MATERIAL MEASUREMENT LABORATORY

NIST National Institute of Standards and Technology U.S. Department of Commerce

Evaluating Sources of Variability in Forensic Fiber Trace Evidence Examination

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Goals and Objectives

Globally, **millions of metric tons** of fibers are produced every year

Performance Chemicals from BASF

Methods of Analysis

- Microscopy
  - Stereo
  - Polarized Light
  - Comparison
  - Fluorescence
- Microspectrophotometry
- Fourier Transform Infrared Spectroscopy
- Scanning Electron Microscopy with Energy Dispersive X-ray
- Pyrolysis Gas Chromatography – Mass Spectrometry

★ ***To improve confidence in and reliability of analyses for fiber evidence.***

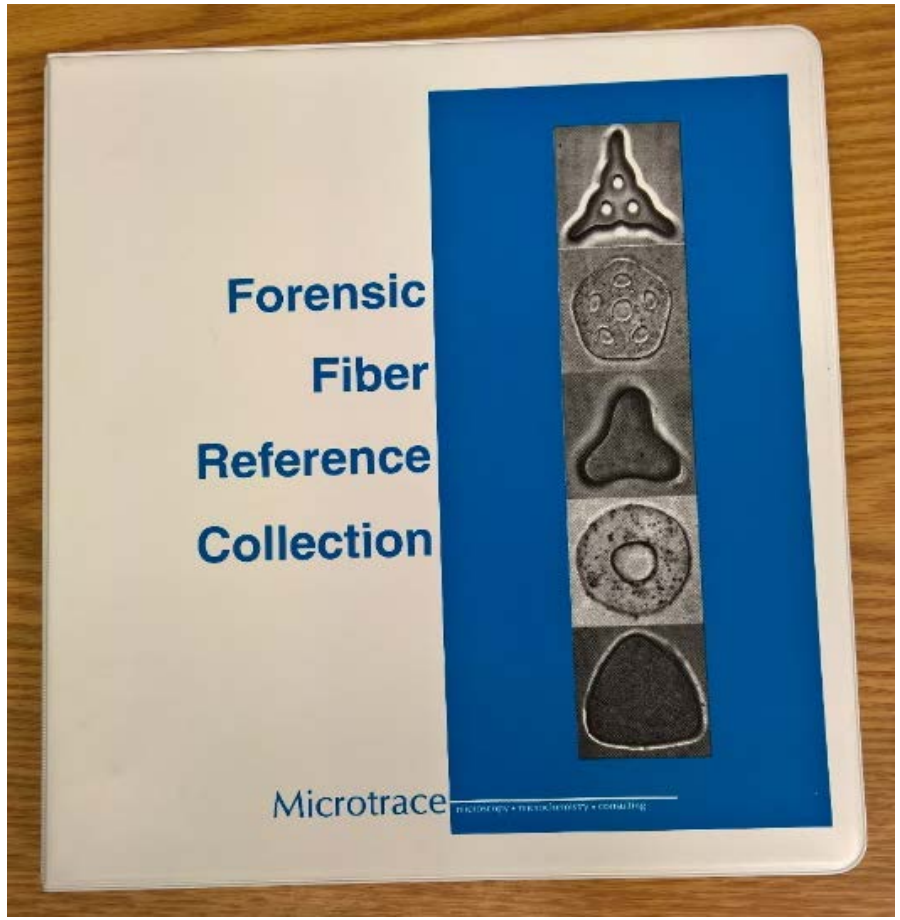
Identify needs and requirements by:

- Examining techniques, instrumentation, and methodology used by forensic science community

Understand potential sources of variability and make recommendations to reduce measurement uncertainty:

- Recommend ways to shift from qualitative observations to quantitative measurements.

Experimental Plan: A 2-Pronged Effort



1. Pre-Compression Measurement of Fiber Characteristics

- Embed fibers in polymer matrix
- Hand-section fibers with razor blade
- Mount thin sections and carbon coat
- Collect images using SEM
- Process images with computer algorithm
- Obtain parameters of interest
- Examine variability within & among fibers

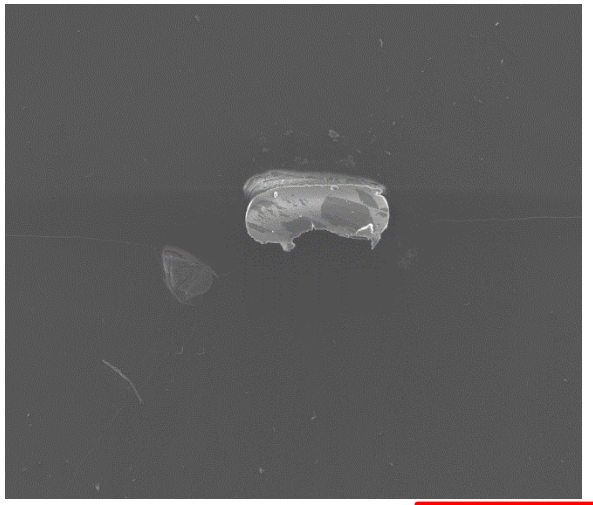
2. Post-Compression Analyses of Fiber Thin Films

- Mount fibers in diamond cell
- Compress at different torques
- Measure film with optical profilometry
- Obtain measurements of film thickness
- Examine variability across compressed areas
- Measure FTIR spectrum at same torques
- Determine if patterns emerge

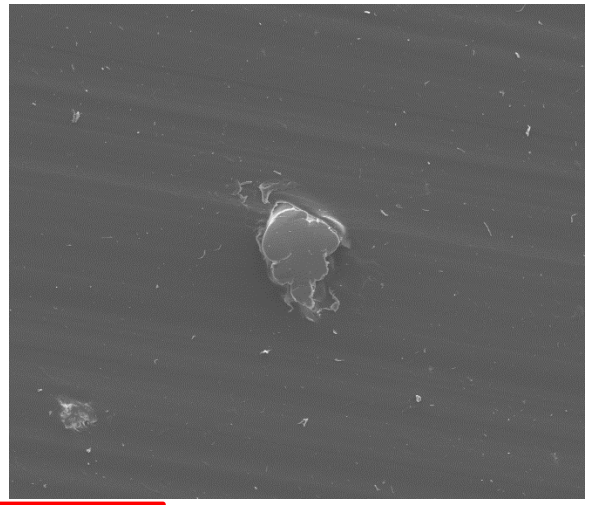
Microtrace Forensic Fiber Reference Collection – https://www.microtracellc.com/service/forensic-fiber-reference-collection/

Pre-Compression: Analysis of Cross-Sectional Images (HFW of images = 144µm)

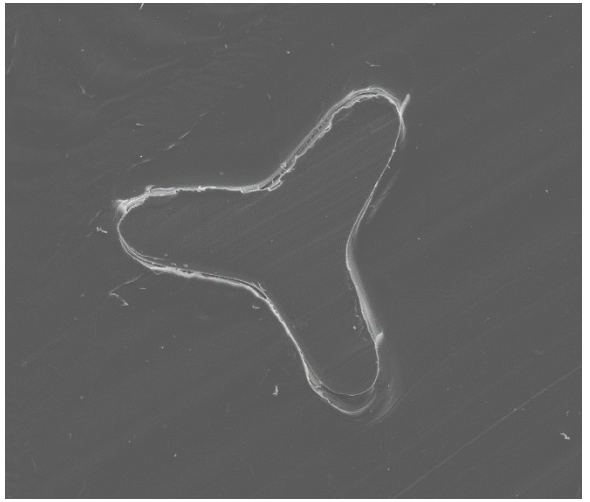
029_Acrylic



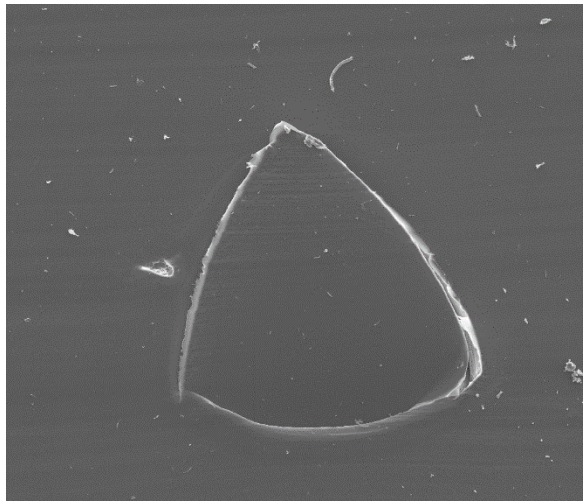
060_Modal



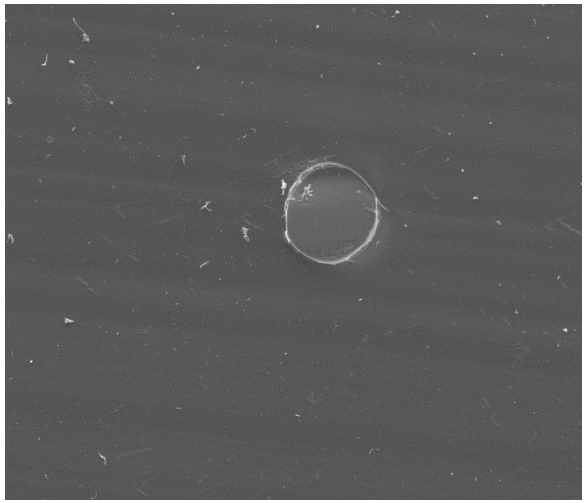
077_Nylon



126_Olefin



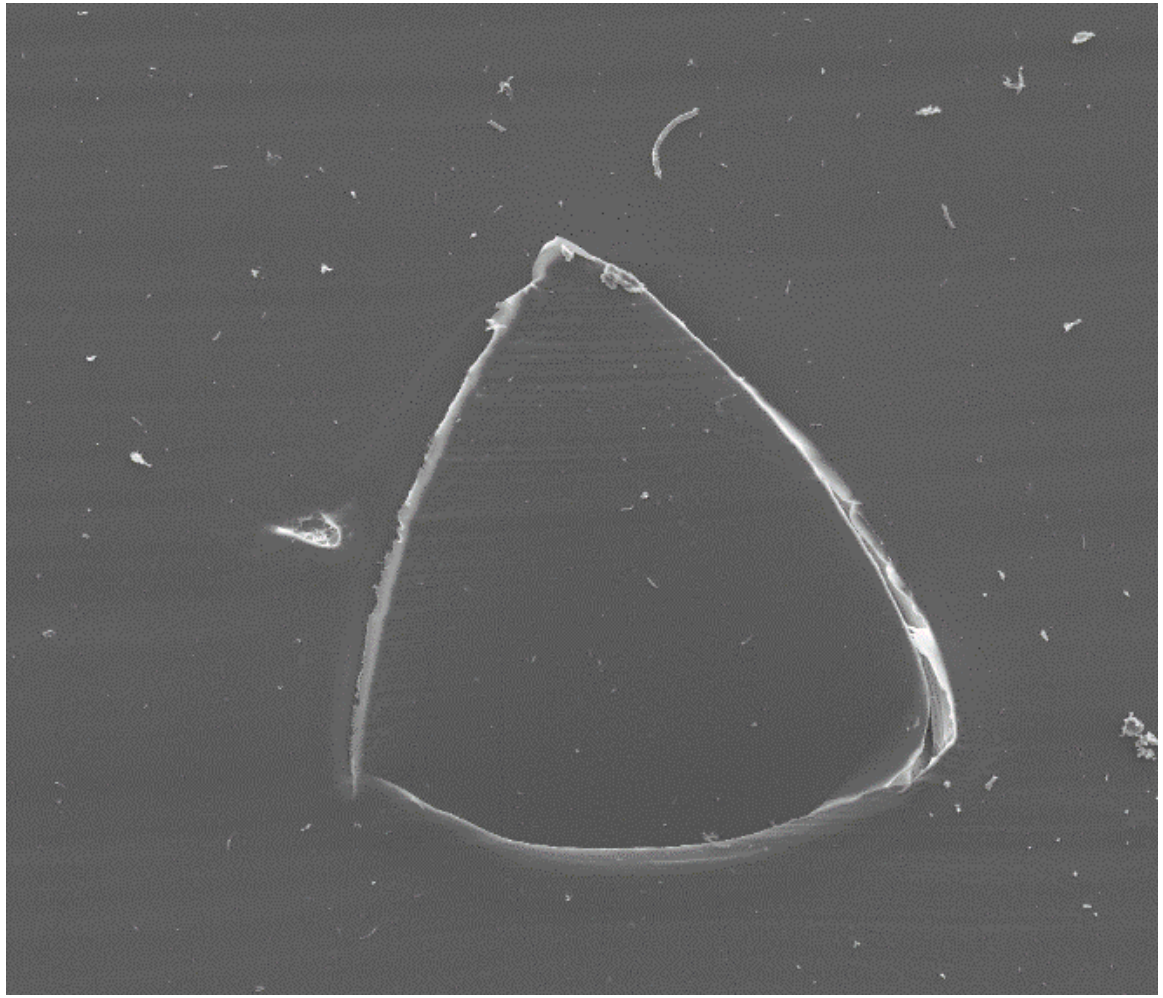
152_Polyester



Pre-Compression: Analysis of Cross-Sectional Images

Image analysis via the *water shed algorithm*:

1. The micrograph can be visually divided into 2 sections, fiber and background, where the bright border acts as a topographic edge. A thresholded image is created as a guess for the algorithm to use.



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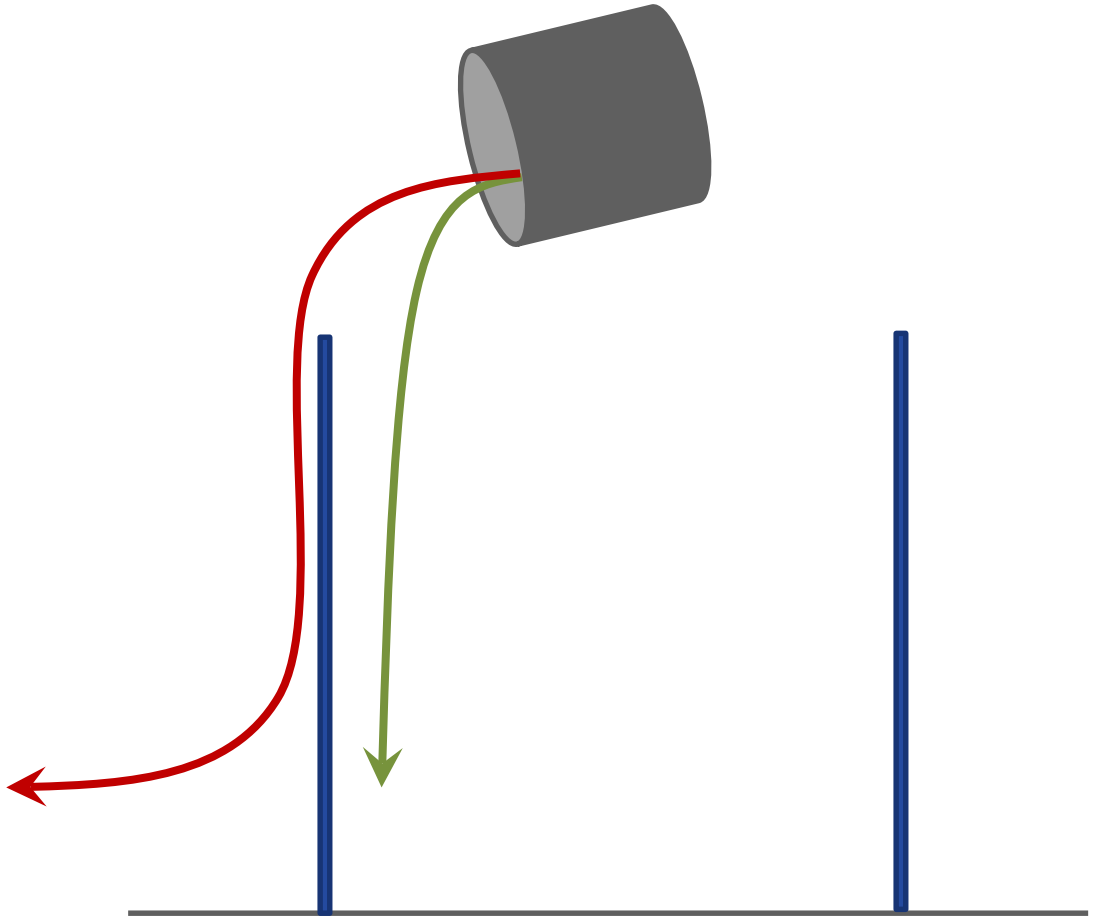

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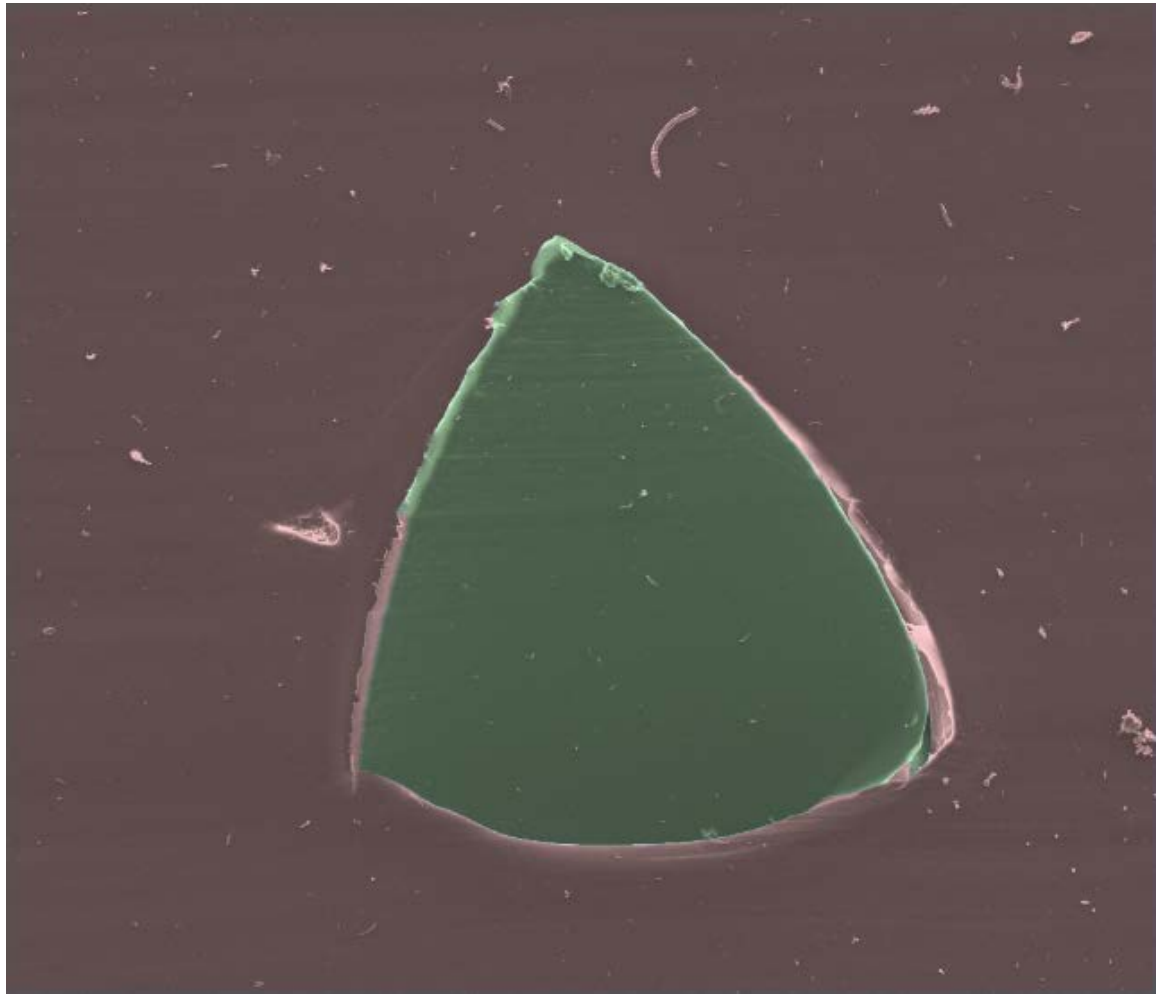

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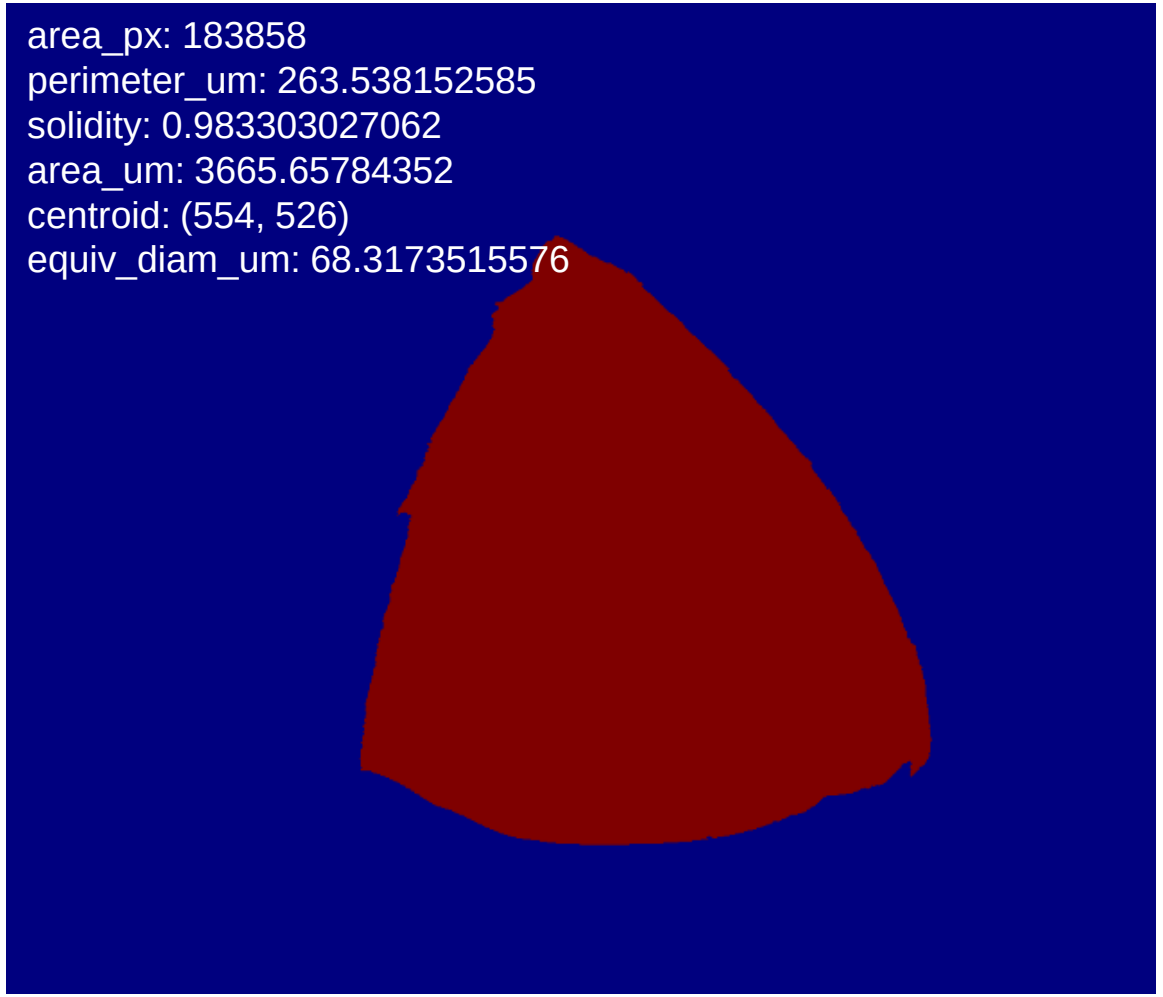
4. Parameters of interest, such as the equivalent diameter are computed



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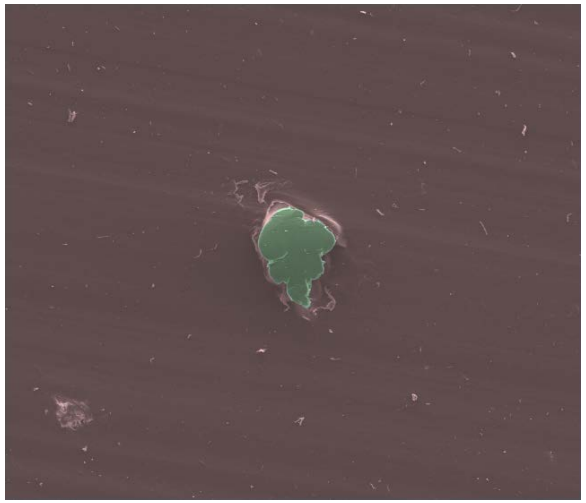

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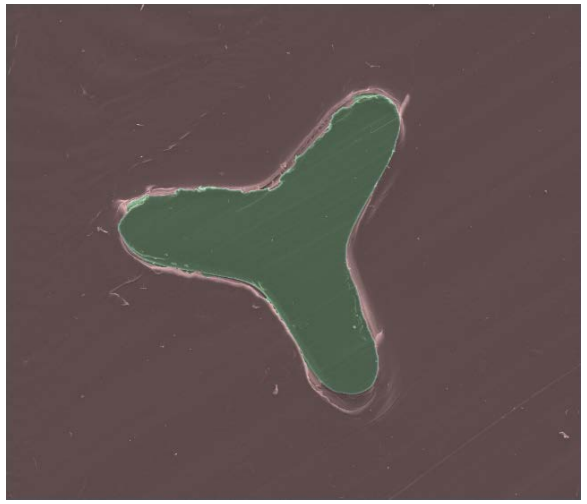

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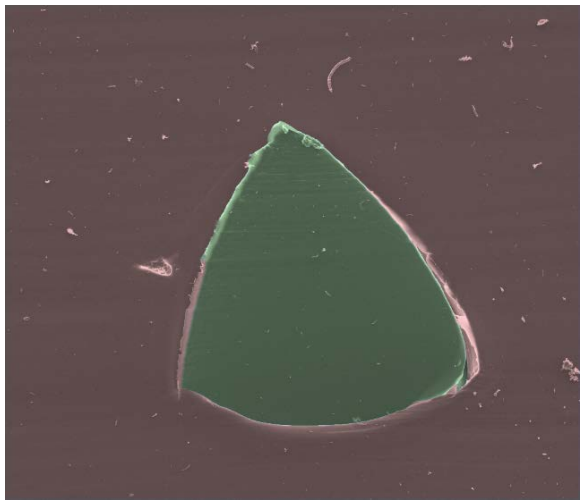

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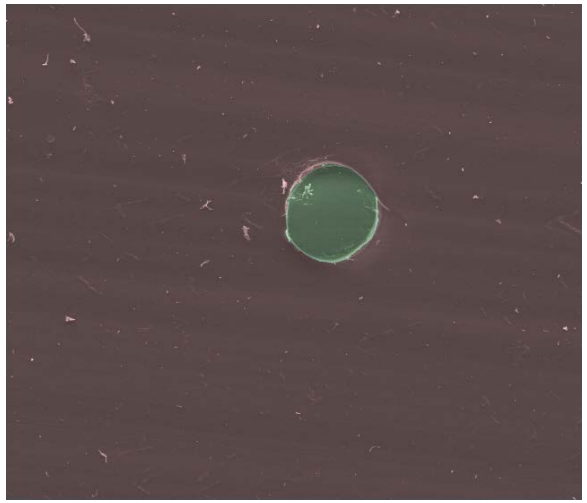

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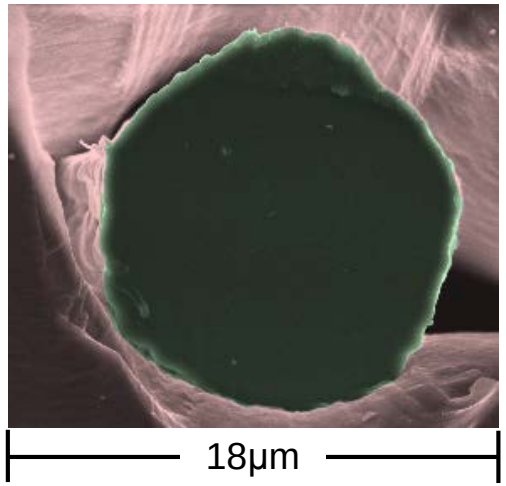

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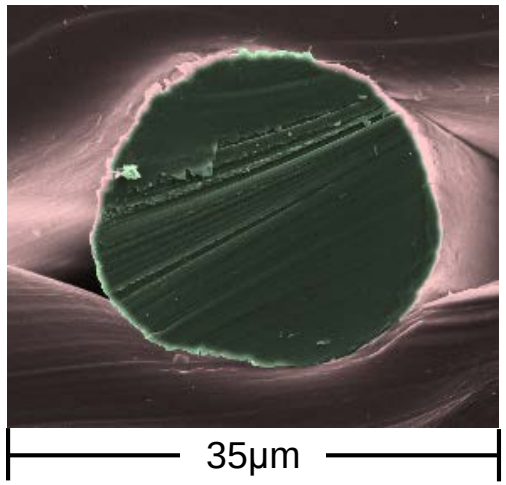

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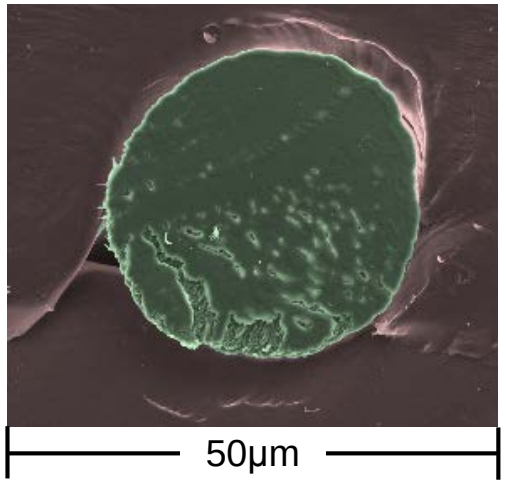

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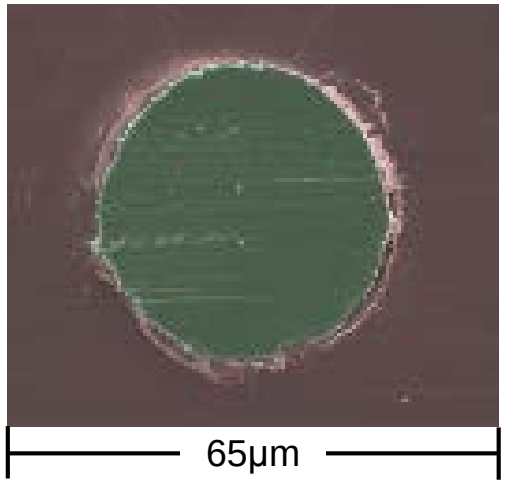
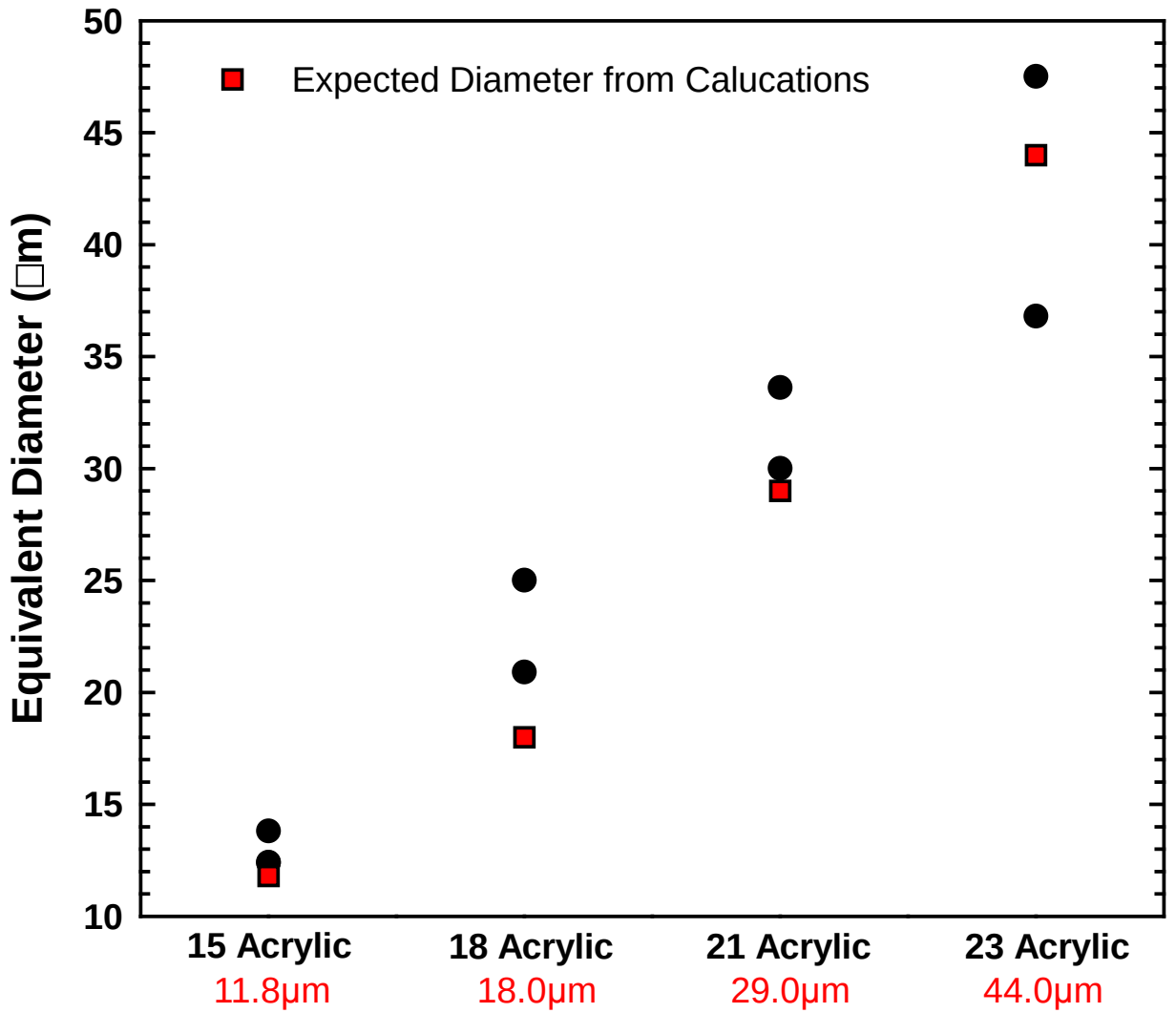
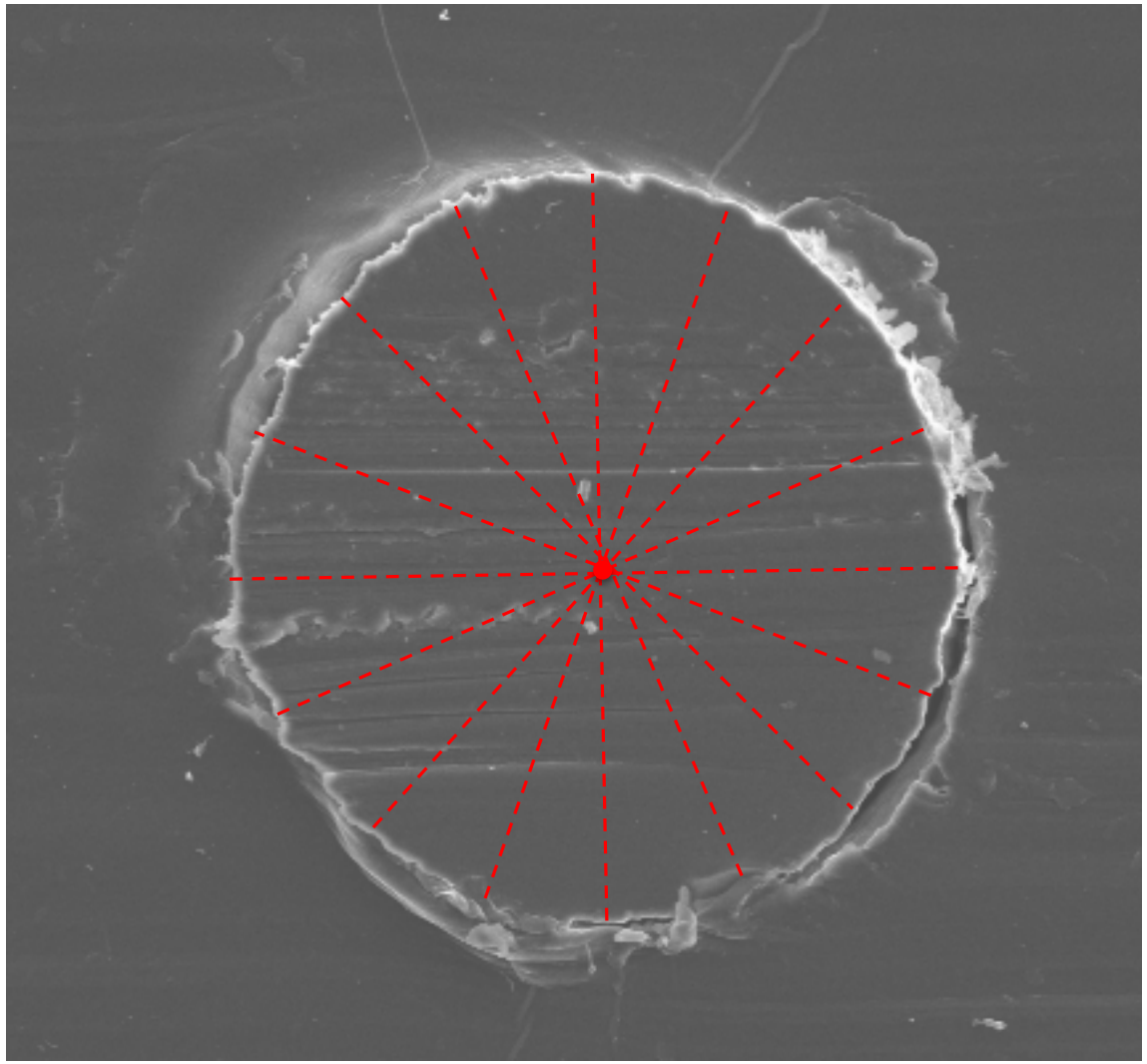
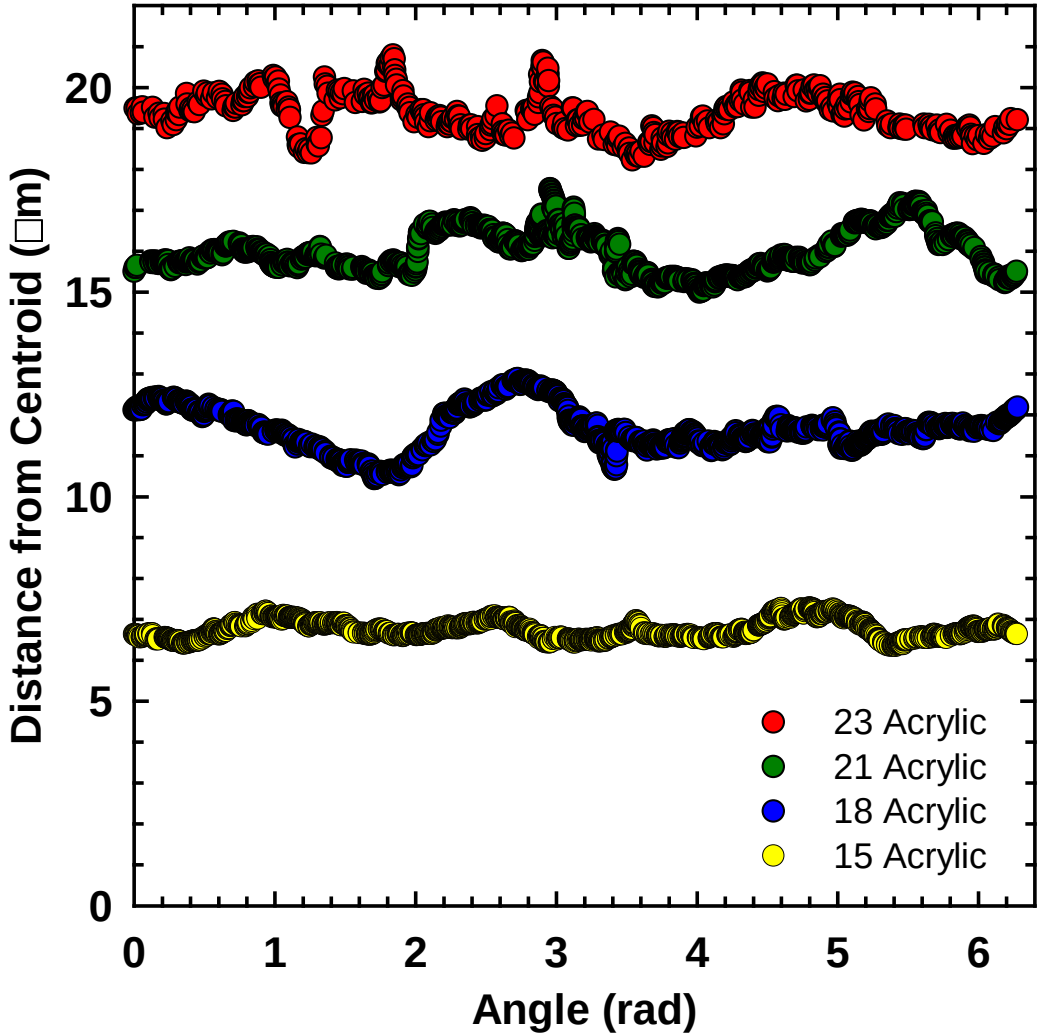




Pre-Compression: Centroid to Radii Distance Measurements





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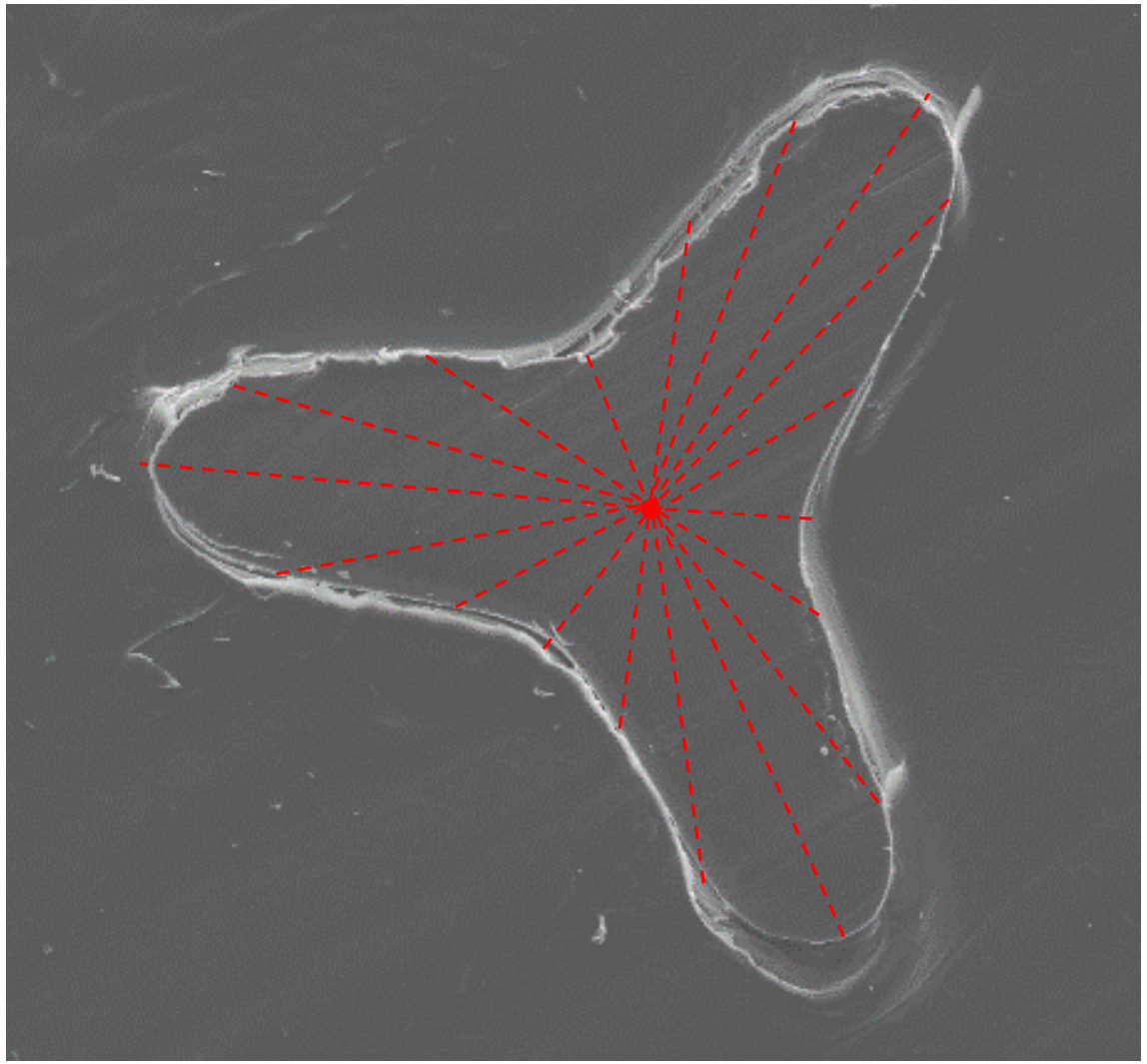

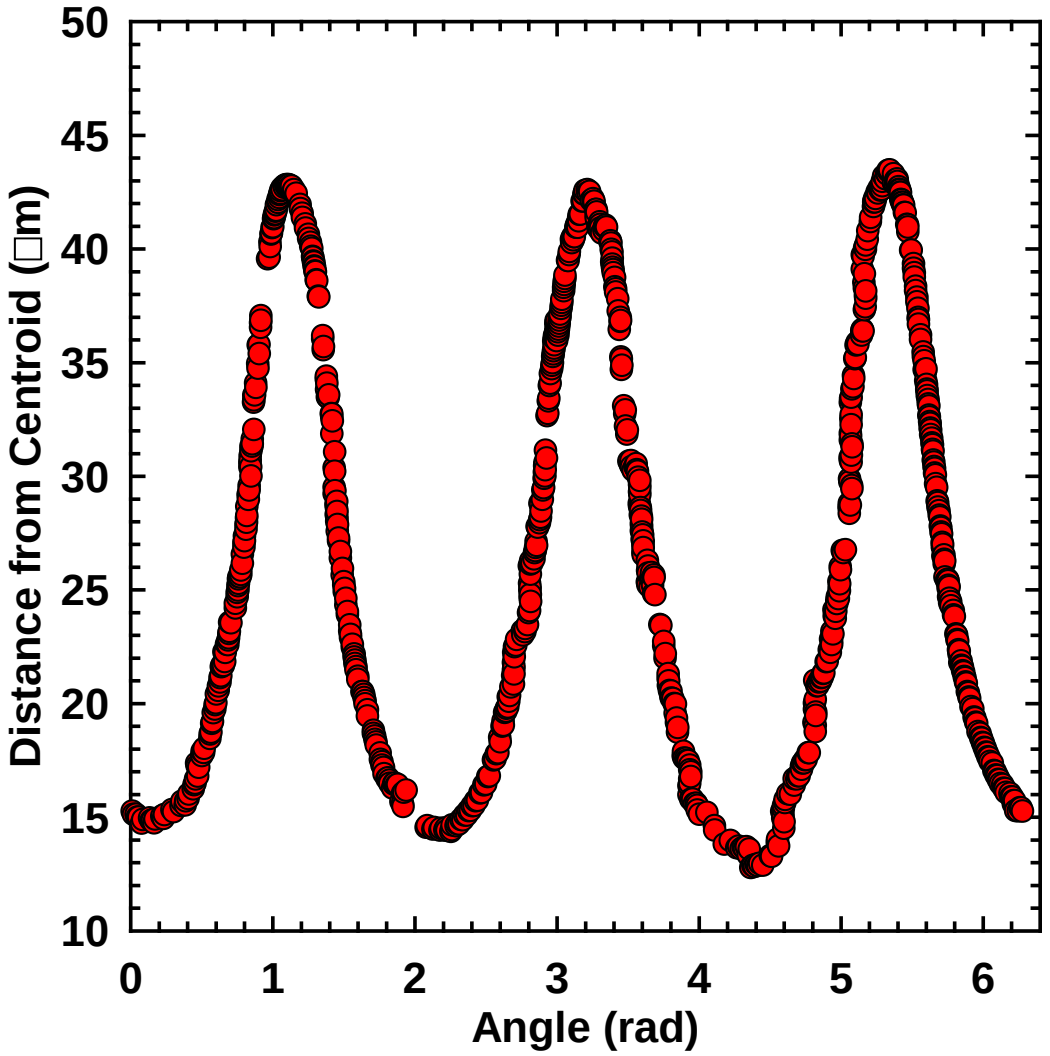

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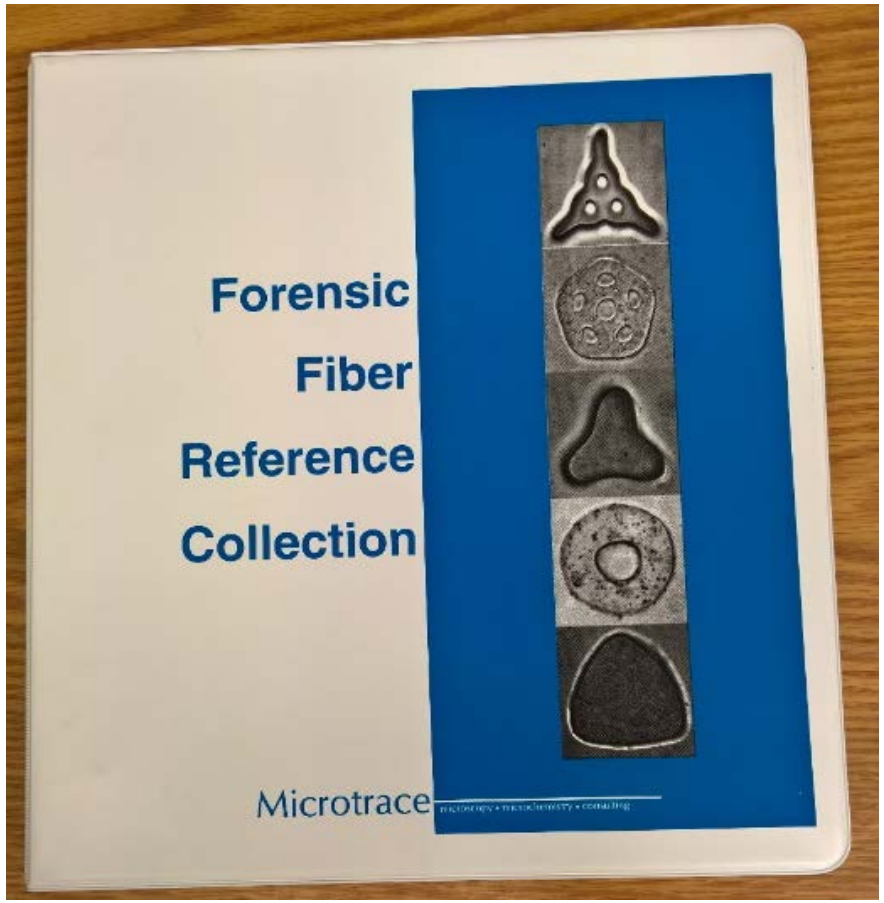

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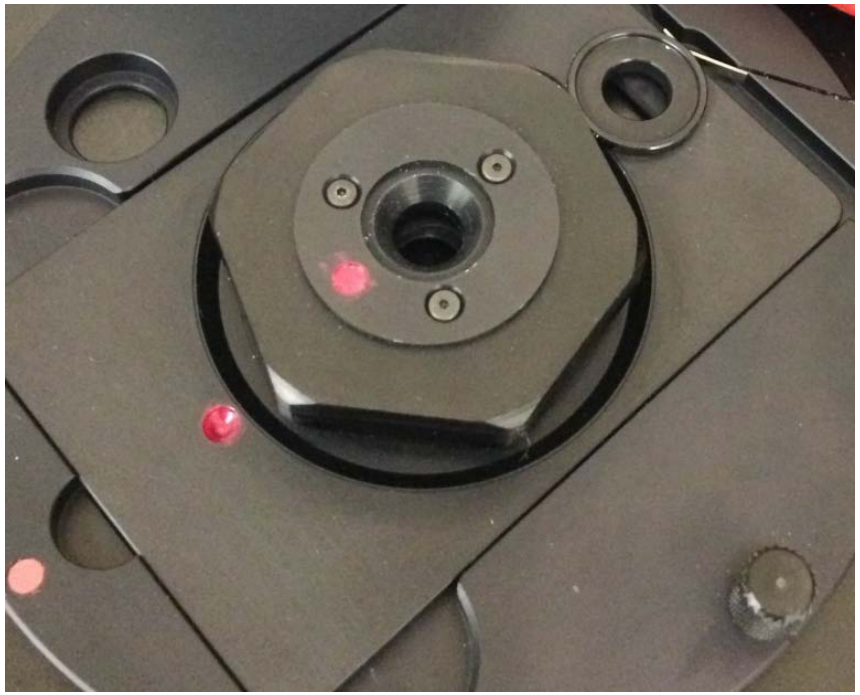
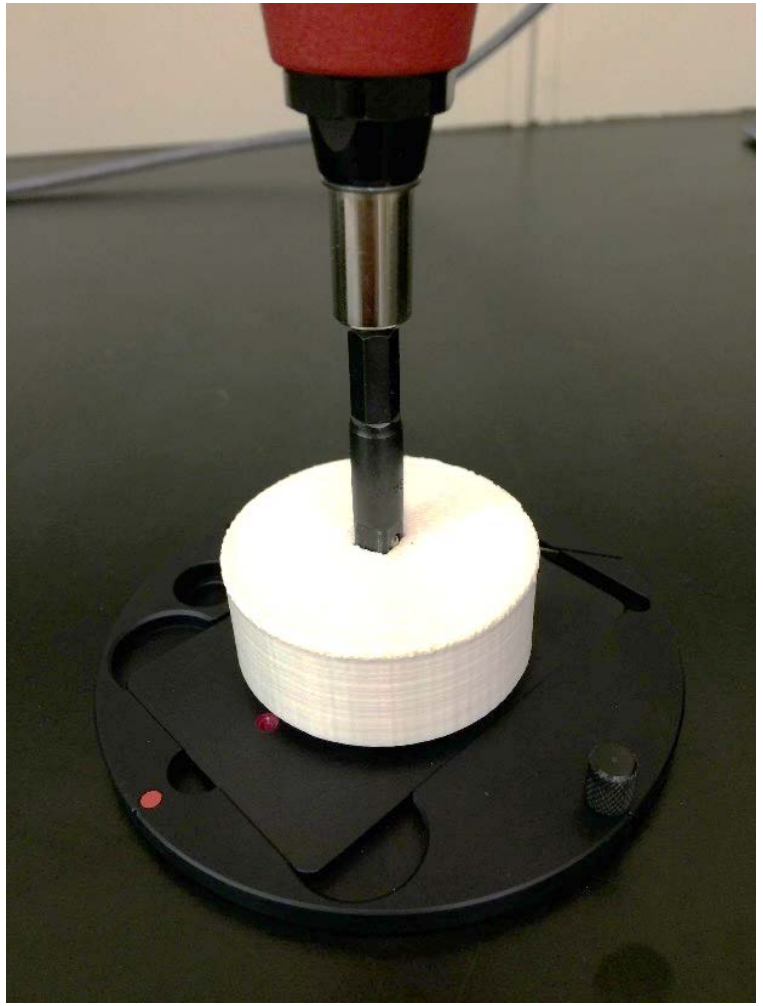
Post-Compression: Understanding Effect of Torque



Diamond Compression Cell

3D Printed Adapter



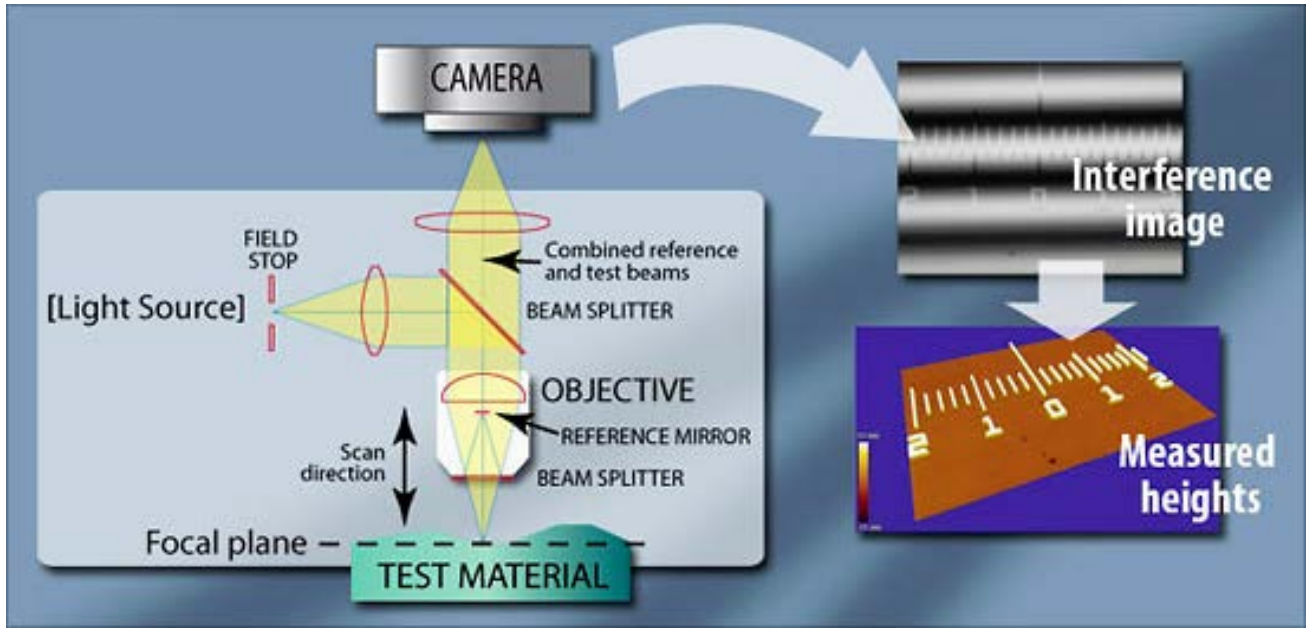
Adapter used with Torque Wrench

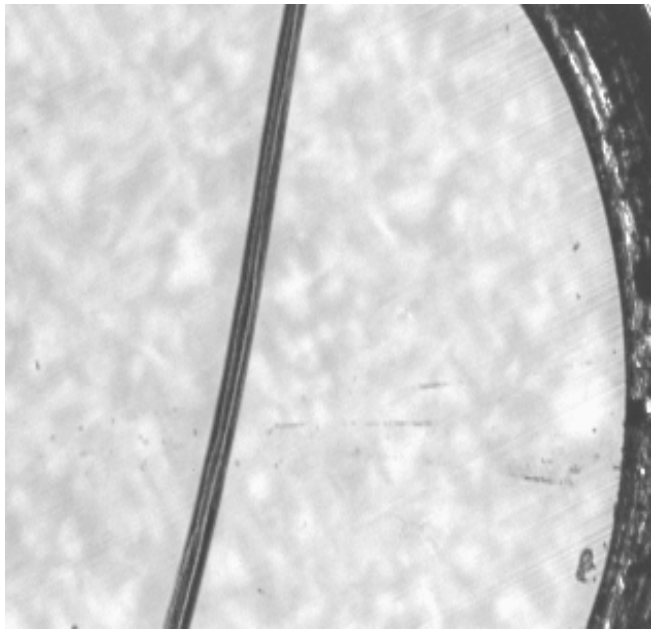
*Torques measured ranged from **4** to **7 in-lb***

Post-Compression: Profilometry of Fiber Films

A profilometer measures the profile of a surface to quantify roughness, or in our case film thickness

- Measuring the difference of light path between a *test surface* and a *reference surface*
- At *equal distances* from the beam splitter, interference fringes are formed
- Fringes are generated by optical path differences *due to height variances* on the test surface

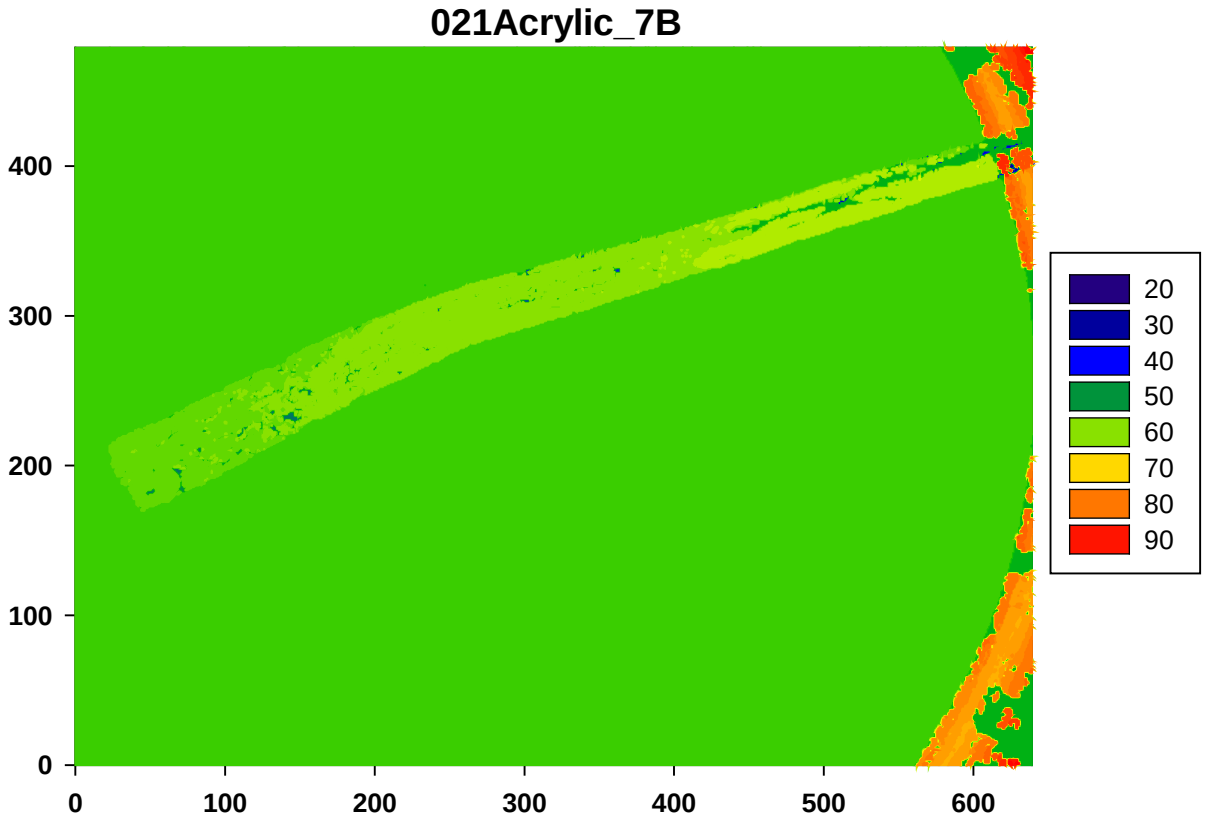


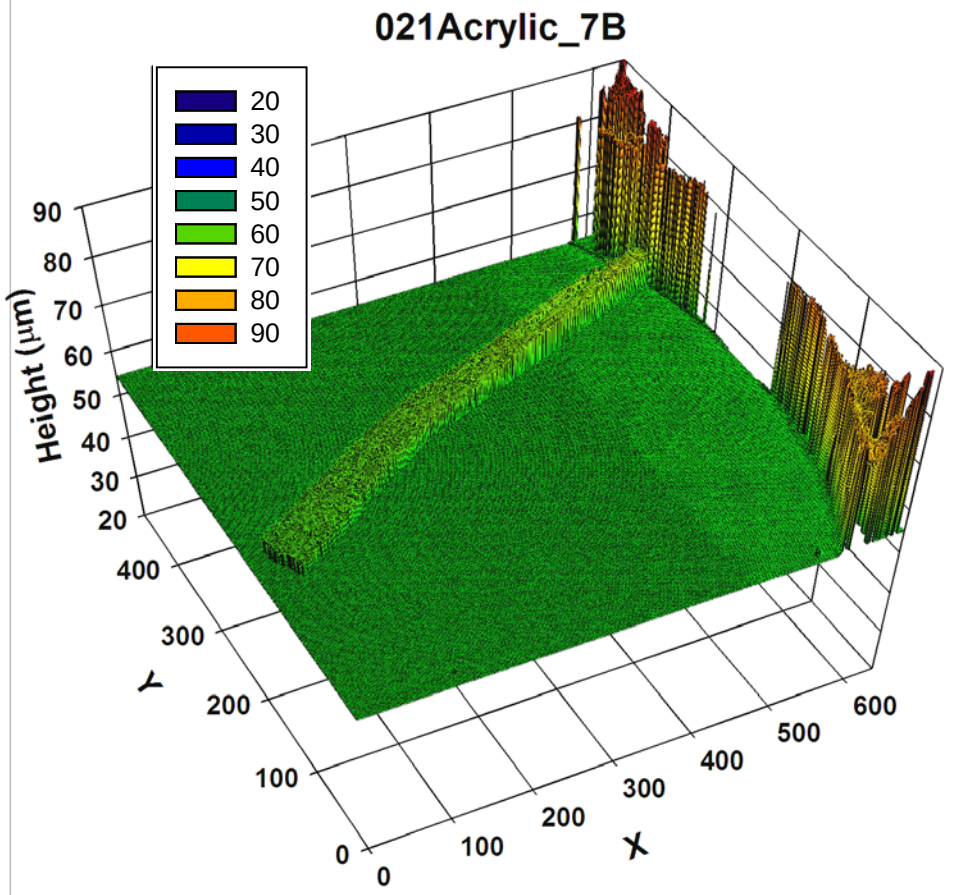


Zygo, “Optical Profiler Basics” – http://www.zygo.com/?/met/profilers/opticalprofilersabout.htm

Post-Compression: Profilometry of Fiber Films

Is the thickness of the fiber film uniform? Does it have variations? What about fiber shape?





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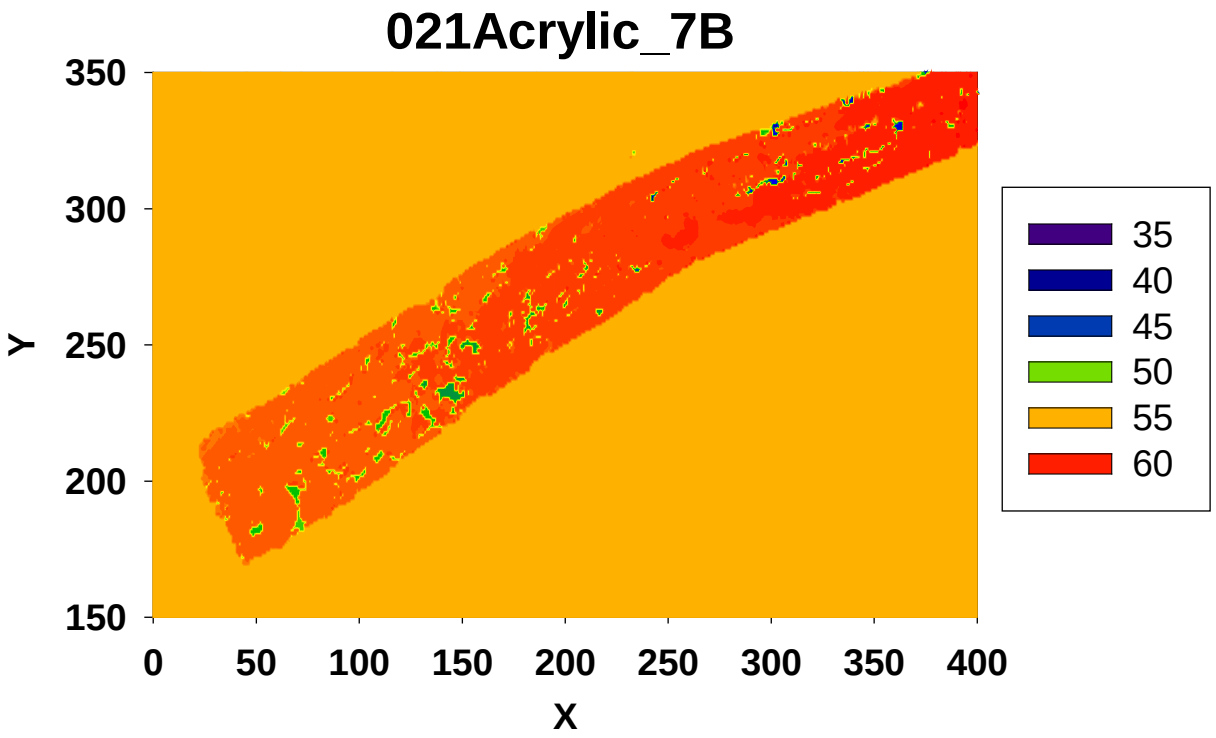
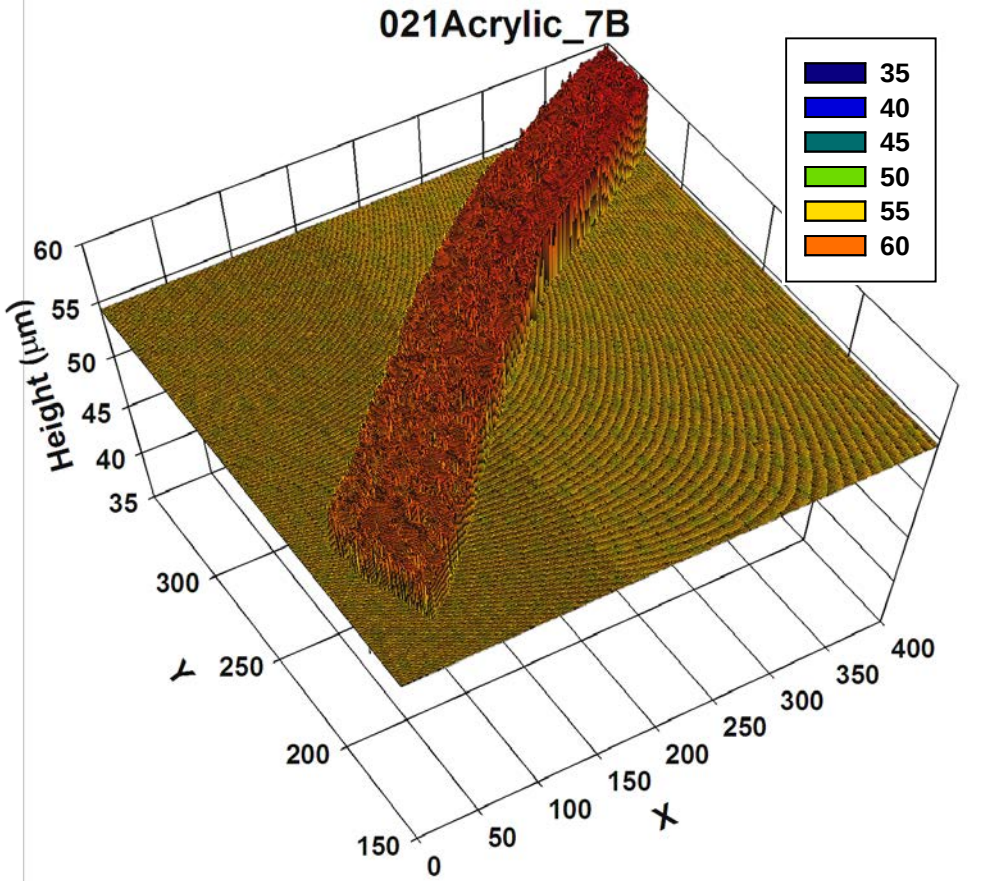
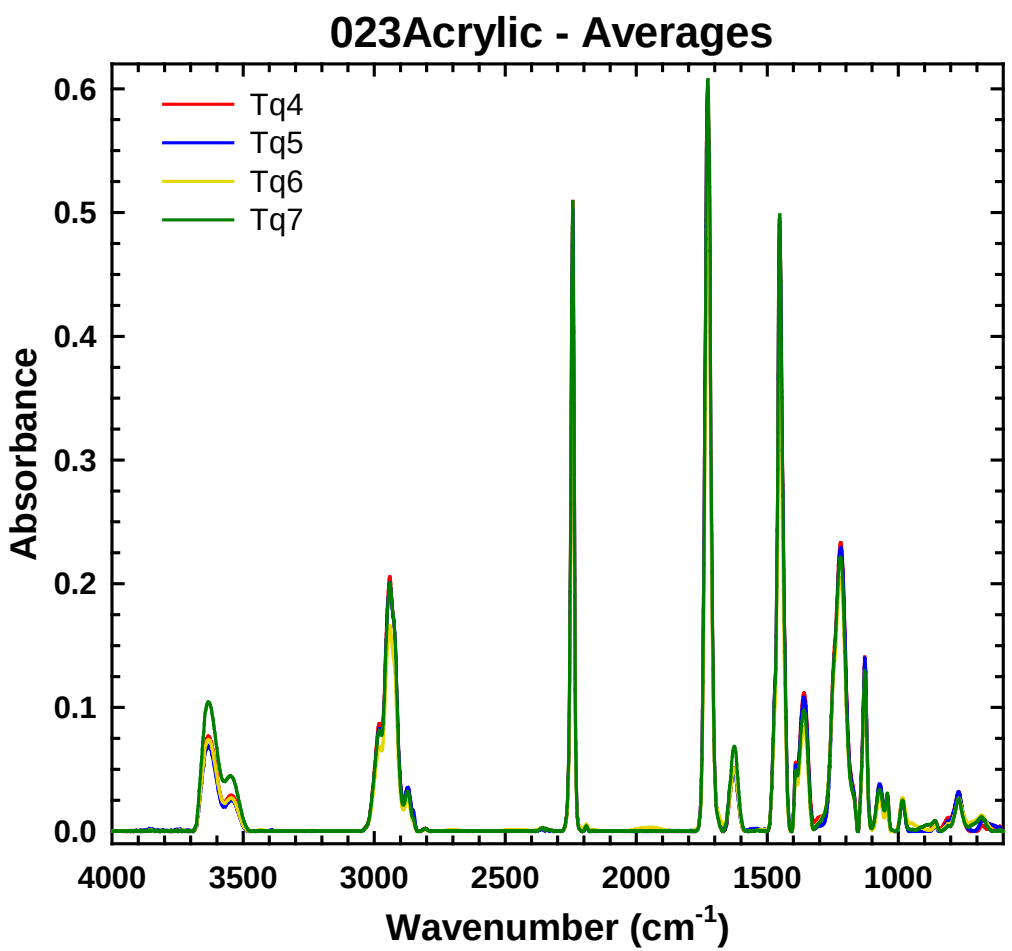
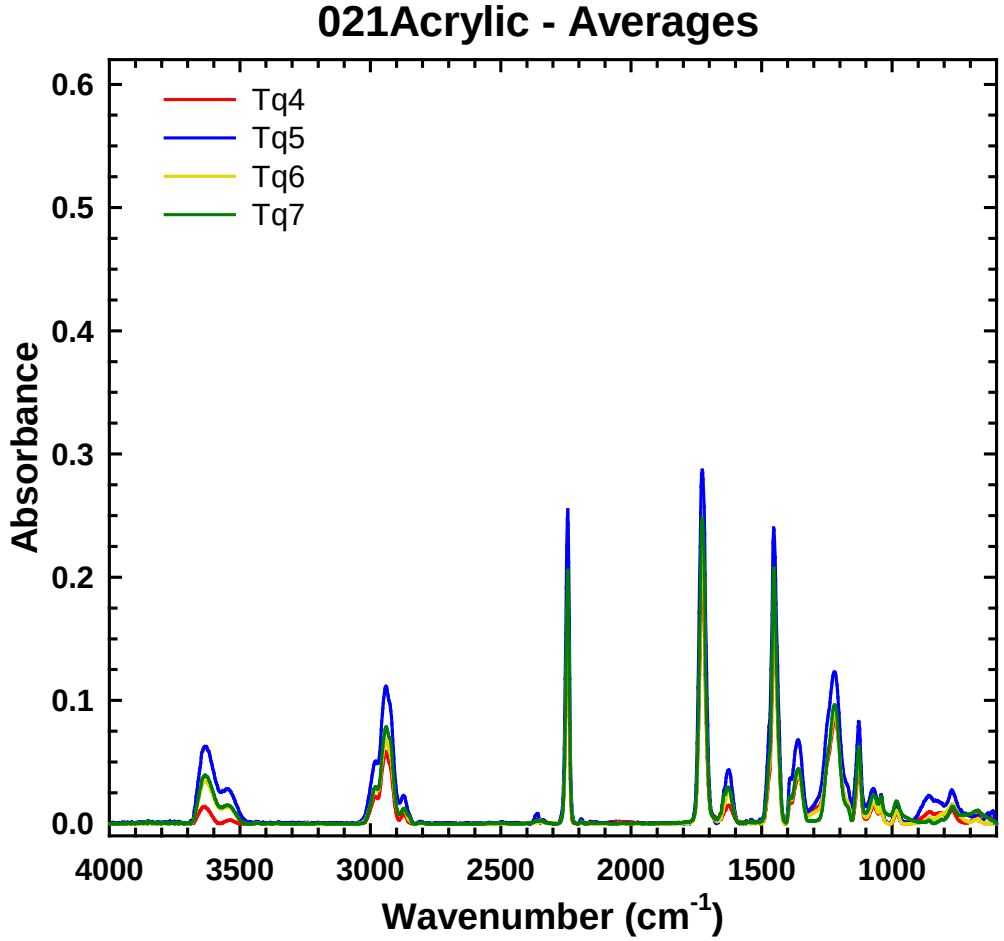




Post-Compression: FTIR of Fiber Films



41.1µm average diameter



31.4µm average diameter

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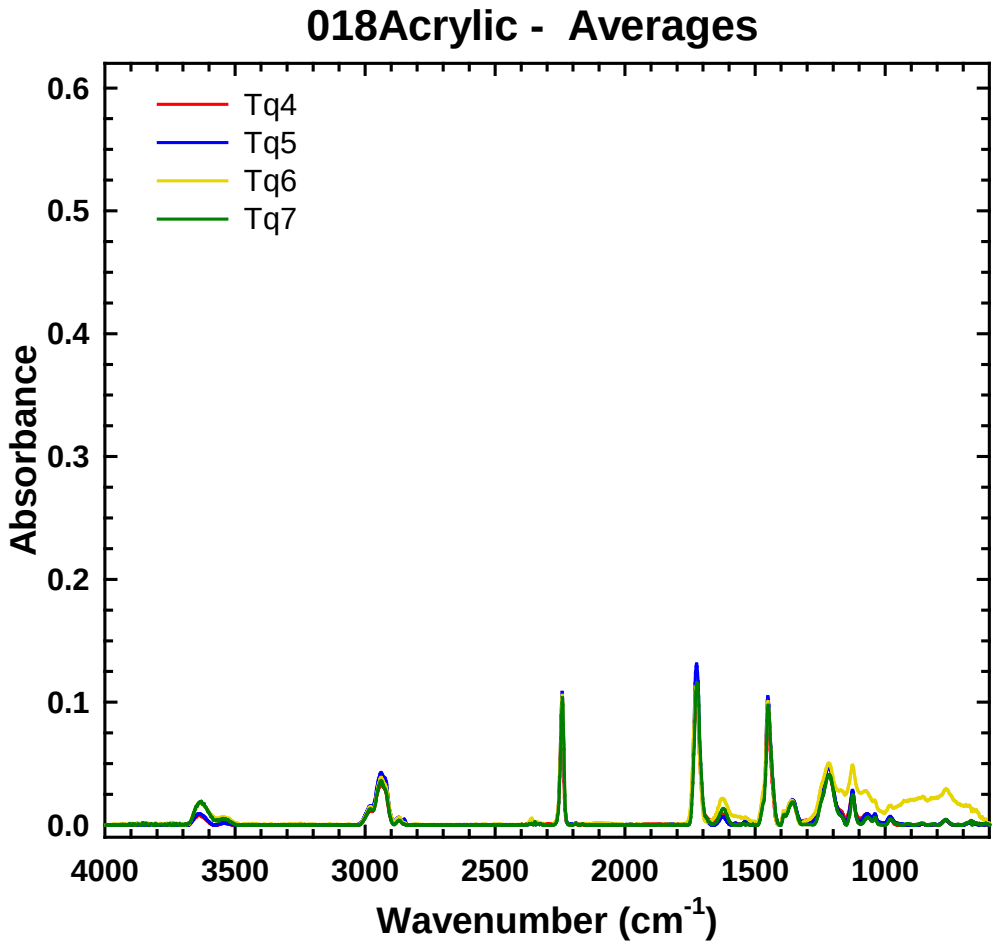
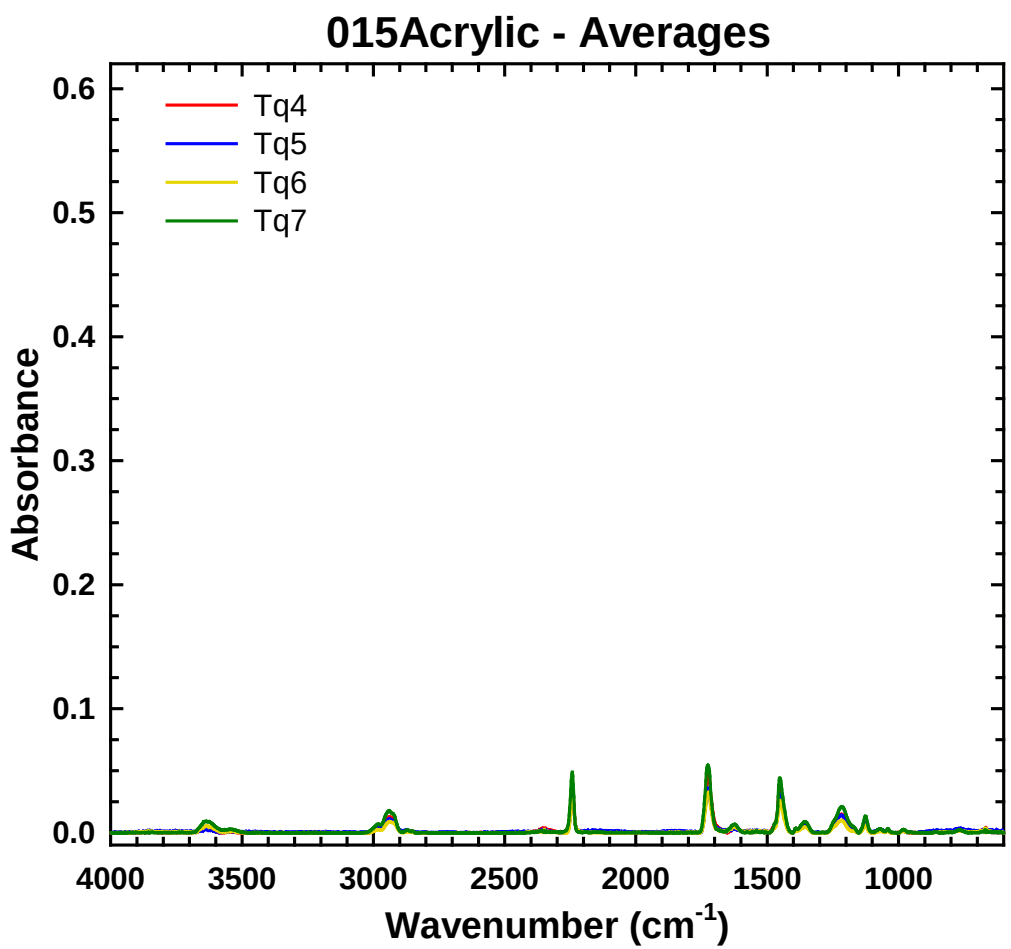


22.6μm average diameter



13.1μm average diameter

Where are we now?

★ ***To improve confidence in and reliability of analyses for fiber evidence.***

Identify needs and requirements by:

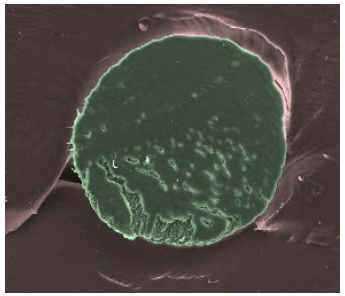
- Examining techniques, instrumentation, and methodology used by forensic science community

Understand potential sources of variability and make recommendations to reduce measurement uncertainty:

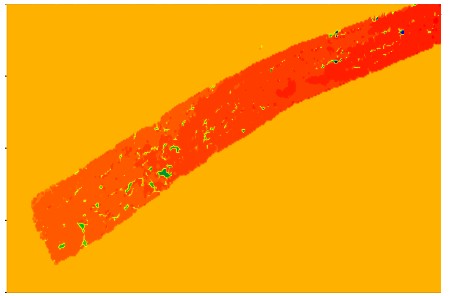
- Recommend ways to shift from qualitative observations to quantitative measurements.

Current Research State:

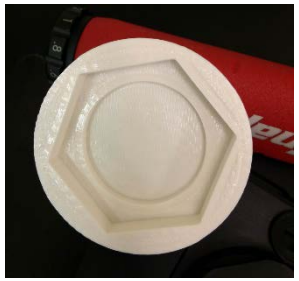
- Examining the use of computer algorithms to aid in image analysis



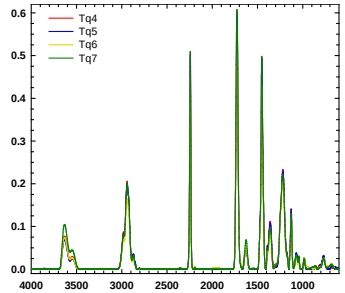
- Measuring fiber film thickness with optical profilometry



- Developed a 3D printed adapter for standardizing compression using a torque wrench



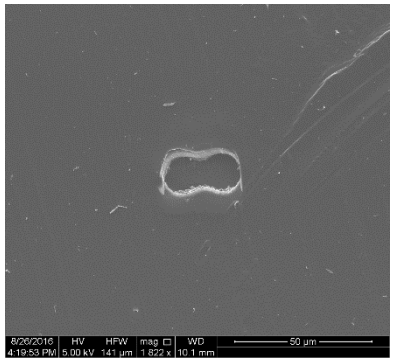
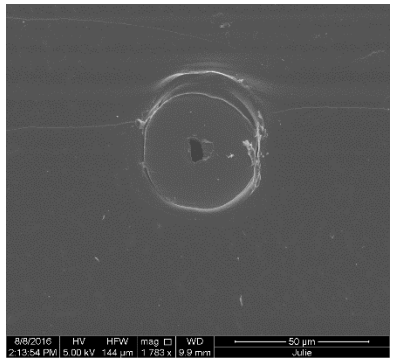
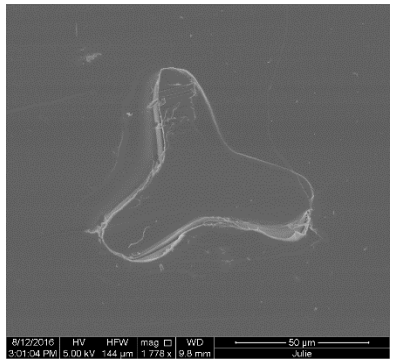
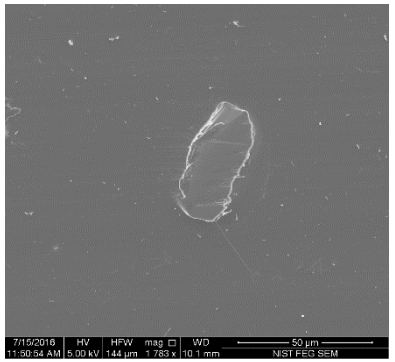
- Exploring the effects of fiber film thickness on FTIR analyses to make recommendation



Future Work and Directions

1. **Continue small scale size study**

2. **Explore the effect of shape on fibers of the same type (acrylic, nylon, etc.)**

3. **Examine how fiber processing techniques may affect compression and analysis**

cabling *heat setting* *color fastening*

twisting *dyeing* *stain protectant*

Thank you for your Attention!

Thanks to:

Eric Steel & Susan Ballou for funding this work

Our undergraduate interns, Sydney Brooks & Ngan Doan

Edwin Chan for use of the profilometer

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Amanda Forster – amanda.forster@nist.gov, 301-975-5632

Jack Glover – jack.glover@nist.gov, 301-975-8821