIBERS

C. K. Hong (PD) and R. P. Wool

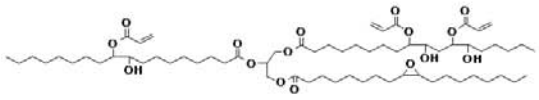
University of Delaware . Center for Composite Materials . Department of Chemical Engineering

Motivation

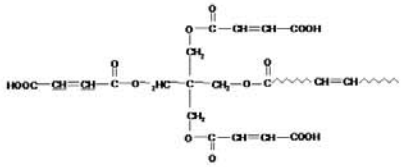
- Higher Speed Electronic Devices (Low-*k*)
- Lightweight Composites (< 1 g/cm³)
- Renewable Resources and Green Composites



Functionalized Soybean Oils



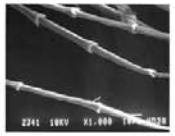
Acrylated Epoxidized Soybean Oil (AESO)

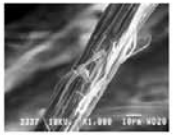


Soybean Oil Pentaerythritol Glyceride Maleates (SOPERMA)

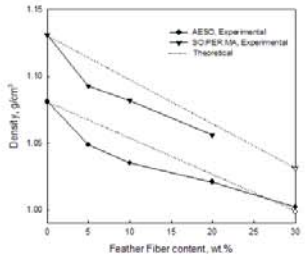
Hollow Keratin Fibers

- Keratin protein fiber
- Density: 0.796 g/cm³
- Average diameter: 6 mm
- Length: 8 mm





Density of the Composites



5% filling of hollow fibers by resin infusion

Air in the Composites

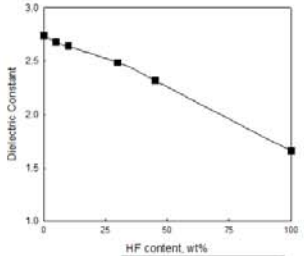
@ 20ºC

@ 40ºC

@ 60ºC

@ 70ºC

Dielectric Constant



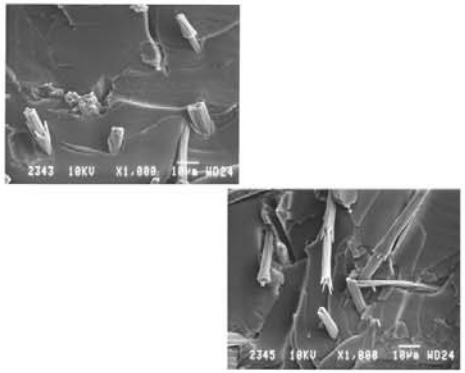
Dielectric Constant
- air = 1.00
- SiO_2 = about 4.0
- Epoxy = 4.1

Thermal Expansion

HF content, wt%	a, mm/m ºC (below Tg)
0	127.2
5	106.1
10	100.4
20	93.1
30	67.4

*. CTE of SiO_2 based material is about 66 ppm/ºC.
S. J. Martin et al., *Adv. Materials*, 12(23), 1769 (2000)

Fracture Surface of the Composites



Fracture Properties

HF Content, wt%	K_{IC}, MPa $m^{1/2}$	G_{IC}, KJ/m^2
0	1.458	1.420
5	1.455	1.610 (+13%)
10	1.524 (+ 4.5%)	1.759 (+24%)
20	1.672 (+14.7%)	1.820 (+28%)
30	1.768 (+21.3%)	1.927 (+36%)

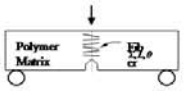
Nail Solution

The fracture energy of the fibers

$$G_{fc} = \frac{1}{2}\mu_e \Sigma L^2 V^m$$

Where, μ_e : the unit length friction coefficient

V : the pullout velocity



$$G_{IC} = \left(\frac{1}{2}\mu_e L\right) L \cdot \Sigma = G_1 \Sigma \qquad G_1 \text{ is the energy to break one fiber}$$

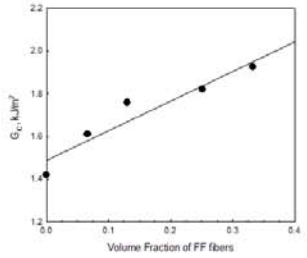
The total energy for composite (Matrix + fiber)

$$G_{total} = G_{IC}(M) + G_{IC}(f)$$

$$G_{IC} = G_{IC}^{M} + G_1\phi \qquad \text{As a volume fraction of keratin fibers}$$

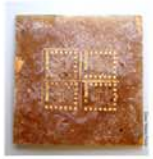
*. R. P. Wool, *Polymer Interfaces: Structure and Strength*, Hanser, NY, 1995.

Fracture Energy



Fracture Strength of a Fiber
- 293.9 MPa, Nail solution
- 85.5 +/- 44 MPa, measured

New Bio-based Microchips



Multi-Chip Module (MCM)

Diffractive Optical Element

Conclusions

- We successfully developed a new electronic material from hollow keratin fibers and soybean oils.
- The lightweight composites show lower dielectric constants than conventional semiconductor materials.
- Incorporation of hollow keratin fibers gives significant improvement of the mechanical properties of soybean composites.

Acknowledgements

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