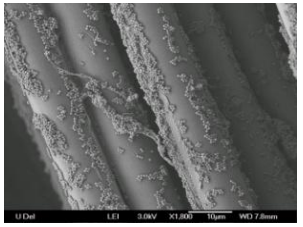
FIBER – PARTICLE INTERFACE MECHANICS

Q. McAllister (PhD MSEG), J.W. Gillespie Jr., M. VanLandingham (ARL)

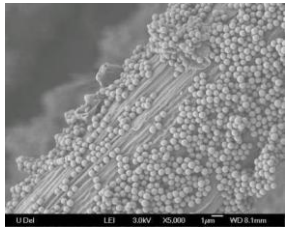
University of Delaware . Center for Composite Materials . Department of Materials Science and Engineering

INTRODUCTION AND BACKGROUND

- Kevlar – STF system in impact event
  - Increase in Particle-Fluid-Fiber system friction
  - Decrease in fiber mobility
    - Increase in energy dissipation[1]



Untested Sample[2]

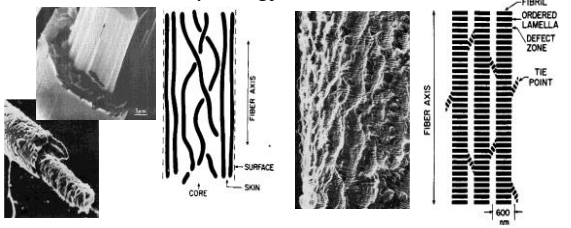


Tested Sample[2]

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

INTRODUCTION AND BACKGROUND FIBER MORPHOLOGY

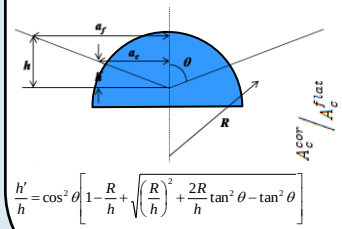
- Poly (p-phenylene terephthalamide) PPTA (e.g. Kevlar, Twaron)
  - Spun from liquid crystalline sol.
  - Highly oriented
  - Hydrogen bonded
    - C=O and N-H
  - Skin-Core Morphology



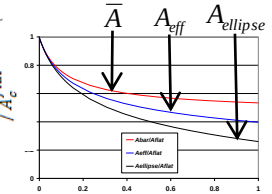
M. Panar et al., *J. Polym. Sci. Polym. Phys.* 21 (1983) 1955-1969

FIBER MEASUREMENTS

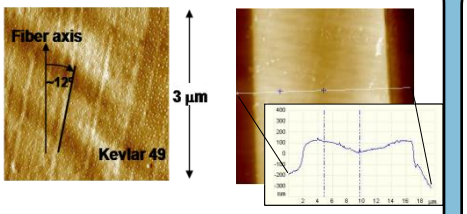
- Equipment
  - Nanoindenter XP
  - Hysitron
  - Atomic Force Microscope
- Fiber Considerations
  - Tip Shape/Size
  - Curvature
  - Transverse Isotropy
  - Viscoelasticity
- Analysis
  - Elastic Modulus
  - Nanomechanics
  - Surface Topography
- Curvature Correction – Projected Area
  - Elliptical
  - Area Average
  - Effective Height/Radius Average



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

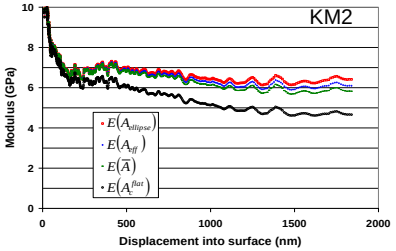


AFM RESULTS



- Microfibril Features
  - ~12º misorientation angle
- Variable Topography Across Microtomed Cross-Section
  - Residual stress gradients

TRANSVERSE INDENTATION

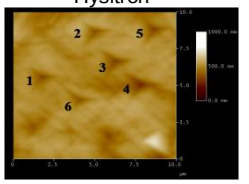


- Sample Preparation
  - Single filaments in ~1µm spun coat epoxy film
- Initial Results
  - $E_{2,KM2,LIT}$ ~ 2 GPa
  - $E_{2,KM2,EXP}$ ~ 5 GPa

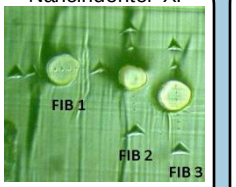
> Microstructure Effects

AXIAL INDENTATION

Hysitron



Nanoindenter XP



- Sample Preparation
  - Tows embedded in epoxy and microtomed
- Initial Results
  - $E_{1c,KM2,LIT}$ ~ 75 Gpa
  - $E_{1c,KM2,EXP}$ ~ 20 Gpa (Hysitron)
  - $E_{1c,KM2,EXP}$ ~ 12 Gpa (NI XP)

> Microstructure Effects

FURTURE DIRECTIONS

- Short Term
  - Microstructure Effects
  - Transverse Isotropy Effects
  - Tow-Tow Deformation
- Long Term
  - Lateral Force Measurements
  - Micro/Nano-Mechanical Model
  - Optimize Particle/Fiber type, size, shape

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