THE PARTICLE-FIBER INTERFACE MECHANICS OF TEXTILE COMPOSITE SYSTEMS

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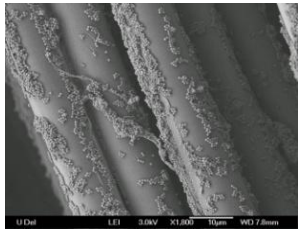
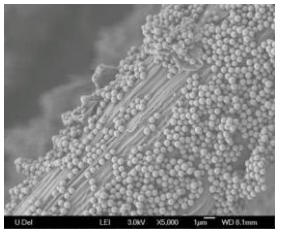
BACKGROUND AND MOTIVATION

- Textile composite protective systems
  - Increased inter-fiber friction
  - Decreased fiber mobility
    - Increased energy dissipation[1]



Untested Sample[2]

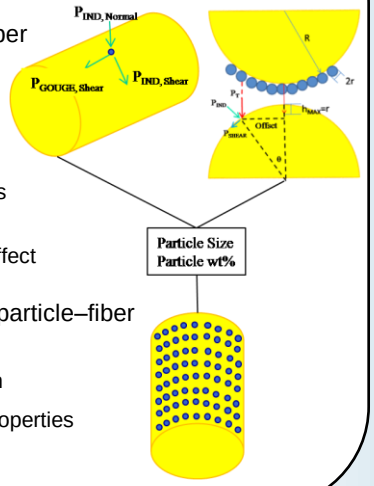


Tested Sample[2]

1. M.J. Decker, C.J. Halbach, C.H. Nam, N.J. Wagner, and E.D. Wetzel, *Comp. Sci. Technol.*, 67 (2007) 565-578
2. A. Lim PhD Candidacy Qualifier

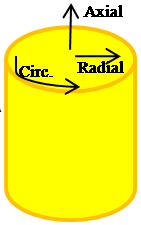
CRITICAL ISSUES

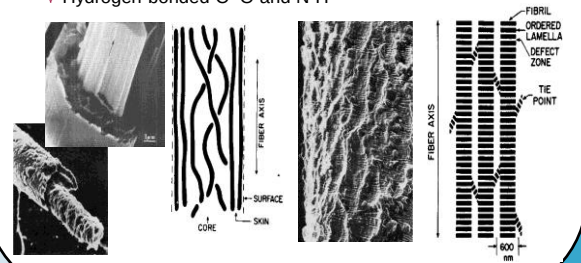
- Energy dissipative role of particles
  - Direct particle – fiber contact
    - Normal + shear contact
    - Indentation and gouging energies
    - Fiber property + microstructure effect
  - Indirect effects of particle–fiber contact
    - Inter-fiber friction
    - Residual fiber properties



SYSTEM CONSTITUENTS

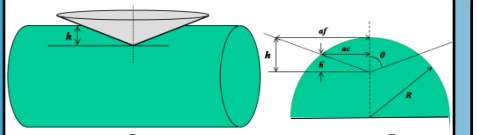
- Particles
  - ~ 500 nm colloidal silica
  - $\text{Stiffness}_{\text{Particle}} \approx 10 \times \text{Stiffness}_{\text{Fiber}}$
    - Particle ≈ Infinitely stiff
- Poly(p-phenylene terephthalamide)-PPTA (i.e. Kevlar, Twaron)
  - Highly oriented – cylindrically orthotropic
  - Skin-core morphology
  - Microfibrillar microstructure
  - Hydrogen bonded C=O and N-H



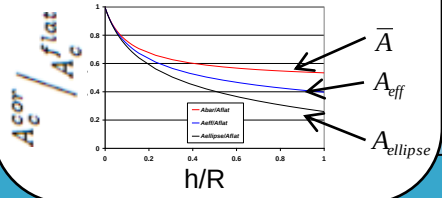


3. M. Panar et al., *J. Polym. Sci. Polym. Phys.* 21 (1983) 1955-1969

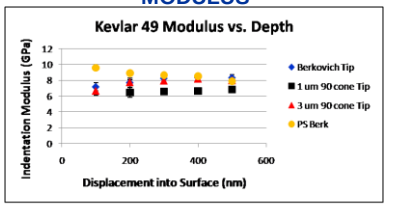
RADIAL INDENTATION
AREA CORRECTION

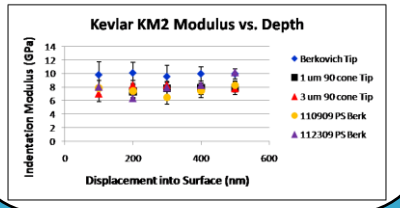


$$\frac{h'}{h} = \cos^2\theta\left[1 - \frac{R}{h} + \sqrt{\left(\frac{R}{h}\right)^2 + \frac{2R}{h}\tan^2\theta - \tan^2\theta}\right]$$

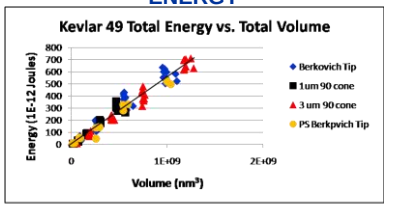


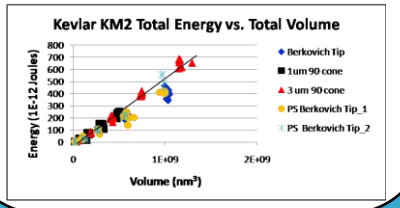
RADIAL INDENTATION
MODULUS



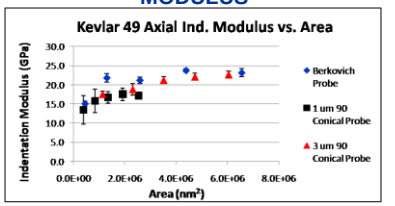


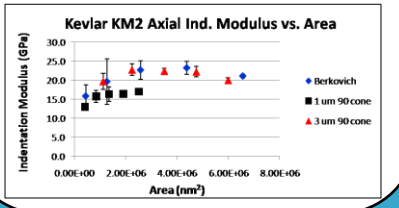
RADIAL INDENTATION
ENERGY





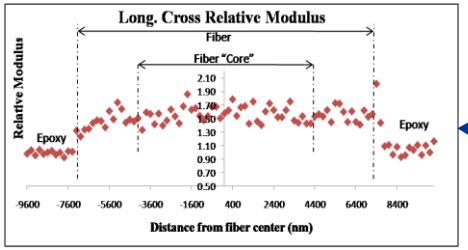
AXIAL INDENTATION
MODULUS

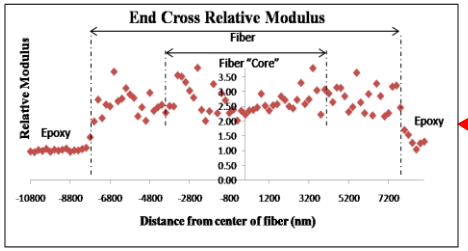




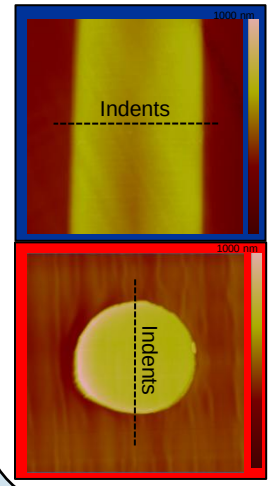
THE PARTICLE-FIBER INTERFACE MECHANICS OF TEXTILE COMPOSITE SYSTEMS
(Continued)

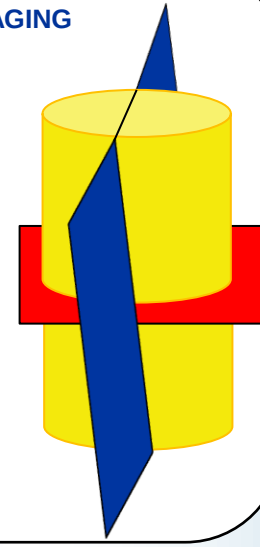
CORE-SHELL MECHANICAL MAPPING KEVLAR 49



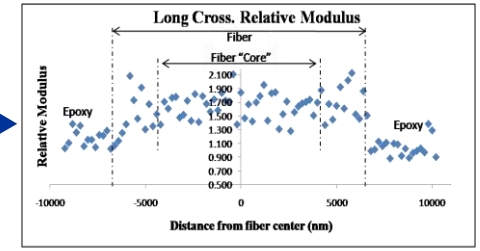


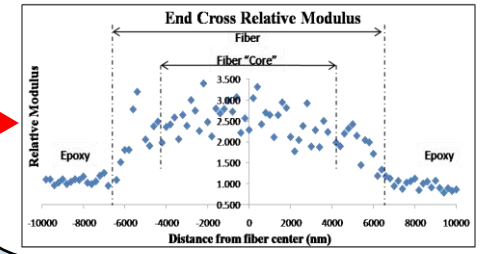
CORE-SHELL MECHANICAL MAPPING AFM IMAGING



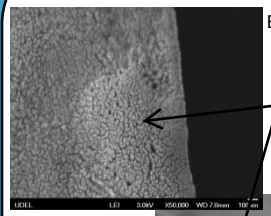


CORE-SHELL MECHANICAL MAPPING KEVLAR KM2

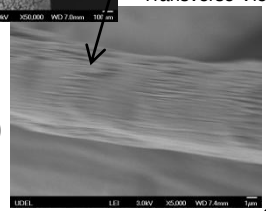




MICROSTRUCTURE IMAGING



Etched Kevlar 49



CYLINDRICAL ORTHOTROPY MATERIAL PROPERTIES

- [4]Indentation Moduli (*M*)
  - f(E_a, E_r, E_c, E_{ar}, E_{ac}, v_{ar}, v_{ac})
- Measure indentation moduli, M_a & M_r
  - Extrapolate material properties, E_a & E_r

Indentation Modulus	Experimental Value (GPa)
M_{axial}	23
M_{radial}	8.3

Material Property	Literature value (GPa)	Extrapolated Value (Gpa)
$E_{axial,c}$	75 ± 6	90
$E_{radial,c}$	2.49 ± 0.4 COV	2.09
G_{ar}	1.8	
v_{ar}	0.62	
v_{rr}	0.24	

4. Delfargue & Ulm, *J. Solids and Structures*, (2004), *41*, 7351-7360

FUTURE DIRECTIONS

- Short Term
  - Complete cylindrical orthotropy characterization
  - Complimentary core-shell gradient studies
  - Time dependent response
  - Off-set contact
  - Gouging contact measurements
  - Damaged fiber property retention
- Long Term
  - Multiple particle-single fiber verification model
  - Optimize particle/fiber type, size, shape

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