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# THE EFFECT OF FLATTENING ON NYLON CARPET FIBERS AS STUDIED BY VISIBLE MICROSPECTROPHOTOMETRY

By

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ABSTRACT

THE EFFECT OF FLATTENING ON NYLON CARPET FIBERS AS STUDIED BY VISIBLE MICROSPECTROPHOTOMETRY

By

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In this project, different colored nylon carpet samples were studied to determine the effect of flattening on their visible spectra using the technique of microspectrophotometry. If flattening the fibers had an effect on their spectra, then the order of analysis for forensic scientists would be critical. Fifty-one samples were tested. The diameters of the fibers were measured initially, as well as after two flattening stages, one using a roller ball, and one using a pellet press. Predictably, the diameters of the fibers were enlarged with each flattening. However, there was no consistency as to the increase in diameters. Using the visible light range of an S.E.E. 1000 Microspectrophotometer, spectra were obtained for each fiber. Analysis of the results showed that, while there was no change in the spectra of several fibers, a disappearance, or dropout, of peaks was observed in 52.9%, or 27 out of 51 spectra. In addition, a decrease in the absorbance occurred as the fibers were flattened. The decrease in absorbance was expected because as a fiber is stretched out, it becomes more transparent, allowing more light to pass through. Based on the results from this study, the order of analysis is critical for forensic scientists. It is imperative to perform infrared spectroscopy prior to microspectrophotometry due to the fact that dropout, or disappearance of peaks may occur.

## DEDICATION

This thesis is dedicated to my wife, Sofia Metz. Without her influence and support, none of this would have been possible. She is my sole inspiration and for that I thank her.

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# INTRODUCTION

Fiber analysis plays an integral role in forensic science investigation. In fact, "Fibers are the most frequently encountered type of trace evidence."[1] A suspect or victim can be associated with a particular location by minute fibers that are transferred to or from the clothing in question. Most fibers that are transferred go unnoticed by the human eye, only detected upon further examination in a laboratory. The key to fiber examination is to determine whether or not a material could be responsible or associated with the fibers collected at a crime scene. There have been several studies, and there is much discussion, as to which is the best way to examine fiber evidence. The ultimate determination of how fibers are analyzed depends upon the instruments available in a particular laboratory. There are advantages and disadvantages to each type of analysis. However, each analysis relies on some type of microscopic examination as well as spectral examination, such as Fourier transform infrared spectrophotometry (FTIR), pyrolysis gas chromatography (P-GC), or microspectrophotometry.

Although there have been numerous studies on how best to analyze fibers, not many of the studies address the issue of whether or not questioned fibers will inherently be affected by the harsh environmental conditions to which they are exposed. Specific problems may arise when a questioned fiber is flattened, stretched or frayed as it is exposed to various environmental conditions at a crime scene. One question that arises is whether or not a flattened fiber has the same visible spectrum as one that has not been exposed to the elements. The reason that this flattening study was done is because many forensic scientists use FTIR to analyze fibers. Before putting a fiber in the instrument it must be flattened when performing FTIR. The question arises then, if the visible microspectrophotometry should be done before FTIR, which would be the case if flattening had an effect on the visible spectrum of the fiber. If flattening has no effect, then it does not matter in which order the tests are completed.

## Background of Fibers as Evidence

Fibers are either natural or man-made. A textile material can be made from either man-made or naturally occurring fibers, or a combination of both. Naturally occurring textile fibers include animal, vegetable, and mineral fibers.[2] These comprise only 25% of textile fibers. Man-made fibers account for 75% of textile fiber production in the United States. There are numerous man-made fibers in use today. The majority include a combination of: rayon, acetate, nylon, acrylic, polyester, and olefin.[3] However, three types of man-made fibers are predominantly used in the construction of carpets—polyester, olefin, and nylon. These three types of fibers consist of long-chain synthetic polymers. Because nylon comprises a large percentage of carpet fibers and they are more likely to be found at a crime scene than other types of carpet fibers, nylon carpet fibers were chosen for analysis in this study.

The important role of fibers in the forensic field is evident from the amount of research that has been done on fiber identification. The exchange principle, formulated by Edmund Locard in 1928, states that whenever two objects come into contact there is always a transfer of material.[4] Pounds and Smalldon expanded upon the Exchange Principle in a series of studies they performed in the 1970's, in which they studied fiber transfer, persistence and recovery.[5] In addition to Pounds and Smalldon's studies which demonstrated the forensic importance of fibers, the Wayne Williams trial of 1981-1982 cemented fiber analysis as an integral part of forensic science. Due to the important developments over the years, fiber research is an invaluable tool that can assist today's forensic scientist.

## Microspectrophotometry

Microspectrophotometry focuses on a molecule's ability to absorb radiation. Microspectrophotometry can analyze reflectance, transmittance/absorbance, and fluorescence of light. This study focused on the transmittance/absorbance of white light as it was exposed to a nylon carpet fiber. When a molecule is exposed to a beam of white light (light in the visible spectrum), the molecule absorbs certain wavelengths of that light. The remaining wavelengths are reflected or transmitted, passing through the molecule. The darker the object, the more light it absorbs. Lighter colors do not absorb much light, allowing more of it to pass through than darker colors. The result of the amount of light absorbed or transmitted at a specific wavelength is recorded in a spectrum (See appendix E for examples of spectra). The wavelength is reported on the x-axis and is done so in nanometers (nm), reflecting the numerical values of colors in the electromagnetic spectrum. The y-axis records the ratio of the intensity of the color. In this study, the data was analyzed using the absorbance value. Absorbance ranges between 0 and 2 and has no units.

The wavelengths that pass through the item, in this case a carpet fiber, are recorded in a spectrum which correspond to a specific color from the electromagnetic spectrum. Often times, however, we encounter fibers that appear to be the same color to the eye, but are in fact, different. When two colors appear to be a visual match under one lighting condition but not another, they are considered to be a metameric pair. In other words, they have different spectral curves. Thus, microspectrophotometry is a valuable tool that can differentiate between metameric pairs because it can detect minute differences in color variations.

Not only can a microspectrophotometer differentiate between minute color differences, but the technique requires little sample size, it is non-destructive, requires little or no prep time, it is quick and the data can be stored for future comparison, or it can be compiled in a spectral database if desired.[6] Nondestructive tests of fibers are preferred when the sample size is extremely limited because the evidence is preserved for possible later analysis.[7] Also the fiber evidence will be available for opposing counsel to analyze as they may see fit.[8]

# LITERATURE REVIEW

As there are many different types of fibers, there are also many different ways to analyze those fibers. Depending on the degree of identification desired, the analyses can range from microscopy and melting point analysis, to instrumental analysis, such as FTIR, P-GC and microspectrophotometry.

Each type of analysis is employed for a specific reason. For example, melting point analysis can help differentiate between types of fibers by studying optical activity. As the temperature is increased at a constant rate and the melting point is approached, the birefringence and internal colors begin to disappear.[9] Continuing on, observation reveals that the fiber melts internally prior to losing its shape. Comparison to a melting point chart can then assist in the identification of a fiber. However, a disadvantage of using analysis of the melting point is that it is destructive, causing partial or complete loss of the fiber in question.

The fact that the sample is destroyed is also problematic with the instrumental analysis of P-GC. Although P-GC is useful because it can be used to obtain a "fingerprint" of the fiber based on chemical composition, it does have two disadvantages. First, P-GC is destructive. Second, because programs are dependent on pyrolysis and column conditions, they are sensitive to day-to-day and laboratory-to-laboratory variations.[10] Thus, a reference collection of spectra is not as useful as a collection of Infrared spectra. Infrared Spectroscopy (IR), especially FTIR, is a great analytical tool and will help "match" or identify certain fibers if there is access to a spectral database. However, for FTIR to be utilized, the fiber must be flattened, which may have an effect on the spectrum.

Whereas fibers are destroyed or altered during most other types of instrumental analysis, microspectrophotometry neither destroys nor alters a fiber's structure. As Gaudette stated in his chapter entitled *The Forensic Aspects of Textile Fiber Examination*, written in Richard Saferstein's *Forensic Science Handbook, Vol. II,* "Microspectrophotometry is a convenient way to record the visible spectrum of even small amounts of fibers without removing them from the microscope slide. The fiber on the microscope stage becomes the sample compartment of the spectrophotometer."[11] Thus, microspectrophotometry demands little preparation time and does not destroy the fiber. In addition, microspectrophotometry is valuable because it can distinguish between metameric pairs, meaning, it is possible for two fibers to appear indistinguishable in color with comparison microscopy, and yet have different UV-visible absorption spectra. Macrae, Dudley and Smalldon, in a 1979 study of wool fibers compared microspectrophotometry to two other methods of analysis, dye extraction coupled with thin layer chromatography and solution spectrophotometry. Macrae et al determined that, "Microspectrophotometry produced discriminating powers similar to those obtained for the two destructive methods on samples five hundred times larger."[12]

As the aforementioned literature mentions, microspectrophotometry is an important aspect of forensic fiber identification, having great discriminating power, using little sample size, as well as being non-destructive. There is limited research, however, involving fiber research and microspectrophotometry. As Katherine Wydeven notes in her research regarding the effect of flattening polyester fibers, "Publications from several decades ago use double beam microspectrophotometers, different from the S.E.E. 1100 instrument that was used in this analysis."[13] This study used an S.E.E. 1000 microspectrophotometer, similar to the single beam S.E.E. 1100 microspectrophotometer used by Wydeven.

Fiber research is governed by guidelines published in 1999 by the Scientific Working Group for Materials Analysis, known as SWGMAT. The guidelines were created to provide uniform testing protocol for fiber examination. Known as the Forensic Fiber Examination Guidelines, SWGMAT's guidelines include everything from sample preparation to range of wavelength analyzed. For example, the guidelines instruct analysts to maintain a log of daily instrument calibrations, to conduct analysis using the same conditions each time, and to run blanks and sample scans in order to ensure the quality of data. In addition, the fiber guidelines state that, "At least five and as many as ten locations along a single fiber or fibers may need to be scanned if the measurements are needed to produce a representative mean absorbance curve and standard deviation curves for an individual fiber."[14]

Dunlop and Adolf have conducted studies involving microspectrophotometry and the amount of natural variation within a single fiber. In *Forensic Examination of Textile Fibers,* Dunlop and Adolf concluded that, "natural fibers have much more color variation than synthetic fibers."[15] SWGMAT guidelines also warn that natural occurring fibers may require more scans due to the possibility of irregular color distribution whereas man-made fibers are more prone to have uniform distribution of color and require less scans to produce a mean absorbance curve. Because this study analyzed the average absorbance curve of synthetic fibers, it was necessary to follow the SWGMAT guidelines and conduct scans at five locations along the questioned fiber.

Because this research analyzed the possibility of spectral shift as a fiber is flattened, it is imperative to understand the pre-determined allowance for error when analyzing the spectral data. Macrae et al. developed a procedure for comparing fiber spectra while conducting research involving two fibers from the same swatch. Their results concluded that, "The largest difference between any corresponding values for duplicates was five nanometers (5 nm)."[16] Thus, any change within a five nanometer range is acceptable proof that the spectra are representative of the same fiber.

METHODS & MATERIALS

Residential carpet fiber samples from five separate manufacturers were obtained and analyzed in this study (Appendix A, Table 1 is a list of all fiber samples by number and manufacturer). All fibers used were 100% nylon and manufactured by one of the following: Hamilton Carpet Mills, Horizon Creations, Dimension Carpets, Dupont Stainmaster and Aladdin Networks. These carpet samples were obtained from retail stores throughout the greater Ft. Lauderdale, Florida area. Analysis of the fiber samples was performed at the Broward Sheriff's Office Crime Lab Trace Evidence Unit.

Out of the hundreds of carpet samples obtained for this study, a wide array of colors was chosen for analysis. The colors chosen for analysis were green, red, purple, blue, brown and black/gray. In total, fifty-one different types of carpet samples were chosen for analysis (Appendix B, Table 2 separates fibers by color). The procedure followed in this study was the same as that used by Katherine Wydeven in her research regarding the effect of flattening on polyester fibers.[17]

**Sample Preparation**

In order to ensure a representative sample was obtained, as well as adhering to SWGMAT guidelines, five fibers were tested from various locations within each carpet sample. Using tweezers to separate individual fibers from the swatches, the five fibers were mounted onto glass microscope slides and covered with cover slips. All slides were labeled numerically, corresponding to their order in Table 1. To ensure the transparency of the slides and cover slips in the visible light range, absorbance scans were taken prior to analysis. When not being analyzed, all mounted fibers were stored on trays and inside a drawer, to prevent any changes or damage that might occur when being left in a vulnerable place, such as thermal degradation or biological deterioration.

## Procedure for Diameter Measurement

The diameter of the five fibers from each carpet sample was measured using a Zeiss polarizing light microscope at 40X magnification. The diameter of a trilobal fiber is determined by measuring the distance from the outside edge of one lobe to the edge of a second lobe. All diameters were measured this way as every fiber was triblobal. A micrometer was mounted in the eyepiece. The samples were rotated until the diameter of the fiber could be read using the micrometer. At 40X magnification, one scale division was equivalent to 2.51micrometers (μm). The diameters of each of the five samples were measured and collected for analysis (See Appendix C, Table 3 which includes **all** diameter measurements for each sample fiber prior to averaging the data. Note: The diameter of each of the five sample fibers was measured before each stage of flattening. This resulted in the use of five measurements when calculating the overall average diameter for each sample fiber at each stage of flattening). Table 4 in Appendix D contains the **average** diameter lengths for all five sample fibers at each stage of flattening.

## Calibration of Microspectrophotometer

For this study a S.E.E 1000 Microspectrophotometer, modified with a 20X microscope, and Grams 32 computer software (version 4.14, level II) was used. This is licensed to the Broward Sheriff's Office. Absorbance was the sampling method used, utilizing a 100-watt halogen lamp. The range of wavelength analyzed was 390nm-850nm. The microspectrophotometer is capable of performing reflectance and fluorescence tests as well as absorbance/transmittance. The microspectrophotometer was calibrated daily using instructions provided by the S.E.E. Corporation. After the instrument warmed up for approximately thirty minutes, daily wavelength calibrations were completed using holmium oxide and didymium oxide filters. These filters are used because they exhibit well defined peaks at certain wavelengths. The holmium oxide and didymium oxide peaks needed to be within 2 nm of the tolerance values listed in the S.E.E. Calibration binder in the crime lab in order to be acceptable for analysis.[18] Neutral density filters of 0.1, 0.5, and 1.0 were also used to calibrate the instrument. The neutral density filters display a flat optical response in the wavelength region from 250nm to 1,000 nm. All filters were part of the NIST traceable filter set provided by S.E.E for the calibration of the instrument.

Prior to use each day, the holmium oxide and didymium oxide filters were cleaned using lens paper and ethanol. The neutral density filters were inspected daily, but not cleaned, as they are easily damaged and the protective coating may be ruined. Using the neutral density filters for calibration, three spectra were produced daily, verifying the accuracy of the instrument. The calibration spectra were compared to known standards and determined to be acceptable. They were printed and stored in a logbook each day.

## Scans of Unflattened Fibers

The procedure used for scanning the unflattened fibers was also used to scan the partially flattened and pressed flat fiber samples:

1) The microscope slide containing the questioned fiber was placed on the stage. Using a 20x objective lens, the fiber was focused upon.
2) A check was done for Kohler illmunation. The stage was moved so the fiber was not seen. The substage aperature was focused to get the circle of light to show dark blue edges (If the light was asymmetrically colored, this was warning that the bulb was in danger of blowing out).
3) Once the Kohler illumination was checked, the blocker was pushed in and a dark scan was taken. The dark scan is taken to store signals resulting from electronic and thermal noise.
4) The blocker was opened and a reference scan was taken. The reference scan stores signal resulting from the slide, coverslip, lamp and detector, allowing an accurate assessment of the sample fiber. The optimal reference scan should register between 3000-4000 counts. If the counts were not in this range, an autogain was performed until the counts fell within this range.
5) If the sampling frequency was changed due to the autogain, a new dark scan and reference scan needed to be taken. When the reference scan counts were in the appropriate range, the calibration was completed using the holmium oxide and didymium oxide filters as well as the neutral density filters. The calibration spectra were printed and stored in the logbook.[19]
6) The stage was moved to focus on the sample fiber. Sample scans were saved in a folder titled, "Tim Metz." The fiber was then scanned and saved using numerical coding. For example, sample #1, fiber #1, scan #1 was saved as "unflat1-1". Sample #1, fiber #1, scan #2 was saved as "unflat1-2", etc., up to sample #1, fiber #5, scan #5 which was saved as "uflat1-25".
    a. After the first scan was done, the stage was moved to another area of the same fiber. A second scan was taken. This procedure was followed until five scans were taken for each sample fiber. The next sample fiber slide was then analyzed. This same process was utilized until all five fibers from each of the fifty-one carpet samples were scanned.

**Procedure for Partially Flattened Fibers**

Fibers were then partially flattened using a roller ball. A Bausch & Lomb visible light microscope was used when flattening the fibers with the roller ball. The microscope slides were placed under the microscope. The cover slip was removed with tweezers. The fibers were transferred to a clean slide where they were flattened. The roller ball was placed on the center of the fiber and seven or eight back and forth motions were made, until the fiber appeared flat under the microscope. The fibers were then placed onto their original microscope slide and covered with the same cover slip.

After the fibers were partially flattened, the diameters were measured again using the Zeiss polarizing light microscope at 40X magnification with mounted micrometer. The visibly flat portion of the fiber was measured and recorded. Averages were calculated after all five fibers from the same carpet sample were measured (See Table 4).

After the diameters were measured, the partially flattened fibers were scanned using the microspectrophotometer. The same procedure that was used for the unflattened fibers was also used for the partially flat fibers. The partially flattened fibers were saved in the "Tim Metz" folder. The fiber was scanned and saved using the same numerical coding as for the unflattened fibers. The scans for sample #1, fiber #1, scan #1-5 were saved as follows, "flat1-1, flat1-2…flat1-5." This process was repeated until all fifty-one carpet samples were scanned.

**Procedure for Pressed Fibers**

After analysis of the partially flattened fibers was completed, the fibers were flattened using a Carver Press. The microscope slide containing the fiber samples was transferred via a microscope slide holder to the room with the Carver Press. Fibers were then removed from the microscope slide and placed onto the KBr pellet maker. The pellet was placed in the press and 2500 psi of pressure was applied for 1-2 seconds. The fiber was placed onto the original microscope slide and covered using the original cover slip. These were referred to as "Pressed Flat" during further analysis.

The fiber diameters were measured using the Zeiss polarizing light microscope at 40X magnification with mounted micrometer. Under the microscope, it was easy to discern which area of the fiber had been pressed flat, making it easy to measure the diameter. The diameter of each fiber was measured and recorded (See Table 3).

The same procedure was used again to take scans of the pressed flat portion of the sample fibers. Five scans were taken of each of the pressed fibers. The scans for sample #1, fiber #1, scan#1 were saved as follows, "press1-1, press1-2…press1-5). Then, scans were taken of sample #1, fiber #2. They were recorded following the same numerical coding procedure as for the unflattened and partially flattened fibers. This was repeated until all fifty-one carpet samples were analyzed.

# RESULTS

After all samples were scanned and spectra were obtained, the carpet samples were organized by color for analysis (See Table 2). Several carpet samples of the colors green, red, purple, brown, and blue were analyzed. Only one black and one gray fiber were analyzed. There were two reasons for this. First, it was suspected that obtaining useful data from a gray or black fiber would be difficult. Black fibers appeared extremely dark and it was suspected that they would absorb the majority of the light, not showing distinct peaks at certain wavelengths. The opposite was thought of regarding the gray fiber. Under the microscope, the gray fiber did not appear to be dark enough and it was thought that this would transmit most of the light it was exposed to and have very small absorbance peaks.

Twenty-five scans were taken at each of the three stages of flattening, resulting in 75 total spectra for each fiber. Such a large number of spectra provided plenty of information for comparison. An average spectrum was compiled for each fiber at each stage of flattening (Figures #1-3, in Appendix E, include the average spectrum for fiber #3 at each stage of flattening. Spectra were initially obtained this way, prior to compiling them into Comparison Spectra as in Appendix F). Prior to averaging all the spectra, measurements of all peaks and absorbance values were taken. This was done in order to assist in answering the main question of this research, "Does flattening have an effect on the visible spectrum of nylon carpet fibers?" Table 5 includes the data compiled from measuring all the peaks and absorbance values of the spectra. All peak measurements were recorded in nanometers (nm) while absorbance values do not have any units assigned.

TABLE 5-Peak Ranges and Absorbance Values at Each Stage of Flattening

| Fiber #1 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 414-416 | 633-635 | n/a | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 635-637 | n/a | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 635 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.09-1.10 | 1.03-1.20 | n/a | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .61-.72 | n/a | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .52-.69 | n/a | n/a | n/a | n/a |

| Fiber #2 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 415-417 | 531-534 | 640 | n/a | n/a | n/a |
| **Part. Flat** | 415-420 | 533-535 | 640 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 532-535 | 640 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.0-1.2 | 1.06-1.15 | .90-.98 | n/a | n/a | n/a |
| **Part. Flat** | .70-.75 | .71-.75 | .58-.61 | n/a | n/a | n/a |
| **Press. Flat** | Dopout | .33-.38 | .20-.24 | n/a | n/a | n/a |

| Fiber #3 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 420-422 | 528-530 | 635-638 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 530-532 | 636-640 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 527-529 | 638-640 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.20-1.25 | 1.40-1.50 | .80-.97 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .52-.69 | .24-.27 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .46-.50 | .24-.26 | n/a | n/a | n/a |

Table 5 Cont.

| **Fiber #4** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 415-417 | 521-523 | 630-635 | n/a | n/a | n/a |
| **Part. Flat** | 416 | 520-524 | 633-635 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 524 | 632-635 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.03-1.15 | 1.0-1.16 | .84-.93 | n/a | n/a | n/a |
| **Part. Flat** | .80-.97 | .92-.1.05 | .75-.85 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .30-.35 | .24-.29 | n/a | n/a | n/a |

| **Fiber #5** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 516-518 | 634-636 | n/a | n/a | n/a | n/a |
| **Part. Flat** | 515-520 | 635-638 | n/a | n/a | n/a | n/a |
| **Press. Flat** | 517-519 | 636-638 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.0-1.2 | .70-.83 | n/a | n/a | n/a | n/a |
| **Part. Flat** | .45-.54 | .30-.35 | n/a | n/a | n/a | n/a |
| **Press. Flat** | .24-.28 | .10-.14 | n/a | n/a | n/a | n/a |

| **Fiber #6** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 588-592 | 632-635 | n/a | n/a | n/a | n/a |
| **Part. Flat** | 588-590 | 632-635 | n/a | n/a | n/a | n/a |
| **Press. Flat** | 588-590 | 633-636 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.24-1.34 | 1.20-1.32 | n/a | n/a | n/a | n/a |
| **Part. Flat** | .60-.65 | .62-.67 | n/a | n/a | n/a | n/a |
| **Press. Flat** | .40-.43 | .39-.44 | n/a | n/a | n/a | n/a |

Table 5 Cont.

| Fiber #7 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 583-585 | 633-635 | n/a | n/a | n/a | n/a |
| **Part. Flat** | 583-587 | 633-636 | n/a | n/a | n/a | n/a |
| **Press. Flat** | 582-585 | 638 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.00-1.04 | 1.01-1.08 | n/a | n/a | n/a | n/a |
| **Part. Flat** | .77-.83 | .80-.88 | n/a | n/a | n/a | n/a |
| **Press. Flat** | .30-.39 | .31-.41 | n/a | n/a | n/a | n/a |

| Fiber #8 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 590-592 | 632-635 | n/a | n/a | n/a | n/a |
| **Part. Flat** | 592 | 633-635 | n/a | n/a | n/a | n/a |
| **Press. Flat** | 591 | 634-636 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | .99-1.05 | 1.00-1.09 | n/a | n/a | n/a | n/a |
| **Part. Flat** | .80-.88 | .72-.89 | n/a | n/a | n/a | n/a |
| **Press. Flat** | .44-.63 | .54-.78 | n/a | n/a | n/a | n/a |

| Fiber #9 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 635-639 | n/a | n/a | n/a | n/a | n/a |
| **Part. Flat** | 635-639 | n/a | n/a | n/a | n/a | n/a |
| **Press. Flat** | 635 | n/a | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | .90-1.20 | n/a | n/a | n/a | n/a | n/a |
| **Part. Flat** | .65-.93 | n/a | n/a | n/a | n/a | n/a |
| **Press. Flat** | .70-.85 | n/a | n/a | n/a | n/a | n/a |

Table 5 Cont.

| Fiber #10 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 405 | 592-596 | 635-640 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 593-595 | 635-640 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 592-597 | 636-639 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | .94-1.15 | 1.12-1.24 | 1.16-1.33 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .60-.86 | .40-.83 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .25-.56 | .31-.5 | n/a | n/a | n/a |

| Fiber #11 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 631-635 | n/a | n/a | n/a | n/a | n/a |
| **Part. Flat** | 632-637 | n/a | n/a | n/a | n/a | n/a |
| **Press. Flat** | 634-636 | n/a | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | .70-.91 | n/a | n/a | n/a | n/a | n/a |
| **Part. Flat** | .55-.76 | n/a | n/a | n/a | n/a | n/a |
| **Press. Flat** | .40-.68 | n/a | n/a | n/a | n/a | n/a |

| Fiber #12 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 593-595 | 633-636 | n/a | n/a | n/a | n/a |
| **Part. Flat** | 594-598 | 633-635 | n/a | n/a | n/a | n/a |
| **Press. Flat** | 595-597 | 636-638 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | .85-1.06 | 1.0-1.12 | n/a | n/a | n/a | n/a |
| **Part. Flat** | .45-.67 | .44-.58 | n/a | n/a | n/a | n/a |
| **Press. Flat** | .23-.28 | .20-.35 | n/a | n/a | n/a | n/a |

Table 5 Cont.

| **Fiber #13** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 422-425 | 557-559 | 635-638 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 556-560 | 636-640 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 557-561 | 638-640 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.48-1.55 | 1.50-1.60 | 1.55-1.59 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .53-.68 | .61-.69 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .43-.59 | .42-.69 | n/a | n/a | n/a |

| **Fiber #14** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 410-415 | 551-556 | 636-641 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 552-556 | 638-641 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 554-556 | 638-641 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.22-1.36 | 1.25-1.56 | 1.15-1.26 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .48-.65 | .40-.46 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .30-.55 | .25-.42 | n/a | n/a | n/a |

| **Fiber #15** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 400-402 | 553-555 | 640-643 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 552-557 | 640-644 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 556 | 642-645 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.16-1.28 | 1.30-1.47 | 1.40-1.55 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .77-.94 | .73-.83 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .35-.42 | .25-.44 | n/a | n/a | n/a |

Table 5 Cont.

| **Fiber #16** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 636-638 | n/a | n/a | n/a | n/a | n/a |
| **Part. Flat** | 635-640 | n/a | n/a | n/a | n/a | n/a |
| **Press. Flat** | 637-640 | n/a | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | .91-1.08 | n/a | n/a | n/a | n/a | n/a |
| **Part. Flat** | .65-.76 | n/a | n/a | n/a | n/a | n/a |
| **Press. Flat** | .25-.35 | n/a | n/a | n/a | n/a | n/a |

| **Fiber #17** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 422-425 | 524-528 | 561-565 | 638-640 | n/a | n/a |
| **Part. Flat** | Dropout | 525-526 | 560-562 | 639-641 | n/a | n/a |
| **Press. Flat** | Dropout | 524-526 | 565 | 638-642 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.02-1.15 | 1.03-1.20 | .95-1.08 | 1.02-1.16 | n/a | n/a |
| **Part. Flat** | Dropout | .38-.42 | .34-.39 | .35-.61 | n/a | n/a |
| **Press. Flat** | Dropout | .22-.26 | .24-.29 | .25-.28 | n/a | n/a |

| **Fiber #18** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 420-422 | 638-642 | n/a | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 638-640 | n/a | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 639-642 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | .95-1.02 | .92-.99 | n/a | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .45-.78 | n/a | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .33-.55 | n/a | n/a | n/a | n/a |

Table 5 Cont.

| Fiber #19 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 413-415 | 592-595 | 638-640 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 595-597 | 640-643 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 592-597 | 639-642 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.04-1.25 | 1.30-1.42 | 1.30-1.38 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .65-.82 | .65-.73 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .51-.70 | .50-.69 | n/a | n/a | n/a |

| Fiber #20 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 410-415 | 592-594 | 638-640 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 595-597 | 642 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 594-596 | 637-641 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.08-1.21 | 1.25-1.40 | 1.32-1.46 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .60-.91 | .60-.83 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .48-.68 | .52-.59 | n/a | n/a | n/a |

| Fiber #21 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 425-427 | 592-595 | 640-645 | n/a | n/a | n/a |
| **Part. Flat** | 422-425 | 596-597 | 641-643 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 593-597 | 640-645 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.10-1.34 | 1.12-1.29 | 1.16-1.32 | n/a | n/a | n/a |
| **Part. Flat** | .75-.98 | .62-.77 | .64-.77 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .48-.71 | .44-.56 | n/a | n/a | n/a |

Table 5 Cont.

| **Fiber #22** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 414-419 | 592-595 | 637-640 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 591-595 | 638-639 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 593-595 | 640 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.01-1.20 | 1.07-1.15 | 1.02-1.13 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .45-.53 | .42-.56 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .31-.51 | .24-.52 | n/a | n/a | n/a |

| **Fiber #23** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 425-430 | 591-595 | 641-645 | n/a | n/a | n/a |
| **Part. Flat** | 426-429 | 591-595 | 640-642 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 593-595 | 640-643 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | .89-1.12 | .94-1.03 | 1.04-1.1 | n/a | n/a | n/a |
| **Part. Flat** | .55-.59 | .40-.52 | .44-.53 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .36-.51 | .40-.46 | n/a | n/a | n/a |

| **Fiber #24** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 410-412 | 595 | 639-640 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 592-595 | 637-641 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 590 | 640-641 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.00-1.12 | .89-.96 | .91-1.01 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .40-.46 | .42-.56 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .25-.46 | .34-.51 | n/a | n/a | n/a |

Table 5 Cont.

| Fiber #25 | | | | | | |
|---|---|---|---|---|---|---|
| | Peak 1 | Peak 2 | Peak 3 | Peak 4 | Peak 5 | Peak 6 |
| Unflattened | 420 | 592-597 | 640-642 | n/a | n/a | n/a |
| Part. Flat | Dropout | 596-597 | 642-645 | n/a | n/a | n/a |
| Press. Flat | Dropout | 592-595 | 640-645 | n/a | n/a | n/a |
| | Abs. Range Peak 1 | Abs. Range Peak 2 | Abs. Range Peak 3 | Abs. Range Peak 4 | Abs. Range Peak 5 | Abs. Range Peak 6 |
| Unflattened | .97-1.25 | .91-1.01 | .93-1.25 | n/a | n/a | n/a |
| Part. Flat | Dropout | .60-.82 | .60-.67 | n/a | n/a | n/a |
| Press. Flat | Dropout | .46-.55 | .47-.53 | n/a | n/a | n/a |

| Fiber #26 | | | | | | |
|---|---|---|---|---|---|---|
| | Peak 1 | Peak 2 | Peak 3 | Peak 4 | Peak 5 | Peak 6 |
| Unflattened | 590 | 635-638 | n/a | n/a | n/a | n/a |
| Part. Flat | 585-590 | 638-640 | n/a | n/a | n/a | n/a |
| Press. Flat | 586-590 | 635-640 | n/a | n/a | n/a | n/a |
| | Abs. Range Peak 1 | Abs. Range Peak 2 | Abs. Range Peak 3 | Abs. Range Peak 4 | Abs. Range Peak 5 | Abs. Range Peak 6 |
| Unflattened | .91-.98 | .92-.96 | n/a | n/a | n/a | n/a |
| Part. Flat | .47-.62 | .40-.49 | n/a | n/a | n/a | n/a |
| Press. Flat | .27-.41 | .22-.28 | n/a | n/a | n/a | n/a |

| Fiber #27 | | | | | | |
|---|---|---|---|---|---|---|
| | Peak 1 | Peak 2 | Peak 3 | Peak 4 | Peak 5 | Peak 6 |
| Unflattened | 587-590 | 636-640 | n/a | n/a | n/a | n/a |
| Part. Flat | 585-590 | 638-641 | n/a | n/a | n/a | n/a |
| Press. Flat | 590 | 636-639 | n/a | n/a | n/a | n/a |
| | Abs. Range Peak 1 | Abs. Range Peak 2 | Abs. Range Peak 3 | Abs. Range Peak 4 | Abs. Range Peak 5 | Abs. Range Peak 6 |
| Unflattened | .99-1.03 | 1.00-1.04 | n/a | n/a | n/a | n/a |
| Part. Flat | .62-.65 | .61-.67 | n/a | n/a | n/a | n/a |
| Press. Flat | .30-.40 | .25-.51 | n/a | n/a | n/a | n/a |

Table 5 Cont.

| Fiber #28 | | | | | | |
|---|---|---|---|---|---|---|
| | Peak 1 | Peak 2 | Peak 3 | Peak 4 | Peak 5 | Peak 6 |
| Unflattened | 592-596 | 638-640 | n/a | n/a | n/a | n/a |
| Part. Flat | 591-596 | 640-642 | n/a | n/a | n/a | n/a |
| Press. Flat | 593-596 | 641-642 | n/a | n/a | n/a | n/a |
| | Abs. Range Peak 1 | Abs. Range Peak 2 | Abs. Range Peak 3 | Abs. Range Peak 4 | Abs. Range Peak 5 | Abs. Range Peak 6 |
| Unflattened | 1.21-1.27 | 1.15-1.37 | n/a | n/a | n/a | n/a |
| Part. Flat | .52-.78 | .51-.71 | n/a | n/a | n/a | n/a |
| Press. Flat | .30-.41 | .33-.38 | n/a | n/a | n/a | n/a |

| Fiber #29 | | | | | | |
|---|---|---|---|---|---|---|
| | Peak 1 | Peak 2 | Peak 3 | Peak 4 | Peak 5 | Peak 6 |
| Unflattened | 452-455 | 555-560 | 635-638 | n/a | n/a | n/a |
| Part. Flat | 452-457 | 557-560 | 636-639 | n/a | n/a | n/a |
| Press. Flat | Dropout | 555-560 | 635-640 | n/a | n/a | n/a |
| | Abs. Range Peak 1 | Abs. Range Peak 2 | Abs. Range Peak 3 | Abs. Range Peak 4 | Abs. Range Peak 5 | Abs. Range Peak 6 |
| Unflattened | 1.10-1.17 | .95-1.06 | .91-.96 | n/a | n/a | n/a |
| Part. Flat | .91-1.02 | .81-.95 | .70-.81 | n/a | n/a | n/a |
| Press. Flat | Dropout | .40-.47 | .33-.51 | n/a | n/a | n/a |

| Fiber #30 | | | | | | |
|---|---|---|---|---|---|---|
| | Peak 1 | Peak 2 | Peak 3 | Peak 4 | Peak 5 | Peak 6 |
| Unflattened | 445-450 | 561-565 | 637-640 | n/a | n/a | n/a |
| Part. Flat | Dropout | 562-564 | 640-641 | n/a | n/a | n/a |
| Press. Flat | Dropout | 562-565 | 640 | n/a | n/a | n/a |
| | Abs. Range Peak 1 | Abs. Range Peak 2 | Abs. Range Peak 3 | Abs. Range Peak 4 | Abs. Range Peak 5 | Abs. Range Peak 6 |
| Unflattened | 1.18-1.31 | 1.03-1.12 | .90-.97 | n/a | n/a | n/a |
| Part. Flat | Dropout | .42-.49 | .45-.56 | n/a | n/a | n/a |
| Press. Flat | Dropout | .30-.34 | .24-.31 | n/a | n/a | n/a |

Table 5 Cont.

| **Fiber #31** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 453-458 | 566-571 | 635-640 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 566-569 | 637-640 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 570-571 | 640 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.01-1.12 | .91-.98 | .85-.97 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .51-.69 | .52-.81 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .24-.55 | .24-.32 | n/a | n/a | n/a |

| **Fiber #32** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 451-455 | 522-527 | 560-562 | 640-642 | n/a | n/a |
| **Part. Flat** | 452-455 | 526-527 | 559-563 | 637-640 | n/a | n/a |
| **Press. Flat** | 455 | 525-527 | 558-561 | 637-641 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.41-1.55 | 1.32-1.36 | 1.24-1.37 | 1.05-1.15 | n/a | n/a |
| **Part. Flat** | .75-.91 | .65-.83 | .64-1.10 | .53-.69 | n/a | n/a |
| **Press. Flat** | .55-.64 | .51-.61 | .41-.59 | .32-.60 | n/a | n/a |

| **Fiber #33** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 520-522 | 545-550 | n/a | n/a | n/a | n/a |
| **Part. Flat** | 520-525 | 548-550 | n/a | n/a | n/a | n/a |
| **Press. Flat** | 520-525 | 545-550 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.34-1.83 | 1.51-1.81 | n/a | n/a | n/a | n/a |
| **Part. Flat** | .88-1.03 | .90-1.20 | n/a | n/a | n/a | n/a |
| **Press. Flat** | .66-.82 | .61-.75 | n/a | n/a | n/a | n/a |

Table 5 Cont.

| Fiber #34 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 405-410 | 455-460 | 485-490 | 530-532 | 559-563 | 637-640 |
| **Part. Flat** | Dropout | 455-458 | 487-490 | 530-535 | 562-564 | 640-642 |
| **Press. Flat** | Dropout | 456-460 | 485-490 | 532-535 | 560-564 | 638-641 |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.22-1.27 | 1.24-1.45 | 1.21-1.38 | 1.31-1.42 | 1.30-1.40 | .85-.91 |
| **Part. Flat** | Dropout | .70-.98 | .72-.85 | .77-.89 | .72-.81 | .35-.45 |
| **Press. Flat** | Dropout | .55-.76 | .59-.71 | .61-.68 | .60-.66 | .30-.36 |

| Fiber #35 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 455-457 | 525-530 | 557-560 | 642-647 | n/a | n/a |
| **Part. Flat** | 457-459 | 528-530 | 558-561 | 645-647 | n/a | n/a |
| **Press. Flat** | 455-459 | 527-530 | 558-562 | 642-647 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.12-1.21 | 1.03-1.09 | .94-.99 | .80-.82 | n/a | n/a |
| **Part. Flat** | .65-.69 | .62-.72 | .51-.57 | .42-.48 | n/a | n/a |
| **Press. Flat** | .47-.63 | .41-.46 | .35-.39 | .31-.45 | n/a | n/a |

| Fiber #36 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 430-432 | 457-460 | 490-495 | 524-528 | 560-565 | 635-640 |
| **Part. Flat** | Dropout | 457-462 | 493-495 | 528-529 | 563-565 | 635-640 |
| **Press. Flat** | Dropout | 460-462 | 490-495 | 525-529 | 560-565 | 637-640 |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.10-1.21 | 1.11-1.19 | 1.05-1.21 | 1.06-1.14 | 1.02-1.13 | .81-.88 |
| **Part. Flat** | Dropout | .65-.72 | .60-.67 | .61-.69 | .55-.62 | .46-.53 |
| **Press. Flat** | Dropout | .42-.55 | .46-.51 | .43-.52 | .42-.49 | .34-.49 |

Table 5 Cont.

| Fiber #37 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 425-427 | 525-530 | 557-561 | 635-640 | n/a | n/a |
| **Part. Flat** | Dropout | 525-527 | 557-560 | 637-640 | n/a | n/a |
| **Press. Flat** | Dropout | 525-530 | 560-562 | 635-640 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.08-1.13 | 1.05-1.15 | 1.04-1.13 | .91-.99 | n/a | n/a |
| **Part. Flat** | Dropout | .64-.79 | .64-.73 | .61-.69 | n/a | n/a |
| **Press. Flat** | Dropout | .40-.44 | .35-.43 | .30-.38 | n/a | n/a |

| Fiber #38 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 430433 | 457-460 | 490-495 | 525-530 | 560-565 | 633-636 |
| **Part. Flat** | 428-433 | 457-460 | 490-495 | 527-530 | 562-565 | 635-638 |
| **Press. Flat** | 432-433 | 460-462 | 492-495 | 527-530 | 562-565 | 633-638 |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.12-1.21 | 1.06-1.12 | 1.05-1.10 | 1.02-1.21 | 1.03-1.15 | .91-.99 |
| **Part. Flat** | .88-1.02 | .91-1.08 | .90-1.10 | .82-.89 | .82-.91 | .75-.86 |
| **Press. Flat** | .40-.48 | .43-.49 | .42-.51 | .43-.61 | .41-.48 | .33-.48 |

| Fiber #39 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 430-435 | 518-522 | 552-557 | 635-640 | n/a | n/a |
| **Part. Flat** | 432-435 | 520-522 | 554-557 | 636-640 | n/a | n/a |
| **Press. Flat** | 432-435 | 520-522 | 555-557 | 638-640 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.31-1.43 | 1.42-1.55 | 1.35-1.59 | .91-.99 | n/a | n/a |
| **Part. Flat** | .91-.97 | .95-1.06 | 1.03-1.15 | .70-.91 | n/a | n/a |
| **Press. Flat** | .42-.61 | .48-.56 | .51-.61 | .25-.35 | n/a | n/a |

Table 5 Cont.

| Fiber #40 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 438-440 | 525-530 | 559-562 | 640-642 | n/a | n/a |
| **Part. Flat** | 439-442 | 527-530 | 560-563 | 641-643 | n/a | n/a |
| **Press. Flat** | 438-443 | 528-530 | 560-563 | 640-644 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.21-1.31 | 1.16-1.26 | 1.13-1.23 | .77-.85 | n/a | n/a |
| **Part. Flat** | .75-.86 | .71-.77 | .70-.75 | .42-.47 | n/a | n/a |
| **Press. Flat** | .37-.42 | .32-.37 | .33-.39 | .18-.41 | n/a | n/a |

| Fiber #41 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 432-437 | 492-495 | 555-560 | 638-640 | n/a | n/a |
| **Part. Flat** | 435-437 | 492-497 | 555-560 | 638-642 | n/a | n/a |
| **Press. Flat** | 435-437 | 492-497 | 555-560 | 640-642 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.11-1.21 | 1.05-1.13 | 1.02-1.09 | .91-.97 | n/a | n/a |
| **Part. Flat** | .71-.78 | .71-.89 | .61-.75 | .55-.61 | n/a | n/a |
| **Press. Flat** | .31-.51 | .25-.35 | .21-.28 | .18-.25 | n/a | n/a |

| Fiber #42 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 428-433 | 557-559 | 638-640 | n/a | n/a | n/a |
| **Part. Flat** | 430-433 | 558-560 | 637-640 | n/a | n/a | n/a |
| **Press. Flat** | 430-433 | 555-559 | 636-641 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.31-1.45 | 1.12-1.20 | 1.02-1.12 | n/a | n/a | n/a |
| **Part. Flat** | .91-1.02 | .71-.78 | .60-.65 | n/a | n/a | n/a |
| **Press. Flat** | .35-.43 | .21-.26 | .18-.24 | n/a | n/a | n/a |

Table 5 Cont.

| **Fiber #43** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 424-426 | 525-530 | 555-558 | 635-639 | n/a | n/a |
| **Part. Flat** | 425-429 | 526-530 | 557-560 | 637-640 | n/a | n/a |
| **Press. Flat** | 425-429 | 525-530 | 555-560 | 639-640 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.21-1.31 | 1.25-1.36 | 1.36-1.51 | 1.11-1.21 | n/a | n/a |
| **Part. Flat** | .71-.85 | .72-.83 | .81-.95 | .61-.75 | n/a | n/a |
| **Press. Flat** | .34-.56 | .33-.41 | .41-.56 | .31-.45 | n/a | n/a |

| **Fiber #44** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 424-429 | 518-520 | 555-560 | 635-640 | n/a | n/a |
| **Part. Flat** | 425-429 | 517-522 | 557-560 | 637-640 | n/a | n/a |
| **Press. Flat** | 426-429 | 517-522 | 555-560 | 635-640 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.12-1.19 | 1.15-1.34 | 1.21-1.34 | 1.04-1.15 | n/a | n/a |
| **Part. Flat** | .81-.92 | .83-1.03 | .86-.94 | .71-.81 | n/a | n/a |
| **Press. Flat** | .31-.45 | .35-.45 | .33-.38 | .22-.31 | n/a | n/a |

| **Fiber #45** | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 420-425 | 515-520 | 556-558 | 631-635 | n/a | n/a |
| **Part. Flat** | 420-425 | 515-520 | 557-560 | 631-635 | n/a | n/a |
| **Press. Flat** | 422-425 | 517-520 | 555-560 | 632-636 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.12-1.23 | 1.08-1.19 | 1.15-1.25 | 1.05-1.16 | n/a | n/a |
| **Part. Flat** | .71-.79 | .75-.86 | .81-1.02 | .74-.85 | n/a | n/a |
| **Press. Flat** | .25-.31 | .25-.35 | .31-.35 | .24-.36 | n/a | n/a |

Table 5 Cont.

| Fiber #46 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 425-430 | 635-640 | n/a | n/a | n/a | n/a |
| **Part. Flat** | 427-430 | 638-640 | n/a | n/a | n/a | n/a |
| **Press. Flat** | 427-430 | 637-640 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.25-1.35 | 1.02-1.21 | n/a | n/a | n/a | n/a |
| **Part. Flat** | 1.05-1.16 | .82-.91 | n/a | n/a | n/a | n/a |
| **Press. Flat** | .31-.43 | .23-.28 | n/a | n/a | n/a | n/a |

| Fiber #47 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 410-415 | 592-595 | 638-643 | n/a | n/a | n/a |
| **Part. Flat** | 412-415 | 594-595 | 640-643 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 590-595 | 638-643 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.05-1.15 | 1.02-1.13 | 1.06-1.13 | n/a | n/a | n/a |
| **Part. Flat** | .81-.88 | .75-.86 | .71-.78 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .22-.29 | .25-.29 | n/a | n/a | n/a |

| Fiber #48 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 417-420 | 562-565 | 593-595 | 635-640 | n/a | n/a |
| **Part. Flat** | Dropout | 562-565 | 596-598 | 637-640 | n/a | n/a |
| **Press. Flat** | Dropout | 560-565 | 593-598 | 635-640 | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.21-1.31 | 1.21-1.26 | 1.22-1.26 | 1.25-1.36 | n/a | n/a |
| **Part. Flat** | Dropout | .70-.85 | .72-.86 | .71-.86 | n/a | n/a |
| **Press. Flat** | Dropout | .31-.46 | .34-.54 | .31-.41 | n/a | n/a |

Table 5 Cont.

| Fiber #49 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 425-430 | 634-638 | n/a | n/a | n/a | n/a |
| **Part. Flat** | 425-430 | 637-639 | n/a | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 634-639 | n/a | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.13-1.20 | 1.05-1.35 | n/a | n/a | n/a | n/a |
| **Part. Flat** | .77-1.05 | .74-.91 | n/a | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .22-.35 | n/a | n/a | n/a | n/a |

| Fiber #50 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 425-430 | 593-595 | 638-640 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | 592-595 | 635-640 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | 592-595 | 635-640 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.25-1.35 | 1.15-1.29 | 1.21-1.36 | n/a | n/a | n/a |
| **Part. Flat** | Dropout | .65-.76 | .69-.81 | n/a | n/a | n/a |
| **Press. Flat** | Dropout | .28-.36 | .29-.34 | n/a | n/a | n/a |

| Fiber #51 | | | | | | |
|---|---|---|---|---|---|---|
| | **Peak 1** | **Peak 2** | **Peak 3** | **Peak 4** | **Peak 5** | **Peak 6** |
| **Unflattened** | 435-440 | 591-594 | 638-640 | n/a | n/a | n/a |
| **Part. Flat** | 437-440 | 592-595 | 635-640 | n/a | n/a | n/a |
| **Press. Flat** | 435-440 | 593-596 | 637-640 | n/a | n/a | n/a |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | **Abs. Range Peak 4** | **Abs. Range Peak 5** | **Abs. Range Peak 6** |
| **Unflattened** | 1.21-1.35 | 1.11-1.25 | 1.12-1.21 | n/a | n/a | n/a |
| **Part. Flat** | .81-.91 | .71-.83 | .74-.86 | n/a | n/a | n/a |
| **Press. Flat** | .35-.41 | .22-.28 | .25-.31 | n/a | n/a | n/a |

As you can see from the data in Table 5, some of the sample fibers had only one or two noticeable peaks. However, the majority of the sample fibers had either three, four or five peaks that were recognizable. A few sample fibers had as many as six peaks. Each peak was measured at each stage of flattening to determine if the five nanometer range established by McRae et al. as acceptable proof that spectra are representative of the same fiber was maintained. There were several cases in which dropout occurred. Dropout is when a peak drops out or disappears from the spectra as flattening progresses. There were 20 cases in which drop out occurred in the partially flattened stage and 7 cases when this occurred in the pressed flat stage. The result was that dropout occurred in more than half (52.9%) of the carpet fibers.

Dropout was observed in every color except for gray. Only one gray and one black fiber were analyzed. While the gray fiber did not experience dropout, the black fiber did, thus making its percent dropout 100%. Blue had the highest percentage of dropout (of fibers with multiple samples) at 66.6%, or 10 out of 15 fibers. Brown and red fibers had the same percent of fibers experience dropout (50%). Two out of 4 brown and 6 out of 12 red fibers showed peak dropout. Green fibers experienced dropout in 5 out of 12 fibers, or 41.6%. Out of all the colors chosen for analysis, purple fibers experienced the lowest percentage of peak dropout, 33.3%, or 2 out of 6 fibers.

In addition to analyzing the peaks for dropout, the fibers were sorted by color for analysis. Seven tables were created, compiling the data for a representative carpet sample from each of the seven colors. The sample fiber was analyzed at each stage of flattening and comparisons were made for the diameter range, range of absorbance values and the range of the major peaks. Table 6 shows the information obtained for the Dupont Stainmaster G01 Big Apple Red fiber (fiber #3).

**Table 6-Data From Red Fiber #3**

| **Fiber #3** | | | | |
|---|---|---|---|---|
| | **Peak 1 (in nm)** | **Peak 2 (in nm)** | **Peak 3 (in nm)** | **Diameter Range (in µm)** |
| **Unflattened** | 420-422 | 528-530 | 635-638 | 42.7-52.7 |
| **Part. Flat** | Dropout | 530-532 | 636-640 | 65.9-87.9 |
| **Press. Flat** | Dropout | 527-529 | 638-640 | 92.9-118.0 |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | |
| **Unflattened** | 1.20-1.25 | 1.40-1.50 | .80-.97 | |
| **Part. Flat** | Dropout | .52-.69 | .24-.27 | |
| **Press. Flat** | Dropout | .46-.50 | .24-.26 | |

Despite the dropout of peak 1 at the partially flattened stage, fiber #3 was an excellent fiber for analysis. The major peaks were well defined for every scan and also remained within the 5nm range, which is imperative in order to verify that two fibers have a common origin. The absorbance values ranged from 0.24 for the pressed fiber all the way to 1.50, signifying that the unflattened fiber #3 absorbed the majority of the light it was exposed to. The diameter range was also significant. As the diameter range increased, the absorbance value decreased. This can be expected because as a fiber was flattened using the roller ball and the pellet press, the fiber appeared to lose some of its color. However, the fiber did not actually lose color. The dye became more spread out throughout the fiber due to the increase in surface area, thus giving the appearance of a lighter shade of color. Fiber #3 showed a gradual increase in diameter range as the fiber was first flattened with a roller ball, then with the pellet press.

The next color analyzed was black. Only one black fiber was studied. Table 7 contains the data for fiber #13, Advanced Generation Aladdin Networks 998 Jet Black.

**Table 7-Data From Black Fiber #13**

| Fiber #13 | | | | |
|---|---|---|---|---|
| | **Peak 1 (in nm)** | **Peak 2 (in nm)** | **Peak 3 (in nm)** | **Diameter Range (in μm)** |
| **Unflattened** | 422-425 | 557-559 | 635-638 | 50.2-62.8 |
| **Part. Flat** | Dropout | 556-560 | 636-640 | 57.7-125.5 |
| **Press. Flat** | Dropout | 557-561 | 638-640 | 82.8-150.6 |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | |
| **Unflattened** | 1.48-1.55 | 1.50-1.60 | 1.55-1.59 | |
| **Part. Flat** | Dropout | .53-.68 | .61-.69 | |
| **Press. Flat** | Dropout | .43-.59 | .42-.69 | |

Although it was thought that the black fiber would be difficult to analyze, this was not the case. Initially, it was expected that the black fiber would absorb the majority of the light to which it was exposed. The absorbance values and diameter range for the unflattened fiber #13 are within a narrow range of values. This suggested that the partially flattened and pressed flat black fibers may, in fact, provide worthwhile information. However, as the black fiber was flattened with the roller ball, dropout occurred in peak 1. In addition, the diameter range increased drastically as the fiber was flattened. The range of diameters for the twenty-five partially flattened fibers was 67.8μm (125.5μm-57.7μm). The range of diameters for the pressed fibers was also 67.8μm (150.6μm-82.8μm). However, there was no direct correlation between diameter increase and absorbance value change. In fact, the partially flattened and pressed flat absorbance values were very similar. Thus, no good information can be deducted from the analysis of the black fiber.

Purple fiber #14 was chosen next for analysis. Fiber #14, Advanced Generation Aladdin Networks 493 Royal Purple, was medium colored. It had optimal peak ranges, great absorbance values and diameter ranges that consistently increased as the fibers were flattened. Table 8 shows the data for fiber #14.

**Table 8-Data From Purple Fiber #14**

| **Fiber #14** | | | | |
|---|---|---|---|---|
| | **Peak 1 (in nm)** | **Peak 2 (in nm)** | **Peak 3 (in nm)** | **Diameter Range (in μm)** |
| **Unflattened** | 410-415 | 551-556 | 636-641 | 50.2-62.8 |
| **Part. Flat** | Dropout | 552-556 | 638-641 | 65.3-92.9 |
| **Press. Flat** | Dropout | 554-556 | 638-641 | 92.9-125.5 |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | |
| **Unflattened** | 1.22-1.36 | 1.25-1.56 | 1.15-1.26 | |
| **Part. Flat** | Dropout | .48-.65 | .40-.46 | |
| **Press. Flat** | Dropout | .30-.55 | .25-.42 | |

Fiber #14 had three well defined peaks. Unfortunately, peak 1 experienced dropout at the partially flattened stage. Despite this, almost every spectrum was indistinguishable, overlapping each other in all parts of the curve. Peak 2 and peak 3 were very reproducible. In addition, with each stage of flattening, the absorbance values and diameter ranges increased consistently. The results were the same for purple fibers #43-45, as well, because these fibers were moderately colored also. The moderate to medium colored purple fibers gave great results. However, fibers #17 and #38, which were a light shade of violet, did not produce quality spectra. There were no distinct peaks observed for these fibers.

The next fiber analyzed was Advanced Generation Aladdin Networks 596 Sapphire Blue (fiber #15). This fiber had three major peaks. Dropout occurred in the partially flattened portion of peak 1. Despite this, fiber #15 was a good fiber to analyze. There were fifteen different fibers that were categorized as blue for this study. Although they were categorized as blue, the perception of their color was subjective. Table 9 shows the data for fiber #15

**Table 9-Data From Blue Fiber #15**

| Fiber #15 | | | | |
|---|---|---|---|---|
| | **Peak 1 (in nm)** | **Peak 2 (in nm)** | **Peak 3 (in nm)** | **Diameter Range (in µm)** |
| **Unflattened** | 400-402 | 553-555 | 640-643 | 45.2-67.8 |
| **Part. Flat** | Dropout | 552-557 | 640-644 | 67.8-85.3 |
| **Press. Flat** | Dropout | 556 | 642-645 | 90.4-138.1 |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | |
| **Unflattened** | 1.16-1.28 | 1.30-1.47 | 1.40-1.55 | |
| **Part. Flat** | Dropout | .77-.94 | .73-.83 | |
| **Press. Flat** | Dropout | .35-.42 | .25-.44 | |

The peak range for fiber #15 was optimal, separated at most by 5nm. The range of absorbance values and diameters provided useful information for the unflattened and partially flattened fibers. For the unflattened fibers, the diameter range was only 22.6µm (67.8µm-45.2µm) while the absorbance values ranged from 1.35-1.54. As the fiber was flattened, it became less absorbent. The pressed flat fiber #15 appeared extremely flat under the microscope. However, it was still useful enough to provide a good absorbance value. Despite the good absorbance values, the range of diameters was from 90.4µm-

138.1μm. This was a difference of 47.7μm between the thinnest and thickest diameter of pressed flat fibers. Thus, the diameter range was not sufficiently similar for comparison.

Just as the black fiber #13 did not provide any significant data, the gray fiber (fiber #16) was not very useful. Fiber #16, Advanced Generation Aladdin Networks 989 Clear Gray, did not have any well defined peaks. Although there was no dropout of peaks in this fiber, it appeared as though the spectra were full of noise. The spectra were jagged, not smooth lines as most of the other spectra were. Table 10 shows the date from fiber #16.

**Table 10-Data From Gray Fiber #16**

| **Fiber #16** | | |
|---|---|---|
| | **Peak 1 (in nm)** | **Diameter Range (in μm)** |
| **Unflattened** | 636-638 | 42.7-57.7 |
| **Part. Flat** | 635-640 | 62.8-80.3 |
| **Press. Flat** | 637-640 | 87.9-113.0 |
| | **Abs. Range Peak 1** | |
| **Unflattened** | .91-1.08 | |
| **Part. Flat** | .65-.76 | |
| **Press. Flat** | .25-.35 | |

Although from the data in Table 10 it appears as though gray might provide useful data, this was not the case. From the outset, the absorbance values were much lower than for the other colors analyzed. The unflattened fibers had a maximum absorbance value of 1.10. This was much lower than the absorbance value for the different colored unflattened fibers. In addition, the absorbance values for the pressed flat fiber were very low, showing that most of the light was transmitted through the fiber. This signified that the color gray is too dispersed within the fiber to absorb much light when it was pressed flat.

The green colored fibers covered a wide range of shades which, in turn, covered a wide range of absorbance values. Fiber #21, Advanced Generation Aladdin Networks 696 Intense Emerald green, had three noticeable peaks when scanned. Dropout occurred in the pressed flat spectra of peak 1. See Table 11 for data regarding fiber #21.

**Table 11-Data From Green Fiber #21**

| **Fiber #21** | | | | |
|---|---|---|---|---|
| | **Peak 1 (in nm)** | **Peak 2 (in nm)** | **Peak 3 (in nm)** | **Diameter Range (in μm)** |
| **Unflattened** | 425-427 | 592-595 | 640-645 | 47.7-55.2 |
| **Part. Flat** | 422-425 | 596-597 | 641-643 | 60.2-92.9 |
| **Press. Flat** | Dropout | 593-597 | 640-645 | 87.9-128.0 |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | |
| **Unflattened** | 1.10-1.34 | 1.12-1.29 | 1.16-1.32 | |
| **Part. Flat** | .75-.98 | .62-.77 | .64-.77 | |
| **Press. Flat** | Dropout | .48-.71 | .44-.56 | |

The final color analyzed was brown. Fiber #42, Dimension Carpet 30 Pine Needle Brown, was chosen for analysis. All brown fibers were extremely difficult to analyze due to their light shades. Although three peaks were observed, none of which had any dropout, the spectra were jagged and appeared to look more like straight lines than spectral curves. Table 12 shows the data for fiber #42.

**Table 12-Data From Brown Fiber #42**

| **Fiber #42** | | | | |
|---|---|---|---|---|
| | **Peak 1 (in nm)** | **Peak 2 (in nm)** | **Peak 3 (in nm)** | **Diameter Range (in µm)** |
| **Unflattened** | 428-433 | 557-559 | 638-640 | 40.2-52.7 |
| **Part. Flat** | 430-433 | 558-560 | 637-640 | 70.3-102.9 |
| **Press. Flat** | 430-433 | 555-559 | 636-641 | 82.8-128.0 |
| | **Abs. Range Peak 1** | **Abs. Range Peak 2** | **Abs. Range Peak 3** | |
| **Unflattened** | 1.31-1.45 | 1.12-1.20 | 1.02-1.12 | |
| **Part. Flat** | .91-1.02 | .71-.78 | .60-.65 | |
| **Press. Flat** | .35-.43 | .21-.26 | .18-.24 | |

The range of peak values for all three stages of flattening fell between 555-560nm. However, the pressed flat absorbance values were almost negligible. In addition, the range of diameters is enormous, possibly causing the data to be skewed.

CONCLUSIONS

**Analysis of Diameter Range**

Understanding how the diameter increased as the fiber was flattened was one goal of this study. Could the increase in diameter width be consistent enough throughout analysis of all fifty-one carpet samples to draw any correlations? As the fiber was flattened at each stage, the diameter increased which lead to a decreased absorbance value. One would expect the diameter increase and absorbance decrease to have a linear relationship, meaning that, as one increases, the other decreases uniformly. However, this was not the case. Thus, the increase in diameter width was not consistent enough throughout analysis to draw any correlations.

The reason no correlations were able to be made was because not every fiber from a particular carpet sample had the same diameter measurement. For example, as noted in Table 13, fiber #13 had pre-flattening measurements that ranged from 50.2μm to 62.8 μm, with no two fiber diameters having the same measurement. The result was an average fiber diameter, prior to any flattening, of 56.7μm.

**Table 13-Diameter Measurements for Fiber #13(in µm)**

| | Pre-Flattening | Partially Flattened | Pressed Flat |
|---|---|---|---|
| Sample #1 | 52.7 | 62.8 | 82.8 |
| Sample #2 | 57.7 | 87.9 | 126 |
| Sample #3 | 62.8 | 126 | 151 |
| Sample #4 | 60.2 | 62.8 | 92.9 |
| Sample #5 | 50.2 | 57.7 | 138 |
| **Average** | **56.7** | **79.3** | **118** |

As can be seen from Table 13, the partially flat and pressed flat diameters increased, but not uniformly. The partially flattened average was 79.3µm and the pressed flat average diameter was 118µm. This is an increase of 22.6µm and 38.7µm with each flattening. The reason for the irregular diameter increase as the fibers were flattened is that, although the measurements were made randomly, the selection of where to measure was subjectively done. This means that despite sections of the fiber being randomly chosen for analysis, they were chosen by the human hand, and thus, the analysis had a subjective tone. In addition, for some samples, the diameters covered such a wide range of values that the average calculation might be skewed, either higher or lower, reflecting an average that is not representative of the majority of sample fibers. For example, the partially flattened diameter reading for sample #3 of fiber #13 (Advanced Generation Aladdin Networks 998 Jet Black fiber), was measured at 126µm. However, the average diameter of the partially flattened samples was calculated to be 79.3µm. This means that some samples must measure well below the average to offset this great discrepancy. The same holds true for the pressed flat samples of fiber #13. While the average of all pressed flat samples for fiber #13 were averaged to be 118μm, sample #1 was measured at only 82.8 μm. This is a difference of 35.2 μm (118μm-82.8μm). In addition, sample #3 of the pressed flat fibers was measured at 151 μm, a difference of 33 μm (151μm - 118μm).

**Spectral Analysis of Peaks**

Another aspect of this study involved what affect flattening had, if any, on the spectra of each fiber. This research revealed that the spectra, as taken with an S.E.E. 1000 Microspectrophotometer, did not vary much as flattening progressed. The intensity of the absorbed spectra diminished, as expected, with flattening. However, the spectra themselves did not change. There was no shift in peaks observed for any of the carpet samples. However, there were several instances where dropout of a peak occurred. Dropout is the disappearance of a peak as flattening progresses. Dropout was observed in 52.9% (27 out of 51) carpet samples. Twenty cases of dropout occurred in the partially flat stage while seven cases of dropout occurred in the pressed flat stage. In addition, dropout occurred in every color except for gray. However, only one gray fiber was analyzed, and therefore, no conclusions can be drawn from this.

Just as one would expect, the more "stretched out" or flattened the fiber became, the less absorbent it became (See Figure #23 in Appendix F for an example of a Comparison Spectra). Figure #23, shows the comparison spectra for sample fiber #20, Advanced Generation Aladdin Networks 565 Teal Blue fiber. Prior to flattening, the spectrum shows absorbance peaking at 1.46 for peak 3. After partially flattening, the absorbance peaks around 0.83 for this peak. Finally, after being pressed flat, the spectrum of the fiber shows an absorbance value of .59 for peak 3. As you can see by looking at the data in Figure #23, as the fiber is flattened through each of the three stages, the absorbance of that fiber decreases. However, as Figure #23 demonstrates, peak 1 drops out of the spectra as the fiber is flattened. Although there is no shift in peaks, the dropping out of a peak is important, as it influences the order of analysis for the forensic scientist.

The main goal of this research was to address the question of whether or not flattening had on effect on the visible spectra of nylon carpet fibers. If flattening did have an effect, then the order of analysis for forensic scientists would be important. If flattening did not have an effect, then the order of analysis was not important. The results of this research revealed that flattening does have an effect on the visible spectra of nylon carpet fibers as studied through microspectrophotometry. Therefore, the order of analysis is quite important. Because dropout occurred in 52.9% of samples as they were flattened, visible mircrospectrophotometry must be completed before infrared spectroscopy. In addition, in forensic cases where the unknown fiber is flat, one would want to flatten the known to the same extent, if possible, as the unknown.

## DISCUSSION

From this research it was determined that peak shifting did not occur in any of the fibers. In addition, the majority of comparison spectra show that despite being flattened, either partially with a roller ball or completely with a pellet press, the spectra still produce adequate results, thus allowing a fiber to be analyzed successfully. However, the fact that 52.9% (27 out of 51 fibers) experienced peak dropout in either the partially flattened or pressed flat stage is indicative that the order of analysis is rather important. Microspectrophotometry must be completed prior to infrared spectroscopy or the result may be a loss of data, which could have grave consequences for the forensic scientist.

Although there was considerable amount of dropout experienced, the results of this project open several more opportunities for research. Projects focusing solely on one color will be beneficial as they will assist in determining if the color, or shade of color, has implications on testing. Whereas lighter colored fibers become more difficult to test as they are flattened due to dropout, it's possible that darker shades of fibers may not experience dropout as often. Dropout occurred more frequently for lightly shaded colors. However, dropout was also observed for dark shades. If the fiber is light colored or lightly shaded, then the order of testing appears may be more critical than for darker shades. Based on this research, no conclusions can be made regarding degree of shading and dropout. Testing on a larger scale will assist in answering this question.

Also, a project which studies flattening at predetermined levels will allow one to determine if flattening does not have an effect on the visible spectra until a certain point. Thus, future research may conclude that the order of analysis may be important only after a certain degree of flattening.

Future testing may assist in mandating laboratory protocols for the analysis of fibers. This research has resulted in the determination that order of analysis is important. Failure to conduct analysis in the correct order may result in the loss of data.

# APPENDICES

# APPENDIX A

## Fiber Number and Manufacturer Information

**Table 1- Fiber Number and Manufacturer Information**

| Fiber # | Name |
|---|---|
| 1 | Horizon Creations 519 Pasture Green |
| 2 | Horizon Creations 5770 Byzantine Red |
| 3 | Dupont Stainmaster Xtra Life G01 Big Apple Red |
| 4 | Dupont Stainmaster Xtra Life G02 Cherry Glaze Red |
| 5 | Hamilton Carpet Mills 23 Ming Red |
| 6 | Dupont Stainmaster Xtra Life G31 Nightfall Blue |
| 7 | Horizon Creations 6928 Virginia Blue |
| 8 | Horizon Creations 6927 Summer Sky Blue |
| 9 | Horizon Creations 520 Chameleon Green |
| 10 | Hamilton Carpet Mills 32 Blue Night Blue |
| | |
| 11 | Hamilton Carpet Mills 35 Lawn Party Green |
| 12 | Horizon Creations 519 Underbrush Green |
| 13 | Advanced Generation Aladdin Networks 998 Jet Black |
| 14 | Advanced Generation Aladdin Networks 493 Royal Purple |
| 15 | Advanced Generation Aladdin Networks 596 Sapphire Blue |
| 16 | Advanced Generation Aladdin Networks 989 Clear Gray |
| 17 | Advanced Generation Aladdin Networks 464 Dusty Violet(purple) |
| 18 | Advanced Generation Aladdin Networks 525 Montego Bay Blue |
| 19 | Advanced Generation Aladdin Networks 594 Flag Blue |
| | |
| 20 | Advanced Generation Aladdin Networks 565 Teal Blue |
| 21 | Advanced Generation Aladdin Networks 696 Intense Emerald Green |
| 22 | Advanced Generation Aladdin Networks 555 Cayman Blue |
| 23 | Advanced Generation Aladdin Networks 566 Catalina Turquoise |
| 24 | Advanced Generation Aladdin Networks 684 Blue Spruce Green |
| 25 | Advanced Generation Aladdin Networks 575 Grecian Blue |
| 26 | Advanced Generation Aladdin Networks 645 Aquarelle Blue |
| 27 | Advanced Generation Aladdin Networks 671 Windsor Green |
| 28 | Advanced Generation Aladdin Networks 698 Laurel Green |
| 29 | Advanced Generation Aladdin Networks 892 Chocolate Brown |
| | |
| 30 | Advanced Generation Aladdin Networks 152 Wild Honey Brown |
| 31 | Advanced Generation Aladdin Networks 636 Moss Green |
| 32 | Advanced Generation Aladdin Networks 898 Rich Walnut Brown |

**Table 1(cont'd).**

| Fiber# | Name |
|---|---|
| 33 | Advanced Gengeration Aladdin Networks 383 Cardinal Red |
| 34 | Advanced Generation Aladdin Networks 394 Cranberry Wine Red |
| 35 | Advanced Generation Aladdin Networks 262 Russet Red |
| 36 | Advanced Generation Aladdin Networks 252 Coronado Coral Red |
| 37 | Advanced Generation Aladdin Networks 364 Rhubarb Red |
| 38 | Advanced Generation Aladdin Networks 458 Wild Violet(purple) |
| 39 | Dimension Carpet 28 Grenadine Red |
| | |
| 40 | Dimension Carpet 32 Chili Red |
| 41 | Dimension Carpet 31 Tea Leaf Red |
| 42 | Dimension Carpet 30 Pine Needle Brown |
| 43 | Dimension Carpet 27 Royal Plum Purple |
| 44 | Dimension Carpet 26 Wildflower Purple |
| 45 | Dimension Carpet 25 Lavender Purple |
| 46 | Dimension Carpet 29 Stage Coach Green |
| 47 | Dimension Carpet 24 Mediterranean Blue |
| 48 | Dimension Carpet 18 Newport Blue |
| 49 | Dimension Carpet 17 Atlantis Blue |
| | |
| 50 | Dimension Carpet 14 Hemlock Green |
| 51 | Dimension Carpet 15 Wood Duck Green |

# APPENDIX B

## Carpet Samples Arranged by Color

**Table 2-Carpet Samples Arranged by Color**

| Sample Color | Manufacturer | Fiber # |
|---|---|---|
| **Green** | HC 519 Pasture | 1 |
| | HC 520 Chameleon | 9 |
| | HCM 35 Lawn Party | 11 |
| | HC 519 Underbrush | 12 |
| | AN 696 Intense Emerald | 21 |
| | AN 684 Blue Spruce | 24 |
| | AN 671 Windsor | 27 |
| | AN 698 Laurel | 28 |
| | AN 636 Moss | 31 |
| | DC 29 Stage Coach | 46 |
| | DC 14 Hemlock | 50 |
| | DC 13 Wood Duck | 51 |
| **Red** | HC 5770 Byzantine | 2 |
| | DS G01 Big Apple | 3 |
| | DS G02 Cherry Glaze | 4 |
| | HCM 23 Ming | 5 |
| | AN 383 Cardinal | 33 |
| | AN 394 Cranberry Wine | 34 |
| | AN 262 Russet | 35 |
| | AN 252 Coronado Coral | 36 |
| | AN 364 Rhubarb | 37 |
| | DC 28 Grenadine | 39 |
| | DC 32 Chili | 40 |
| | DC 31 Tea Leaf | 41 |
| **Black/Gray** | AN 998 Jet Black | 13 |
| | AN 989 Clear Gray | 16 |
| **Purple** | AN 493 Royal | 14 |
| | AN 464 Dusty Violet | 17 |
| | AN 458 Wild Violet | 38 |
| | DC 27 Royal Plum | 43 |
| | DC 26 Wildflower | 44 |
| | DC 25 Lavender | 45 |

**Table 2 (cont'd.)**

| Sample Color | Manufacturer | Fiber # |
|---|---|---|
| **Brown** | AN 892 Chocolate | 29 |
| | AN 152 Wild Honey | 30 |
| | AN 898 Rich Walnut | 32 |
| | DC 30 Pine Needle | 42 |
| **Blue** | DS G31 Nightfall | 6 |
| | HC 6928 Virginia | 7 |
| | HC 6927 Summer Sky | 8 |
| | HCM 32 Blue Night | 10 |
| | AN 596 Sapphire | 15 |
| | AN 525 Montego Bay | 18 |
| | AN 594 Flag | 19 |
| | AN 565 Teal | 20 |
| | AN 555 Cayman | 22 |
| | AN 566 Catalina Turq. | 23 |
| | AN 575 Grecian | 25 |
| | AN 645 Aquarelle | 26 |
| | DC 24 Mediterranean | 47 |
| | DC 18 Newport | 48 |
| | DC 17 Atlantis | 49 |

**AN=Aladdin Networks** **DS=Dupont Stainmaster**
**DC=Dimension Carpet** **HC=Horizon Creations**
**HCM=Hamilton Carpet Mills**

# APPENDIX C

## Diameter Measurements for the Five Fibers at Each Stage of Flattening

Table 3-Diameter Measurements for the Five Fibers at Each Stage of Flattening(in μm)

| | | Unflattened | Partially Flattened | Pressed Flat |
|---|---|---|---|---|
| **Fiber #1** | Sample #1 | 50.2 | 60.2 | 115.5 |
| | Sample #2 | 47.7 | 62.8 | 120.5 |
| | Sample #3 | 47.7 | 87.9 | 125.5 |
| | Sample #4 | 50.2 | 67.8 | 150.6 |
| | Sample #5 | 50.2 | 72.8 | 130.5 |
| | **Average** | **49.2** | **70.3** | **128.5** |
| | | | | |
| **Fiber #2** | Sample #1 | 55.2 | 95.4 | 113.0 |
| | Sample #2 | 50.2 | 102.9 | 110.4 |
| | Sample #3 | 52.7 | 65.3 | 107.9 |
| | Sample #4 | 50.2 | 70.3 | 128.0 |
| | Sample #5 | 52.7 | 95.4 | 100.4 |
| | **Average** | **52.2** | **85.8** | **111.9** |
| | | | | |
| **Fiber #3** | Sample #1 | 42.7 | 70.3 | 118.0 |
| | Sample #2 | 50.2 | 67.8 | 125.5 |
| | Sample #3 | 52.7 | 87.9 | 92.9 |
| | Sample #4 | 50.2 | 87.9 | 110.4 |
| | Sample #5 | 42.7 | 65.3 | 105.4 |
| | **Average** | **47.7** | **75.8** | **110.4** |
| | | | | |
| **Fiber #4** | Sample #1 | 45.2 | 75.3 | 92.9 |
| | Sample #2 | 47.7 | 55.2 | 82.8 |
| | Sample #3 | 42.7 | 65.8 | 125.5 |
| | Sample #4 | 37.7 | 80.3 | 100.4 |
| | Sample #5 | 40.2 | 67.8 | 82.8 |
| | **Average** | **42.7** | **68.9** | **96.9** |
| | | | | |
| **Fiber #5** | Sample #1 | 42.7 | 80.3 | 92.9 |
| | Sample #2 | 37.7 | 72.8 | 100.4 |
| | Sample #3 | 45.2 | 80.3 | 92.9 |
| | Sample #4 | 45.2 | 67.8 | 102.9 |
| | Sample #5 | 37.7 | 82.8 | 100.4 |
| | **Average** | **41.7** | **76.8** | **97.9** |
| | | | | |
| **Fiber #6** | Sample #1 | 37.7 | 57.7 | 70.3 |
| | Sample #2 | 42.7 | 72.8 | 90.4 |
| | Sample #3 | 42.7 | 65.3 | 85.3 |
| | Sample #4 | 37.7 | 60.2 | 92.9 |
| | Sample #5 | 40.2 | 55.2 | 87.9 |
| | **Average** | **40.2** | **62.2** | **85.3** |

Table 3 (Cont.)

| | | Unflattened | Partially Flattened | Pressed Flat |
|---|---|---|---|---|
| **Fiber #7** | Sample #1 | 32.6 | 80.3 | 105.4 |
| | Sample #2 | 37.7 | 92.9 | 125.5 |
| | Sample #3 | 35.1 | 90.4 | 102.9 |
| | Sample #4 | 37.7 | 100.4 | 113.0 |
| | Sample #5 | 37.7 | 87.9 | 123.0 |
| | **Average** | **36.1** | **90.4** | **114.0** |
| | | | | |
| **Fiber #8** | Sample #1 | 37.7 | 62.8 | 100.4 |
| | Sample #2 | 37.7 | 100.4 | 110.4 |
| | Sample #3 | 37.7 | 67.8 | 100.4 |
| | Sample #4 | 37.7 | 75.3 | 130.5 |
| | Sample #5 | 35.1 | 67.8 | 77.8 |
| | **Average** | **37.1** | **74.8** | **103.9** |
| | | | | |
| **Fiber #9** | Sample #1 | 42.7 | 80.3 | 113.0 |
| | Sample #2 | 42.7 | 100.4 | 107.9 |
| | Sample #3 | 42.7 | 70.3 | 125.5 |
| | Sample #4 | 45.2 | 65.3 | 107.9 |
| | Sample #5 | 45.2 | 95.4 | 153.1 |
| | **Average** | **43.7** | **82.3** | **121.5** |
| | | | | |
| **Fiber #10** | Sample #1 | 40.2 | 75.3 | 115.5 |
| | Sample #2 | 42.7 | 55.2 | 105.4 |
| | Sample #3 | 42.7 | 60.2 | 75.3 |
| | Sample #4 | 47.7 | 55.2 | 113.0 |
| | Sample #5 | 45.2 | 60.2 | 113.0 |
| | **Average** | **43.7** | **61.2** | **104.4** |
| | | | | |
| **Fiber #11** | Sample #1 | 40.2 | 65.3 | 100.4 |
| | Sample #2 | 40.2 | 65.3 | 100.4 |
| | Sample #3 | 42.7 | 57.7 | 85.3 |
| | Sample #4 | 42.7 | 70.3 | 87.9 |
| | Sample #5 | 45.2 | 65.3 | 82.8 |
| | **Average** | **42.2** | **64.8** | **91.4** |
| | | | | |
| **Fiber #12** | Sample #1 | 47.7 | 87.9 | 123.0 |
| | Sample #2 | 45.2 | 65.3 | 115.5 |
| | Sample #3 | 45.2 | 87.9 | 120.5 |
| | Sample #4 | 47.7 | 82.8 | 125.5 |
| | Sample #5 | 50.2 | 95.4 | 150.6 |
| | **Average** | **47.2** | **83.8** | **127.0** |

Table 3 (Cont.)

| | | Unflattened | Partially Flattened | Pressed Flat |
|---|---|---|---|---|
| **Fiber #13** | Sample #1 | 52.7 | 62.8 | 82.8 |
| | Sample #2 | 57.7 | 87.9 | 125.5 |
| | Sample #3 | 62.8 | 125.5 | 150.6 |
| | Sample #4 | 60.2 | 62.8 | 92.9 |
| | Sample #5 | 50.2 | 57.7 | 138.1 |
| | **Average** | **56.7** | **79.3** | **118.0** |
| | | | | |
| **Fiber #14** | Sample #1 | 52.7 | 77.8 | 113.0 |
| | Sample #2 | 50.2 | 80.3 | 92.9 |
| | Sample #3 | 50.2 | 90.4 | 125.5 |
| | Sample #4 | 62.8 | 92.9 | 107.9 |
| | Sample #5 | 62.8 | 65.3 | 100.4 |
| | **Average** | **55.7** | **81.3** | **107.9** |
| | | | | |
| **Fiber #15** | Sample #1 | 55.2 | 80.3 | 115.5 |
| | Sample #2 | 47.7 | 67.8 | 138.1 |
| | Sample #3 | 45.2 | 70.3 | 90.4 |
| | Sample #4 | 57.7 | 85.3 | 100.4 |
| | Sample #5 | 67.8 | 80.3 | 100.4 |
| | **Average** | **54.7** | **76.8** | **108.9** |
| | | | | |
| **Fiber #16** | Sample #1 | 42.7 | 72.8 | 100.4 |
| | Sample #2 | 57.7 | 70.3 | 113.0 |
| | Sample #3 | 55.2 | 62.8 | 87.9 |
| | Sample #4 | 57.7 | 67.8 | 100.4 |
| | Sample #5 | 55.2 | 80.3 | 105.4 |
| | **Average** | **53.7** | **70.8** | **101.4** |
| | | | | |
| **Fiber #17** | Sample #1 | 47.7 | 92.9 | 125.5 |
| | Sample #2 | 62.8 | 87.9 | 138.1 |
| | Sample #3 | 47.7 | 65.3 | 113.0 |
| | Sample #4 | 47.7 | 67.8 | 107.9 |
| | Sample #5 | 50.2 | 85.3 | 95.4 |
| | **Average** | **51.2** | **79.8** | **116.0** |
| | | | | |
| **Fiber #18** | Sample #1 | 47.7 | 70.3 | 100.4 |
| | Sample #2 | 42.7 | 80.3 | 125.5 |
| | Sample #3 | 62.8 | 82.8 | 95.4 |
| | Sample #4 | 50.2 | 100.4 | 95.4 |
| | Sample #5 | 70.3 | 90.4 | 125.5 |
| | **Average** | **54.7** | **84.8** | **108.4** |

Table 3 (Cont.)

| | | Unflattened | Partially Flattened | Pressed Flat |
|---|---|---|---|---|
| **Fiber #19** | Sample #1 | 55.2 | 75.3 | 95.4 |
| | Sample #2 | 55.2 | 65.3 | 105.4 |
| | Sample #3 | 40.2 | 57.7 | 87.9 |
| | Sample #4 | 47.7 | 67.8 | 97.9 |
| | Sample #5 | 57.7 | 87.9 | 105.4 |
| | **Average** | **51.2** | **70.8** | **98.4** |
| | | | | |
| **Fiber #20** | Sample #1 | 52.7 | 72.8 | 90.4 |
| | Sample #2 | 47.7 | 72.8 | 118.0 |
| | Sample #3 | 52.7 | 75.3 | 100.4 |
| | Sample #4 | 55.2 | 75.3 | 113.0 |
| | Sample #5 | 50.2 | 87.9 | 125.5 |
| | **Average** | **51.7** | **76.8** | **109.4** |
| | | | | |
| **Fiber #21** | Sample #1 | 52.7 | 67.8 | 128.0 |
| | Sample #2 | 47.7 | 60.2 | 113.0 |
| | Sample #3 | 52.7 | 70.3 | 118.0 |
| | Sample #4 | 55.2 | 90.4 | 87.9 |
| | Sample #5 | 52.7 | 92.9 | 95.4 |
| | **Average** | **52.2** | **76.3** | **108.4** |
| | | | | |
| **Fiber #22** | Sample #1 | 55.2 | 80.3 | 138.1 |
| | Sample #2 | 67.8 | 100.4 | 118.0 |
| | Sample #3 | 50.2 | 72.8 | 113.0 |
| | Sample #4 | 52.7 | 105.4 | 113.0 |
| | Sample #5 | 52.7 | 82.8 | 150.6 |
| | **Average** | **55.7** | **88.4** | **126.5** |
| | | | | |
| **Fiber #23** | Sample #1 | 57.7 | 107.9 | 125.5 |
| | Sample #2 | 57.7 | 92.9 | 107.9 |
| | Sample #3 | 52.7 | 102.9 | 113.0 |
| | Sample #4 | 55.2 | 115.5 | 130.5 |
| | Sample #5 | 57.7 | 92.9 | 120.5 |
| | **Average** | **56.2** | **102.4** | **119.5** |
| | | | | |
| **Fiber #24** | Sample #1 | 55.2 | 90.4 | 125.5 |
| | Sample #2 | 52.7 | 87.9 | 125.5 |
| | Sample #3 | 60.2 | 85.3 | 107.9 |
| | Sample #4 | 47.7 | 65.3 | 125.5 |
| | Sample #5 | 60.2 | 107.9 | 135.5 |
| | **Average** | **55.2** | **87.3** | **124.0** |

Table 3 (Cont.)

| | | Unflattened | Partially Flattened | Pressed Flat |
|---|---|---|---|---|
| **Fiber #25** | Sample #1 | 52.7 | 92.9 | 130.5 |
| | Sample #2 | 57.7 | 87.9 | 130.5 |
| | Sample #3 | 47.7 | 87.9 | 100.4 |
| | Sample #4 | 52.7 | 102.9 | 113.0 |
| | Sample #5 | 60.2 | 87.9 | 102.9 |
| | **Average** | **54.2** | **91.9** | **115.5** |
| | | | | |
| **Fiber #26** | Sample #1 | 50.2 | 87.9 | 105.4 |
| | Sample #2 | 50.2 | 92.9 | 112.9 |
| | Sample #3 | 47.7 | 87.9 | 112.9 |
| | Sample #4 | 50.2 | 75.3 | 105.4 |
| | Sample #5 | 60.2 | 112.9 | 125.5 |
| | **Average** | **51.7** | **91.4** | **112.4** |
| | | | | |
| **Fiber #27** | Sample #1 | 52.7 | 100.4 | 105.4 |
| | Sample #2 | 57.7 | 87.9 | 100.4 |
| | Sample #3 | 60.2 | 100.4 | 115.5 |
| | Sample #4 | 57.7 | 138.1 | 150.6 |
| | Sample #5 | 52.7 | 125.5 | 133.0 |
| | **Average** | **56.2** | **110.4** | **121.0** |
| | | | | |
| **Fiber #28** | Sample #1 | 57.7 | 100.4 | 113.0 |
| | Sample #2 | 55.2 | 97.9 | 110.4 |
| | Sample #3 | 60.2 | 105.4 | 115.5 |
| | Sample #4 | 52.7 | 95.4 | 105.4 |
| | Sample #5 | 55.2 | 100.4 | 113.0 |
| | **Average** | **56.2** | **99.9** | **111.4** |
| | | | | |
| **Fiber #29** | Sample #1 | 50.2 | 95.4 | 107.9 |
| | Sample #2 | 47.7 | 95.4 | 107.9 |
| | Sample #3 | 55.2 | 102.9 | 118.0 |
| | Sample #4 | 55.2 | 125.5 | 138.1 |
| | Sample #5 | 47.7 | 90.4 | 105.4 |
| | **Average** | **51.2** | **101.9** | **115.5** |
| | | | | |
| **Fiber #30** | Sample #1 | 45.2 | 95.4 | 105.4 |
| | Sample #2 | 47.7 | 95.4 | 107.9 |
| | Sample #3 | 55.2 | 125.5 | 130.5 |
| | Sample #4 | 55.2 | 87.9 | 97.9 |
| | Sample #5 | 62.8 | 105.4 | 113.0 |
| | **Average** | **53.2** | **101.9** | **110.9** |

Table 3 (Cont.)

| | | **Unflattened** | **Partially Flattened** | **Pressed Flat** |
|---|---|---|---|---|
| **Fiber #31** | Sample #1 | 60.2 | 113.0 | 120.5 |
| | Sample #2 | 55.2 | 100.4 | 115.5 |
| | Sample #3 | 60.2 | 95.4 | 105.4 |
| | Sample #4 | 62.8 | 92.9 | 105.4 |
| | Sample #5 | 57.7 | 105.4 | 125.5 |
| | **Average** | **59.2** | **101.4** | **114.5** |
| | | | | |
| **Fiber #32** | Sample #1 | 70.3 | 138.1 | 145.6 |
| | Sample #2 | 55.2 | 87.9 | 102.9 |
| | Sample #3 | 55.2 | 113.0 | 123.0 |
| | Sample #4 | 50.2 | 100.4 | 115.5 |
| | Sample #5 | 62.8 | 105.4 | 120.5 |
| | **Average** | **58.7** | **108.9** | **121.5** |
| | | | | |
| **Fiber #33** | Sample #1 | 55.2 | 77.8 | 90.4 |
| | Sample #2 | 50.2 | | 118.0 |
| | Sample #3 | 55.2 | 100.4 | 113.0 |
| | Sample #4 | 50.2 | 97.9 | 105.4 |
| | Sample #5 | 57.7 | 100.4 | 113.0 |
| | **Average** | **53.7** | **97.9** | **107.9** |
| | | | | |
| **Fiber #34** | Sample #1 | 55.2 | 100.4 | 110.4 |
| | Sample #2 | 50.2 | 102.9 | 113.0 |
| | Sample #3 | 55.2 | 97.9 | 107.9 |
| | Sample #4 | 52.7 | 107.9 | 120.5 |
| | Sample #5 | 60.2 | 105.4 | 115.5 |
| | **Average** | **54.7** | **102.9** | **113.5** |
| | | | | |
| **Fiber #35** | Sample #1 | 55.2 | 87.9 | 97.9 |
| | Sample #2 | 60.2 | 80.3 | 90.4 |
| | Sample #3 | 50.2 | 77.8 | 87.9 |
| | Sample #4 | 55.2 | 87.9 | 97.9 |
| | Sample #5 | 55.2 | 90.4 | 100.4 |
| | **Average** | **55.2** | **84.8** | **94.9** |
| | | | | |
| **Fiber #36** | Sample #1 | 57.7 | 100.4 | 113.0 |
| | Sample #2 | 55.2 | 97.9 | 107.9 |
| | Sample #3 | 52.7 | 95.4 | 107.9 |
| | Sample #4 | 57.7 | 102.9 | 118.0 |
| | Sample #5 | 62.8 | 100.4 | 113.0 |
| | **Average** | **57.2** | **99.4** | **111.9** |

Table 3 (Cont.)

| | | **Unflattened** | **Partially Flattened** | **Pressed Flat** |
|---|---|---|---|---|
| **Fiber #37** | Sample #1 | 62.8 | 92.9 | 102.9 |
| | Sample #2 | 52.7 | 80.3 | 95.4 |
| | Sample #3 | 57.7 | 95.4 | 105.4 |
| | Sample #4 | 50.2 | 75.3 | 92.9 |
| | Sample #5 | 50.2 | 72.8 | 92.9 |
| | **Average** | **54.7** | **83.3** | **97.9** |
| | | | | |
| **Fiber #38** | Sample #1 | 52.7 | 95.4 | 110.4 |
| | Sample #2 | 57.7 | 97.9 | 110.4 |
| | Sample #3 | 60.2 | 105.4 | 125.5 |
| | Sample #4 | 55.2 | 92.9 | 105.4 |
| | Sample #5 | 65.3 | 90.4 | 102.9 |
| | **Average** | **58.2** | **96.4** | **110.9** |
| | | | | |
| **Fiber #39** | Sample #1 | 55.2 | 82.8 | 90.4 |
| | Sample #2 | 60.2 | 72.8 | 97.9 |
| | Sample #3 | 52.7 | 70.3 | 113.0 |
| | Sample #4 | 62.8 | 107.9 | 110.4 |
| | Sample #5 | 62.8 | 75.3 | 150.6 |
| | **Average** | **58.7** | **81.8** | **112.4** |
| | | | | |
| **Fiber #40** | Sample #1 | 40.2 | 92.9 | 110.4 |
| | Sample #2 | 50.2 | | 107.9 |
| | Sample #3 | 42.7 | 65.3 | 105.4 |
| | Sample #4 | 62.8 | 102.9 | 115.5 |
| | Sample #5 | 70.3 | 75.3 | 95.4 |
| | **Average** | **53.2** | **87.9** | **106.9** |
| | | | | |
| **Fiber #41** | Sample #1 | 52.7 | 90.4 | 95.4 |
| | Sample #2 | 42.7 | 80.3 | 100.4 |
| | Sample #3 | 40.2 | 82.8 | 97.9 |
| | Sample #4 | 50.2 | 80.3 | 125.5 |
| | Sample #5 | 55.2 | 90.4 | 148.1 |
| | **Average** | **48.2** | **84.8** | **113.5** |
| | | | | |
| **Fiber #42** | Sample #1 | 45.2 | 102.9 | 128.0 |
| | Sample #2 | 40.2 | 75.3 | 100.4 |
| | Sample #3 | 45.2 | 92.9 | 105.4 |
| | Sample #4 | 50.2 | 70.7 | 82.8 |
| | Sample #5 | 52.7 | 77.8 | 87.9 |
| | **Average** | **46.7** | **83.8** | **100.9** |

Table 3 (Cont.)

| | | Unflattened | Partially Flattened | Pressed Flat |
|---|---|---|---|---|
| **Fiber #43** | Sample #1 | 52.7 | 75.3 | 90.4 |
| | Sample #2 | 42.7 | 95.4 | 107.9 |
| | Sample #3 | 47.7 | 95.4 | 105.4 |
| | Sample #4 | 50.2 | 100.4 | 143.1 |
| | Sample #5 | 50.2 | 87.9 | 97.9 |
| | **Average** | **48.7** | **90.9** | **108.9** |
| | | | | |
| **Fiber #44** | Sample #1 | 42.7 | 113.0 | 135.5 |
| | Sample #2 | 50.2 | 113.0 | 125.5 |
| | Sample #3 | 50.2 | 77.8 | 100.4 |
| | Sample #4 | 45.2 | 85.3 | 100.4 |
| | Sample #5 | 45.2 | 100.4 | 140.6 |
| | **Average** | **46.7** | **97.9** | **120.5** |
| | | | | |
| **Fiber #45** | Sample #1 | 45.2 | 87.9 | 95.4 |
| | Sample #2 | 45.2 | 100.4 | 118.0 |
| | Sample #3 | 50.2 | 92.9 | 105.4 |
| | Sample #4 | 55.2 | 87.9 | 95.4 |
| | Sample #5 | 42.7 | 90.4 | 100.4 |
| | **Average** | **47.7** | **91.9** | **102.9** |
| | | | | |
| **Fiber #46** | Sample #1 | 50.2 | 107.9 | 123.0 |
| | Sample #2 | 42.7 | 80.3 | 100.4 |
| | Sample #3 | 40.2 | 67.8 | 100.4 |
| | Sample #4 | 50.2 | 105.4 | 113.0 |
| | Sample #5 | 52.7 | 100.4 | 113.0 |
| | **Average** | **47.2** | **92.4** | **109.9** |
| | | | | |
| **Fiber #47** | Sample #1 | 47.7 | 70.3 | 95.4 |
| | Sample #2 | 45.2 | 75.3 | 105.4 |
| | Sample #3 | 47.7 | 105.4 | 118.0 |
| | Sample #4 | 45.2 | 107.9 | 115.5 |
| | Sample #5 | 42.7 | 87.9 | 100.4 |
| | **Average** | **45.7** | **89.4** | **106.9** |
| | | | | |
| **Fiber #48** | Sample #1 | 47.7 | 82.8 | 100.4 |
| | Sample #2 | 52.7 | 102.9 | 115.5 |
| | Sample #3 | 45.2 | 85.3 | 100.4 |
| | Sample #4 | 47.7 | 82.8 | 102.9 |
| | Sample #5 | 55.2 | 95.4 | 107.9 |
| | **Average** | **49.7** | **89.9** | **105.4** |

Table 3 (Cont.)

| | | Unflattened | Partially Flattened | Pressed Flat |
|---|---|---|---|---|
| **Fiber #49** | Sample #1 | 42.7 | 95.4 | 118.0 |
| | Sample #2 | 45.2 | 100.4 | 105.4 |
| | Sample #3 | 45.2 | 85.3 | 100.4 |
| | Sample #4 | 42.7 | 87.9 | 100.4 |
| | Sample #5 | 42.7 | 85.3 | 100.4 |
| | **Average** | **43.7** | **90.9** | **104.9** |
| | | | | |
| **Fiber #50** | Sample #1 | 42.7 | 90.4 | 100.4 |
| | Sample #2 | 50.2 | 90.4 | 95.4 |
| | Sample #3 | 50.2 | 102.9 | 123.0 |
| | Sample #4 | 50.2 | 85.3 | 105.4 |
| | Sample #5 | 47.7 | 105.4 | 125.5 |
| | **Average** | **48.2** | **94.9** | **109.9** |
| | | | | |
| **Fiber #51** | Sample #1 | 47.7 | 125.5 | 150.6 |
| | Sample #2 | 47.7 | 87.9 | 107.9 |
| | Sample #3 | 30.1 | 100.4 | 115.5 |
| | Sample #4 | 50.2 | 100.4 | 125.5 |
| | Sample #5 | 42.7 | 90.4 | 102.9 |
| | **Average** | **43.7** | **100.9** | **120.5** |

# APPENDIX D

## Average Diameter Length at Each Stage of Flattening

Table 4- Average Diameter Length at Each Stage of Flattening(in μm)

| Fiber # | Unflattened | Partially Flattened | Pressed Flat |
|---|---|---|---|
| 1 | 49.2 | 70.3 | 129 |
| 2 | 52.2 | 85.8 | 112 |
| 3 | 4737 | 75.8 | 111 |
| 4 | 42.7 | 68.9 | 96.9 |
| 5 | 41.7 | 76.8 | 97.9 |
| 6 | 40.2 | 62.2 | 85.3 |
| 7 | 36.1 | 90.4 | 114 |
| 8 | 37.1 | 74.8 | 104 |
| 9 | 43.7 | 82.3 | 121 |
| 10 | 43.7 | 61.2 | 104 |
| 11 | 42.2 | 64.8 | 91.4 |
| 12 | 47.2 | 83.8 | 127 |
| 13 | 56.7 | 79.3 | 118 |
| 14 | 55.7 | 81.3 | 108 |
| 15 | 54.7 | 76.8 | 109 |
| 16 | 53.7 | 70.8 | 101 |
| 17 | 51.2 | 79.8 | 116 |
| 18 | 54.7 | 84.8 | 108 |
| 19 | 54.2 | 70.8 | 98.4 |
| 20 | 51.7 | 76.8 | 109 |
| 21 | 52.2 | 76.3 | 108 |
| 22 | 55.7 | 88.4 | 127 |
| 23 | 56.2 | 102 | 119 |
| 24 | 55.2 | 87.3 | 124 |
| 25 | 54.2 | 91.9 | 115 |
| 26 | 51.7 | 91.4 | 112 |
| 27 | 56.2 | 111 | 1221 |
| 28 | 56.2 | 99.9 | 111 |
| 29 | 51.2 | 102 | 115 |
| 30 | 53.2 | 102 | 111 |
| 31 | 59.2 | 101 | 114 |
| 32 | 58.7 | 109 | 121 |
| 33 | 53.7 | 97.9 | 108 |
| 34 | 54.7 | 103 | 113 |
| 35 | 55.2 | 84.8 | 94.9 |
| 36 | 57.2 | 99.4 | 112 |
| 37 | 54.7 | 83.3 | 97.9 |
| 38 | 58.2 | 96.4 | 111 |
| 39 | 58.7 | 81.8 | 112 |
| 40 | 53.2 | 87.9 | 107 |

Table 4 (cont.)

| Fiber # | Unflattened | Partially Flattened | Pressed Flat |
|---|---|---|---|
| 41 | 48.2 | 84.8 | 113 |
| 42 | 46.7 | 83.8 | 101 |
| 43 | 48.7 | 90.9 | 109 |
| 44 | 46.7 | 97.9 | 121 |
| 45 | 47.7 | 91.9 | 103 |
| 46 | 47.2 | 92.4 | 109 |
| 47 | 45.7 | 89.4 | 107 |
| 48 | 49.7 | 89.9 | 105 |
| 49 | 43.7 | 90.9 | 105 |
| 50 | 48.2 | 94.9 | 109 |
| 51 | 43.7 | 101 | 121 |

# APPENDIX E

## Examples of Averaged Spectra for All Sample Scans of Fiber #3

## (Dupont Stainmaster Xtra Life G01 Big Apple Red Fiber)

## at Each Stage of Flattening

Figure #1-Average of All Unflattened Dupont Stainmaster XtraLife G01 Big Apple Red Sample Fibers

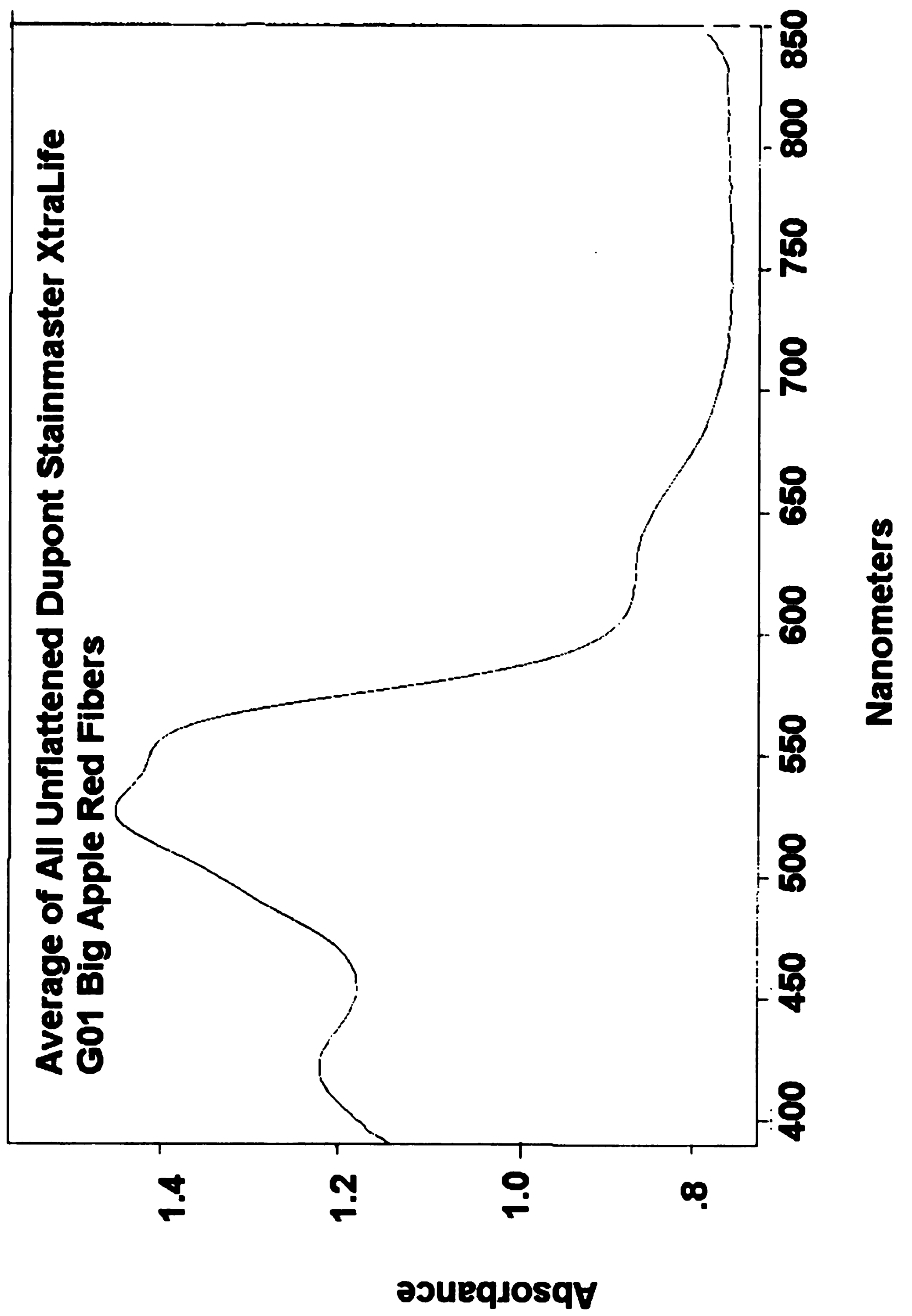


Figure #2-Average of All Partially Flattened Dupont Stainmaster XtraLife G01 Big Apple Red Sample Fibers

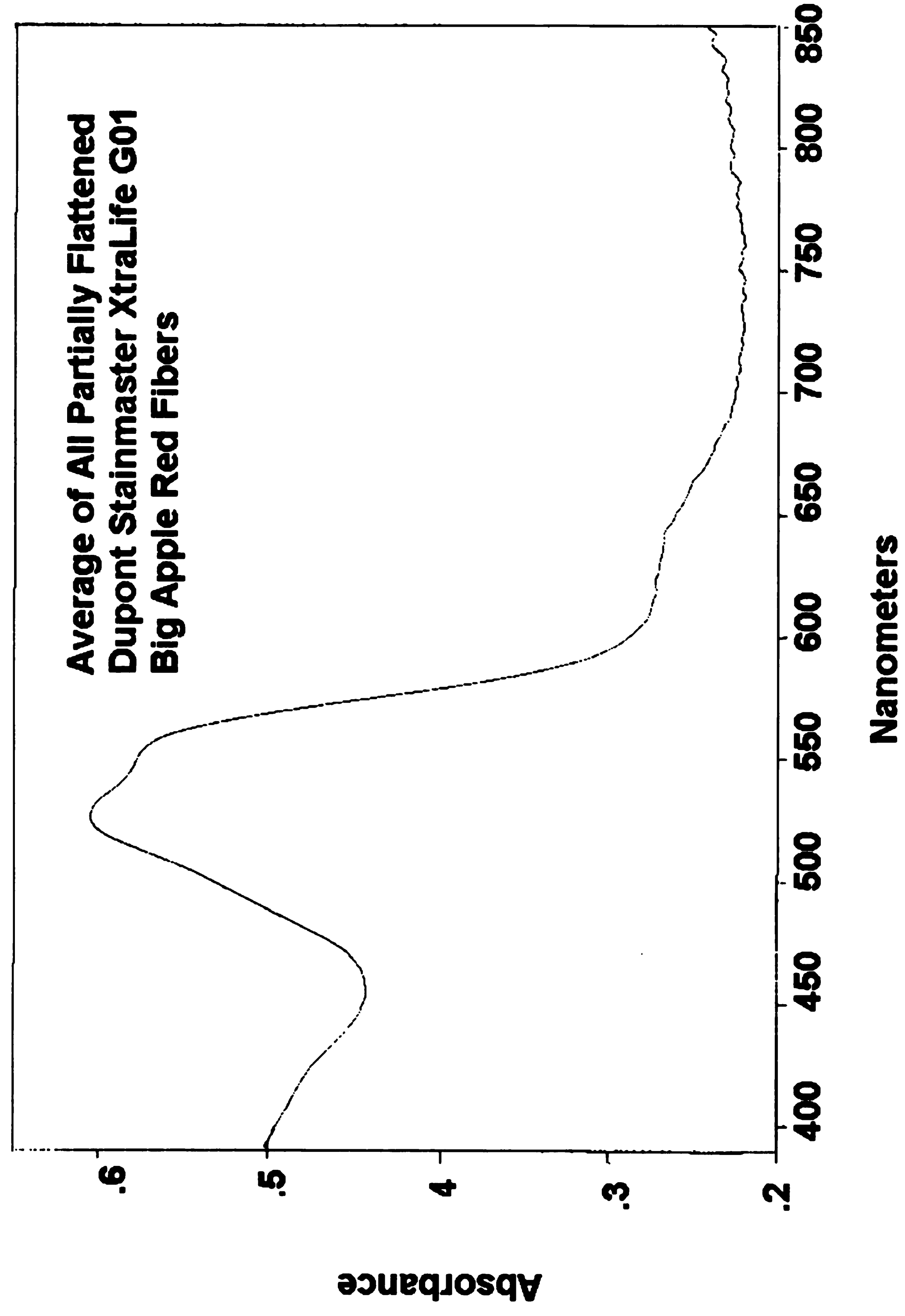
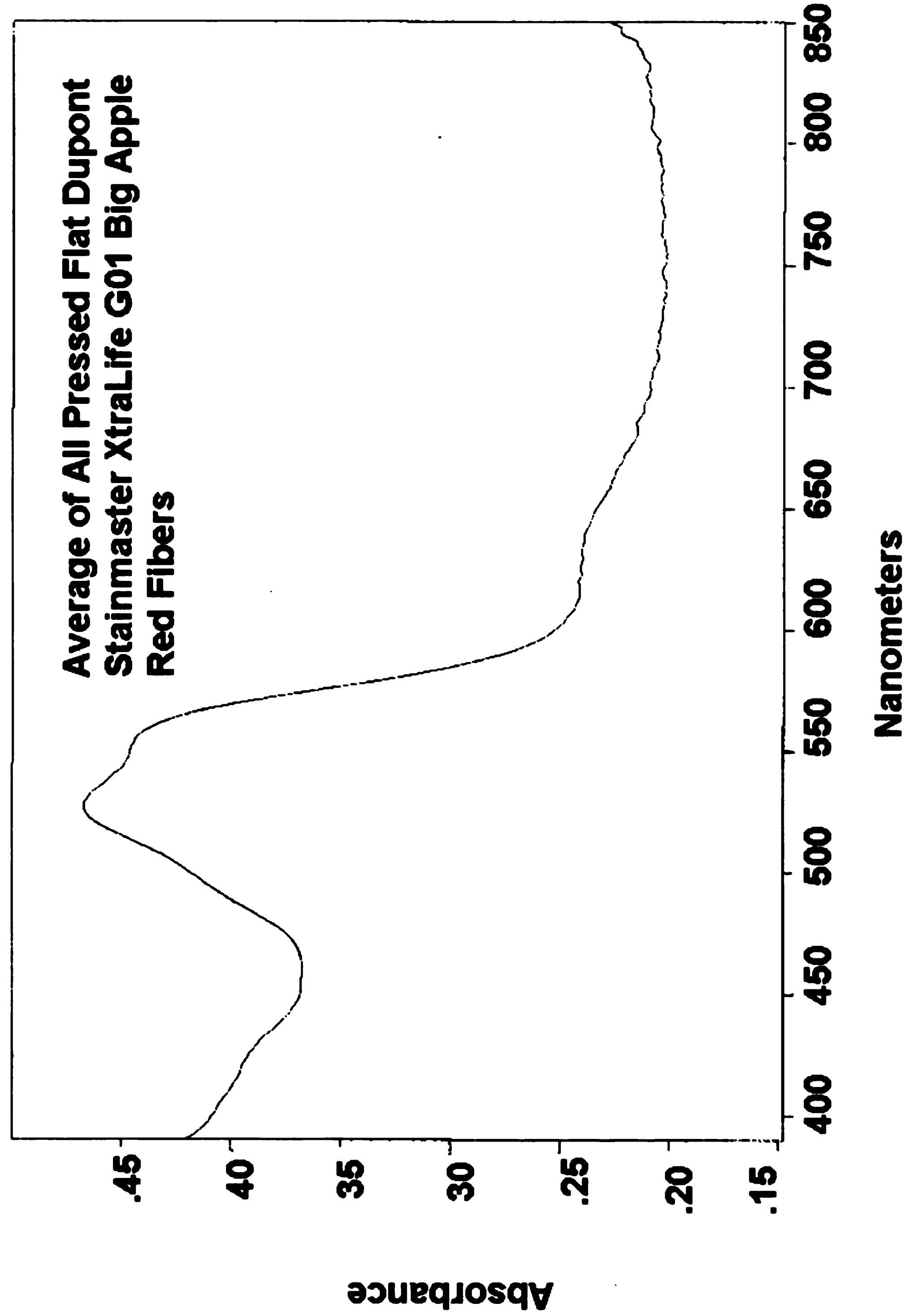


Figure #3-Average of All Pressed Flat Dupont Stainmaster XtraLife G01 Big Apple Red Sample Fibers



# APPENDIX F

## Comparison Spectra of Unflattened, Partially Flattened and Pressed Flat Sample Fibers

Figure #4-Comparison Spectra of Fiber #1

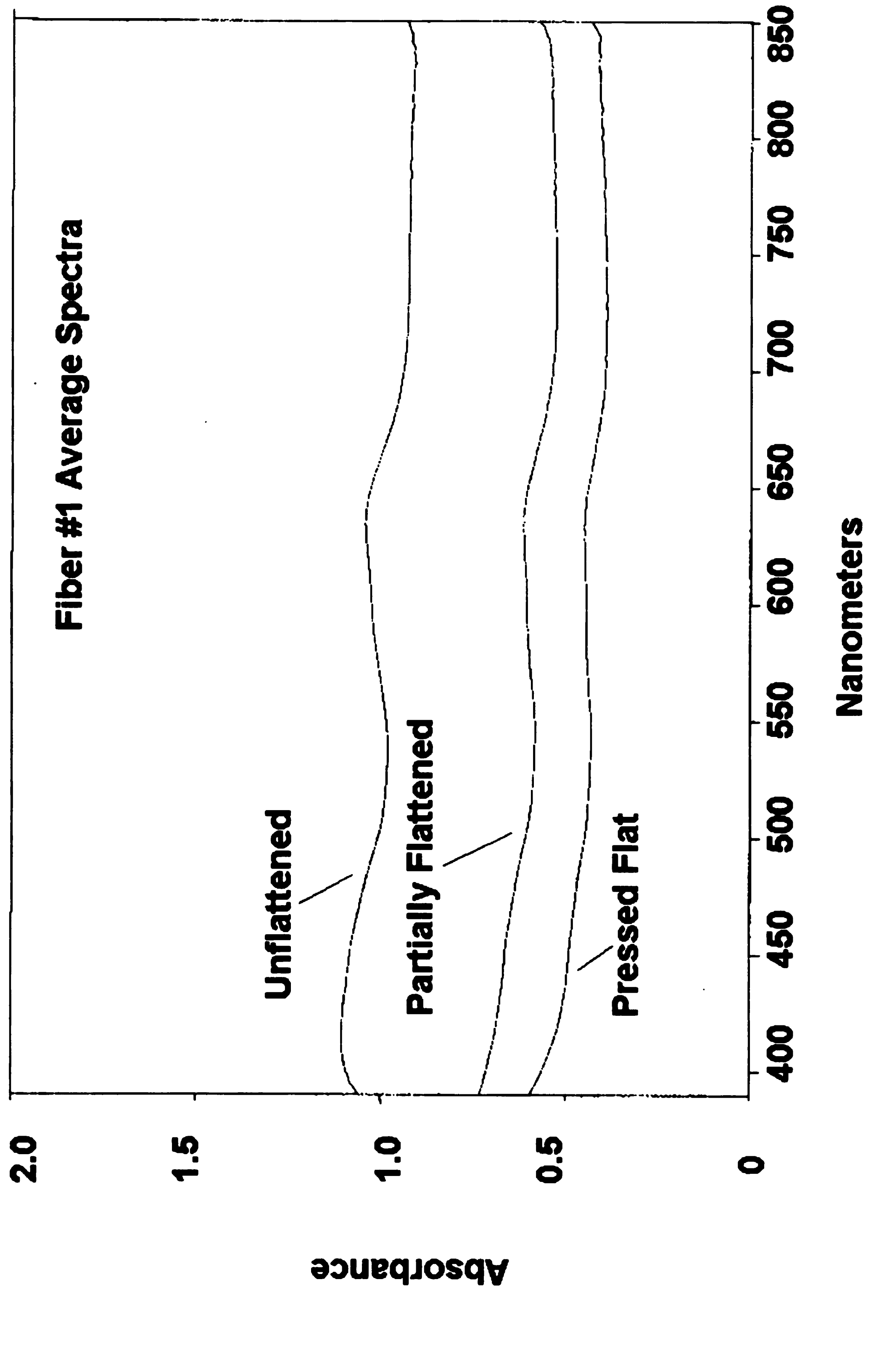


Figure #5-Comparison Spectra of Fiber #2

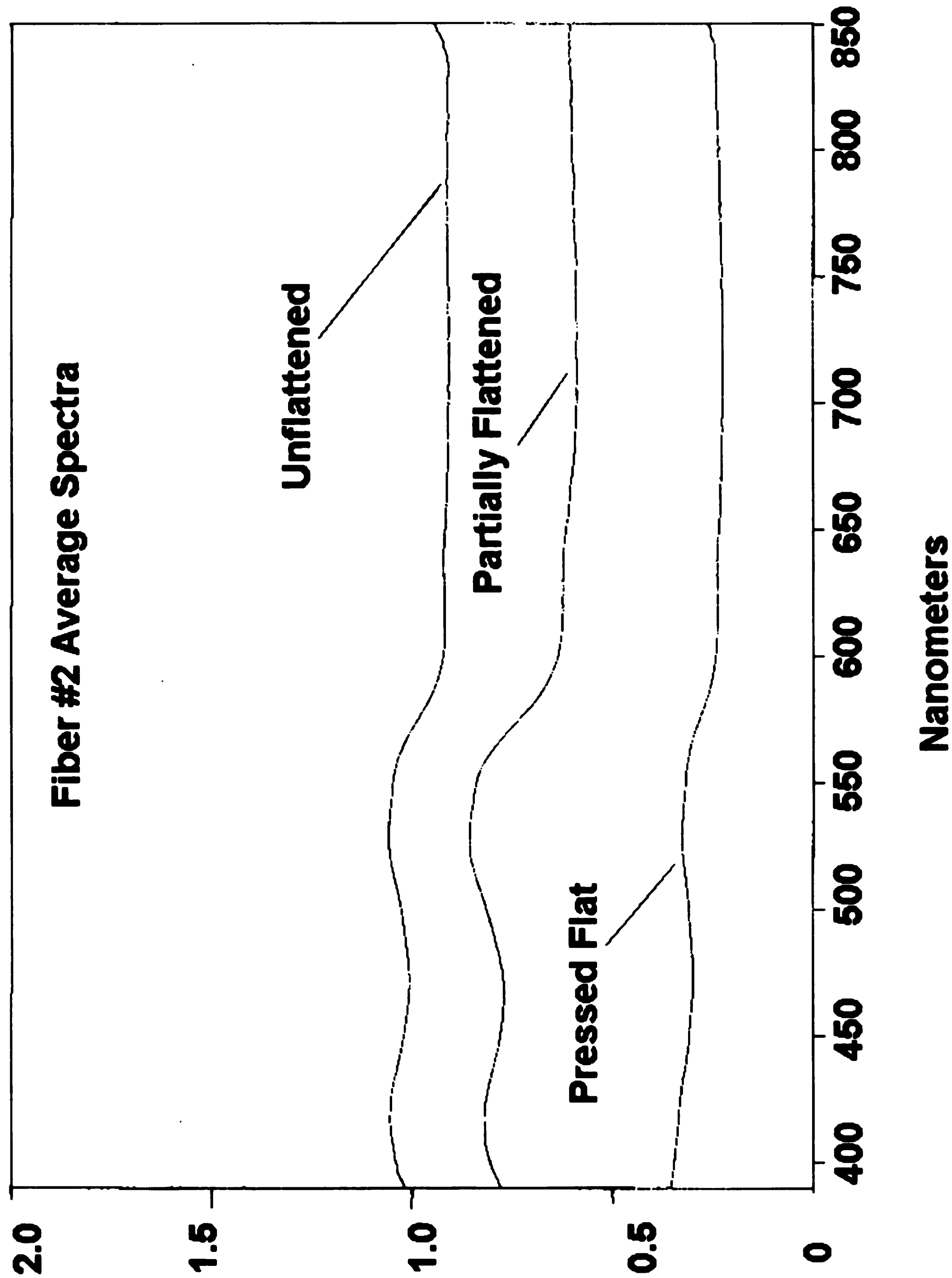


Figure #6-Comparison Spectra of Fiber #3

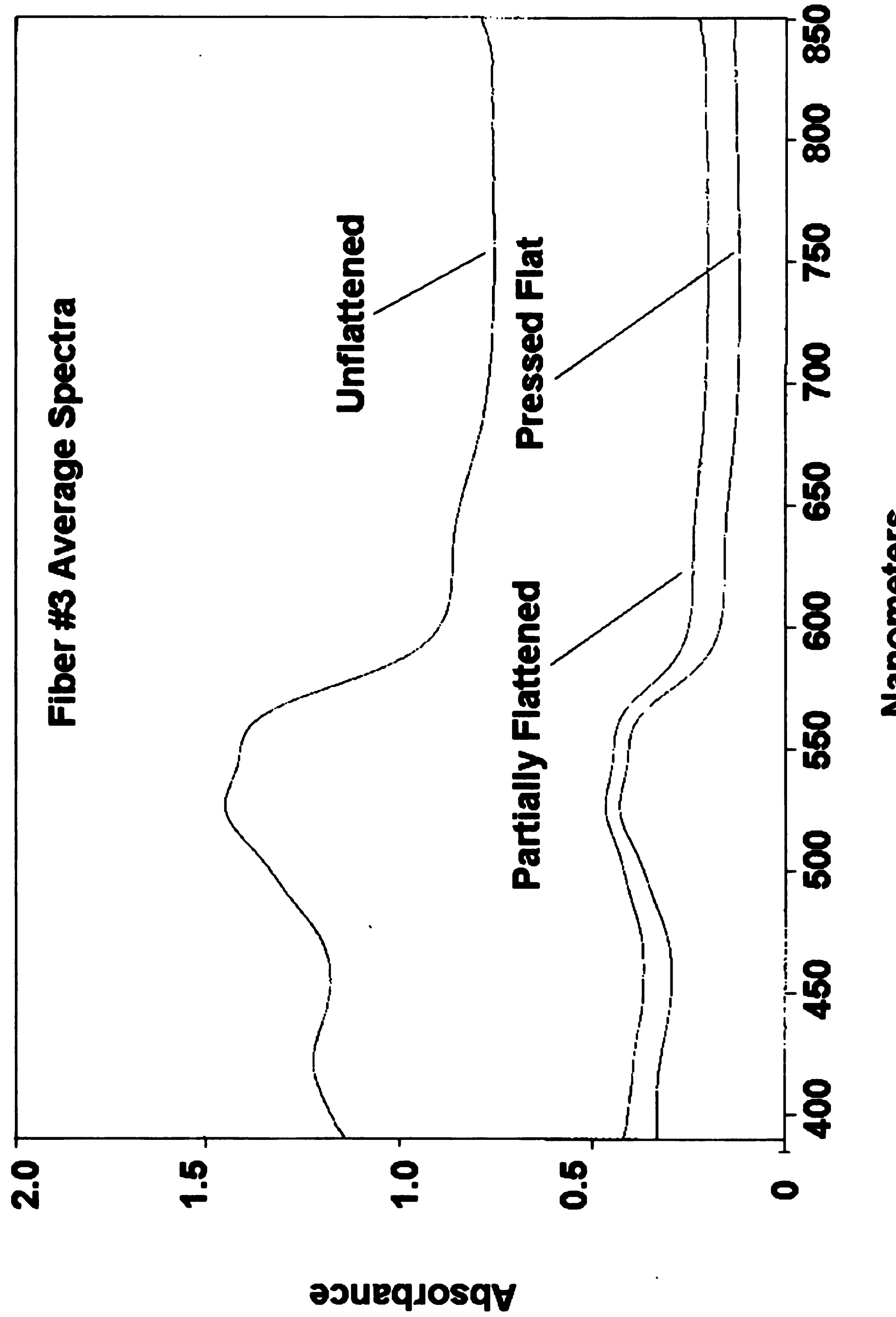


Figure #7-Comparison Spectra of Fiber #4

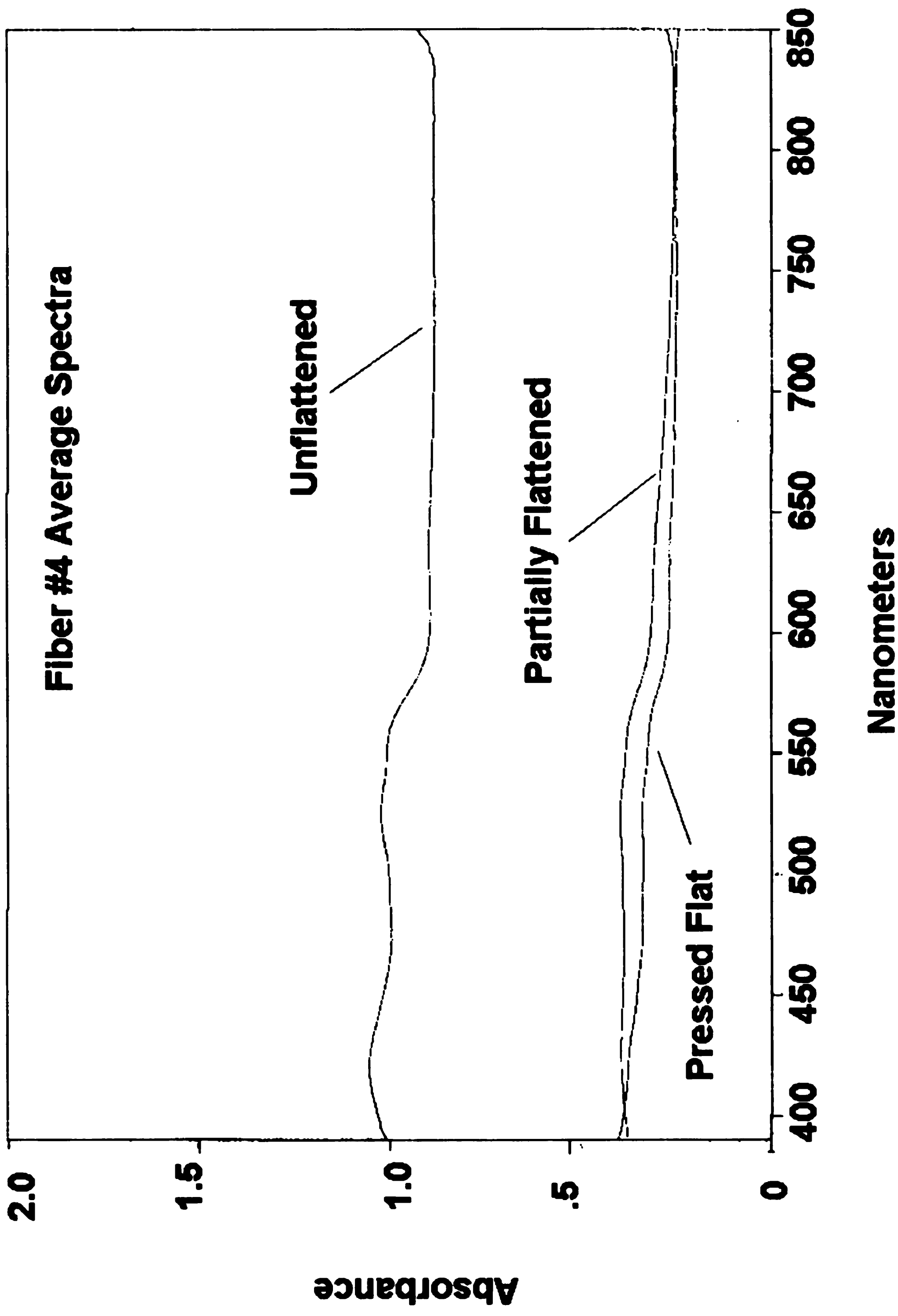


Figure #8-Comparison Spectra of Fiber #5

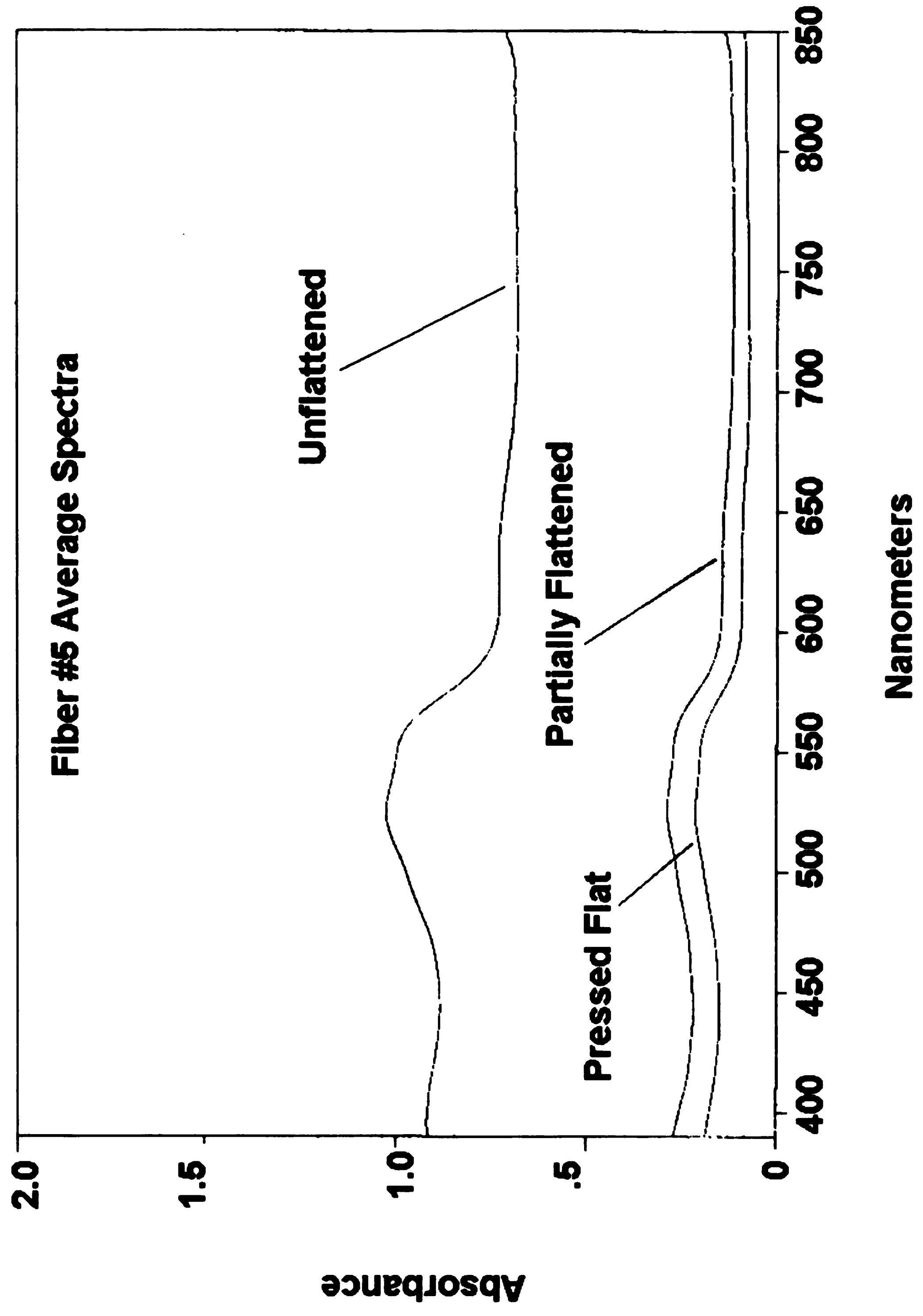


Figure #9-Comparison Spectra of Fiber #6

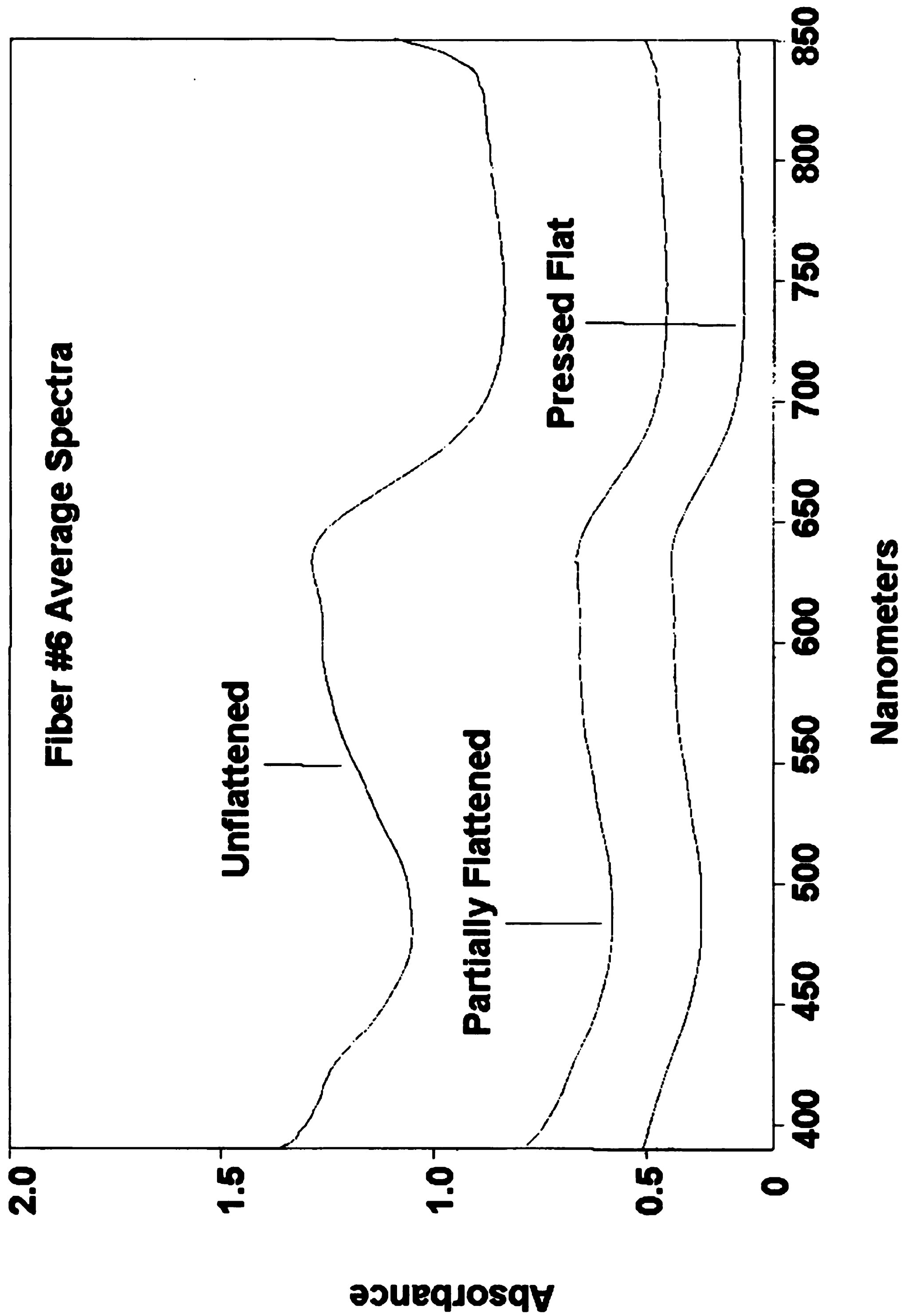


Figure #10-Comparison Spectra of Fiber #7

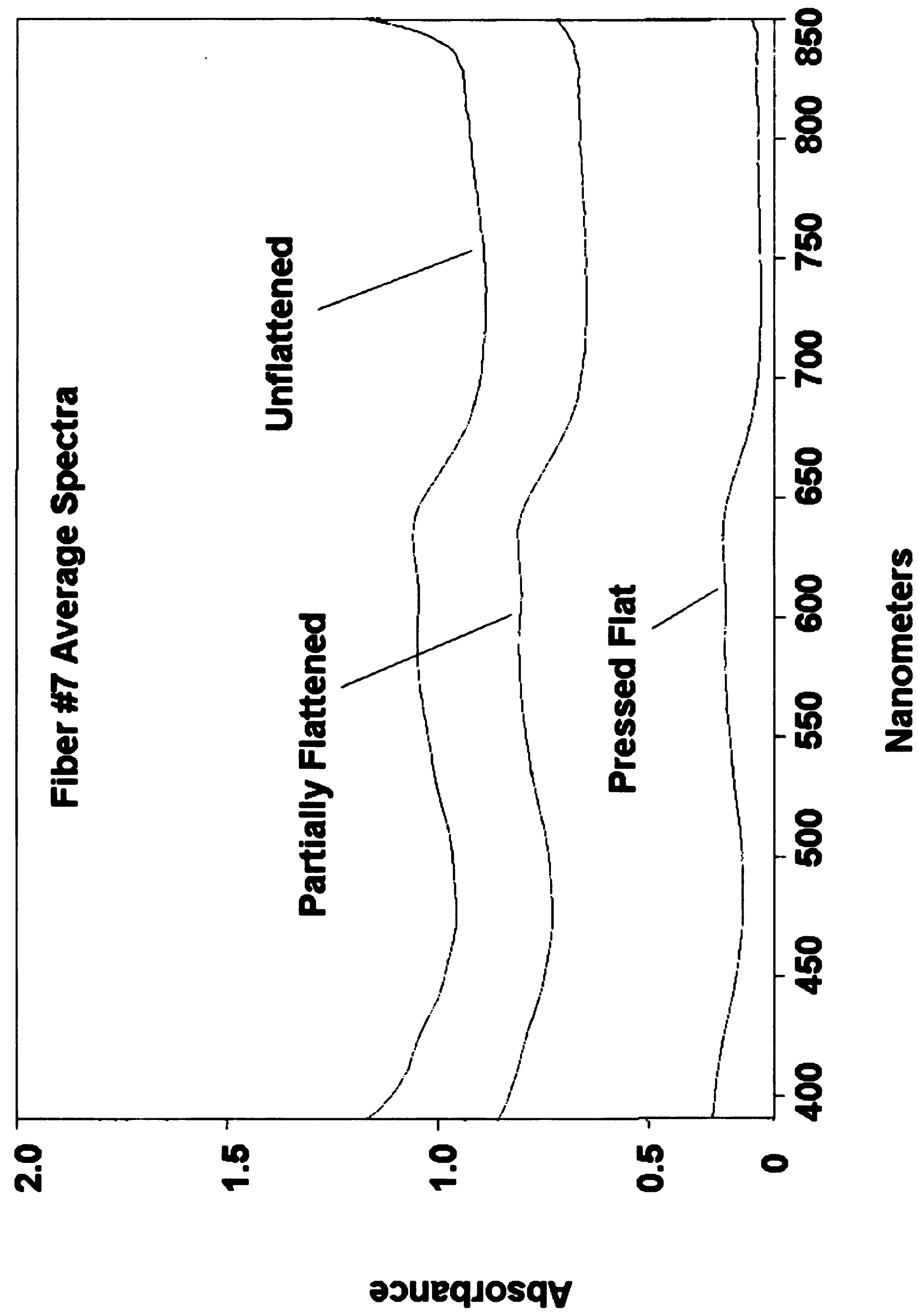


Figure #11-Comparison Spectra of Fiber #8

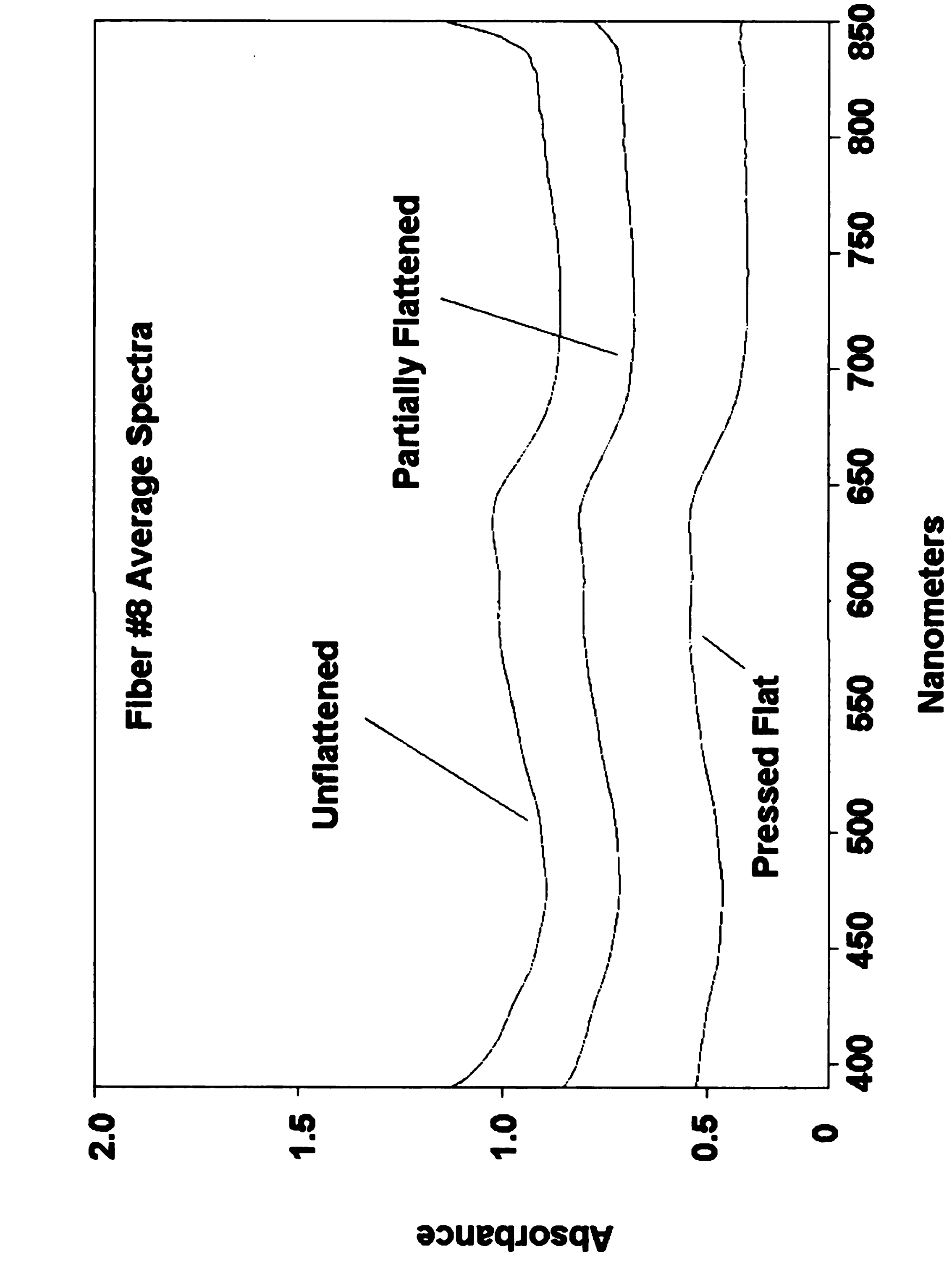


Figure #12-Comparison Spectra of Fiber #9

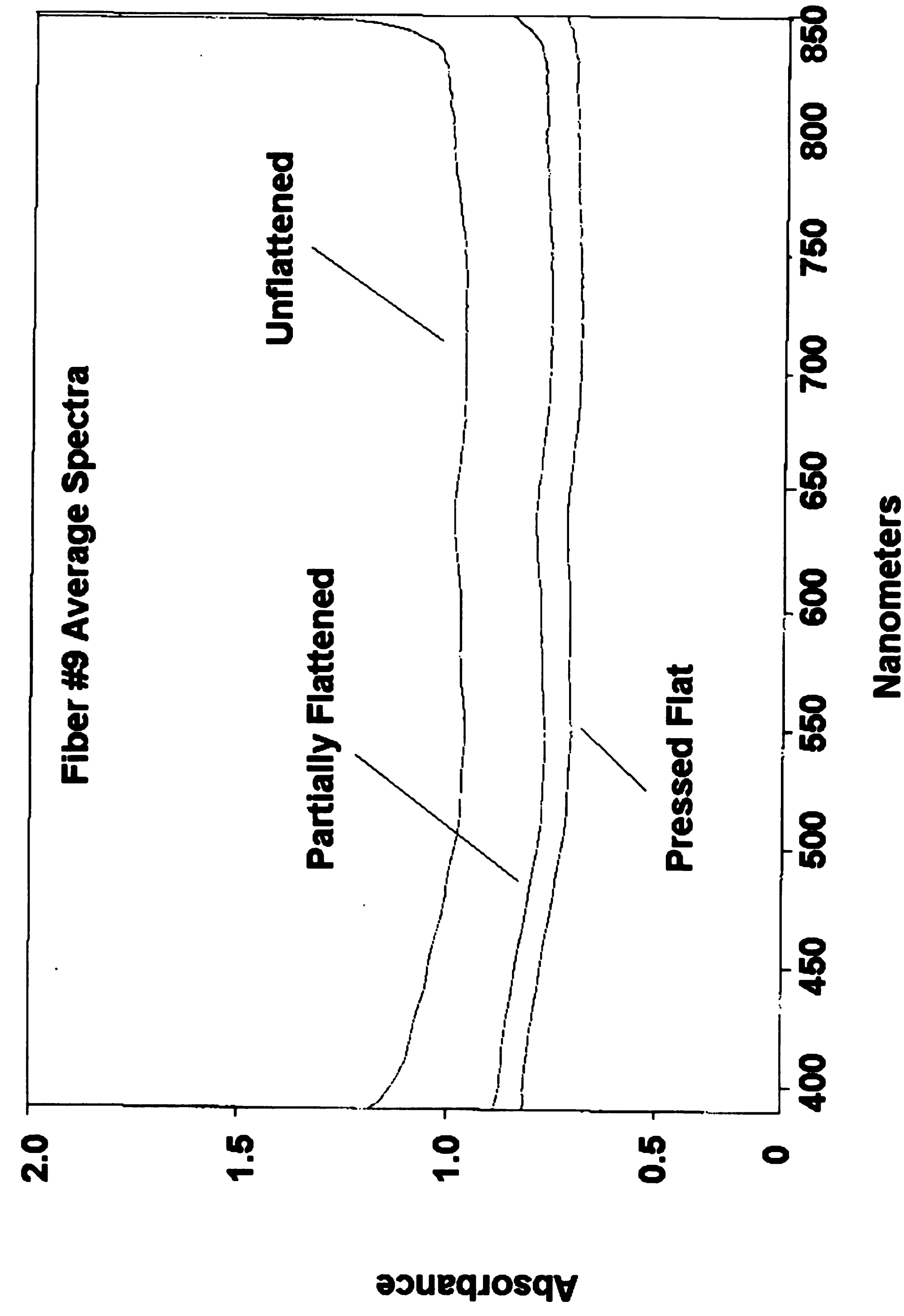


Figure #13-Comparison Spectra of Fiber #10

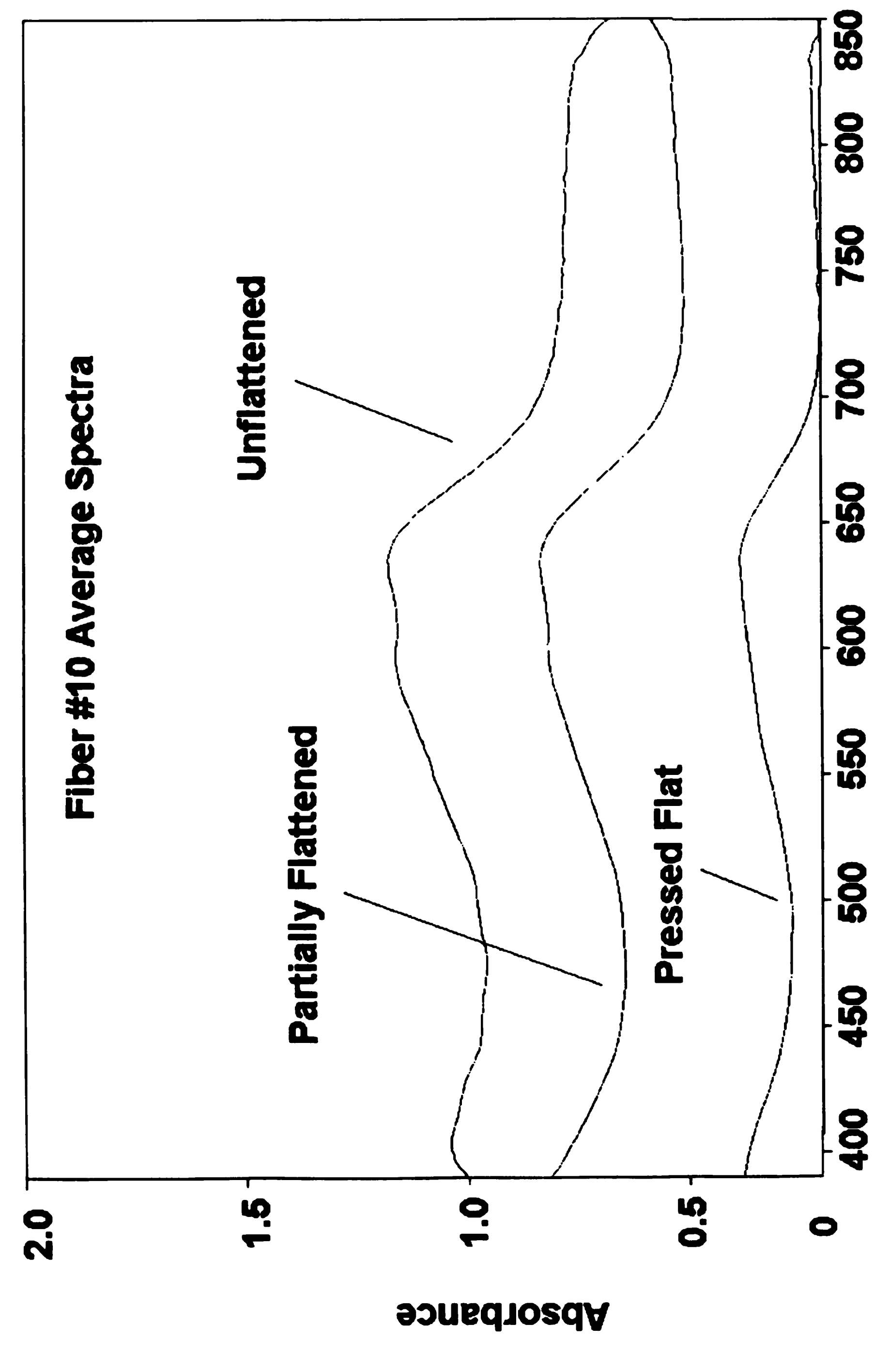


Figure #14-Comparison Spectra of Fiber #11

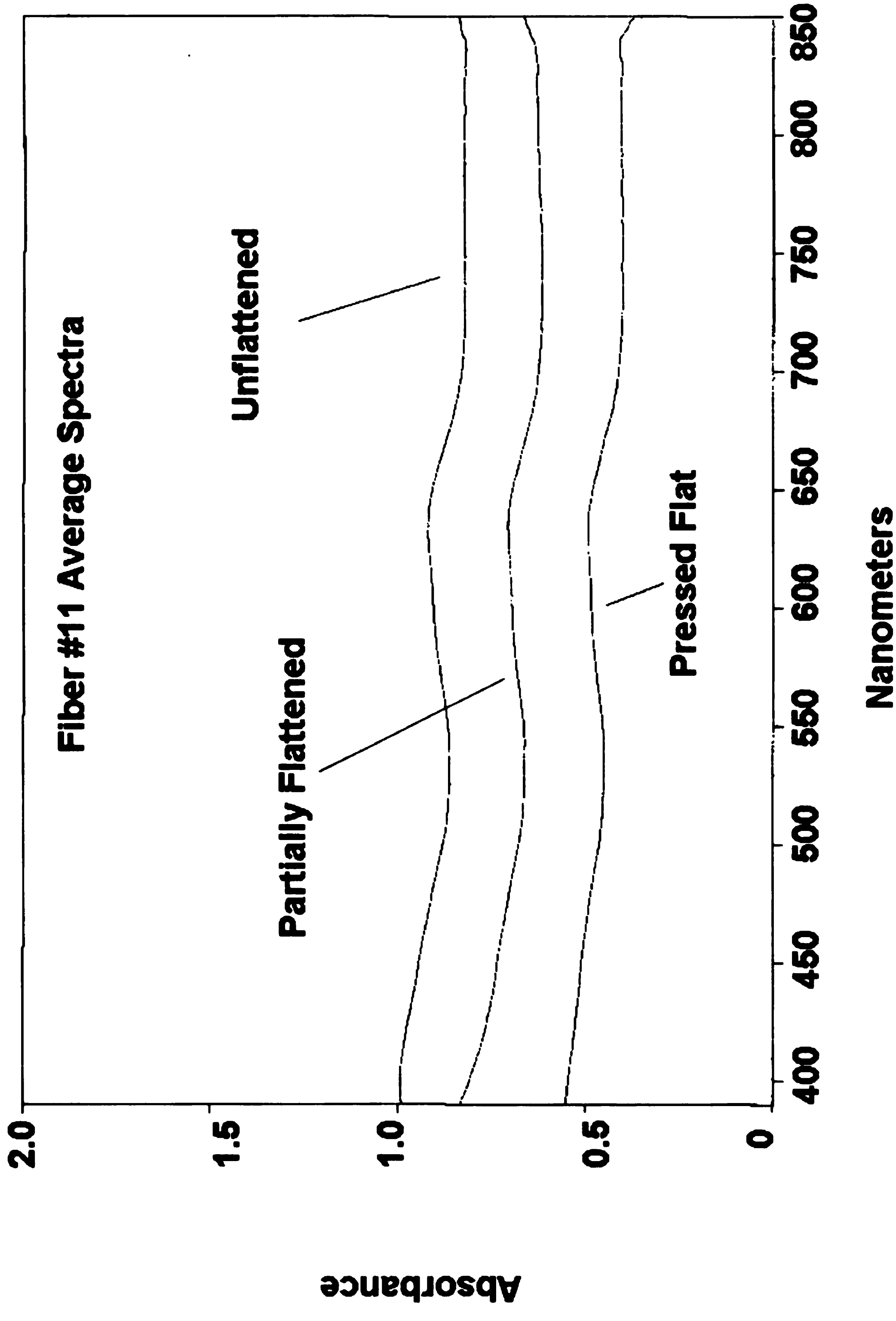


Figure #15-Comparison Spectra of Fiber #12

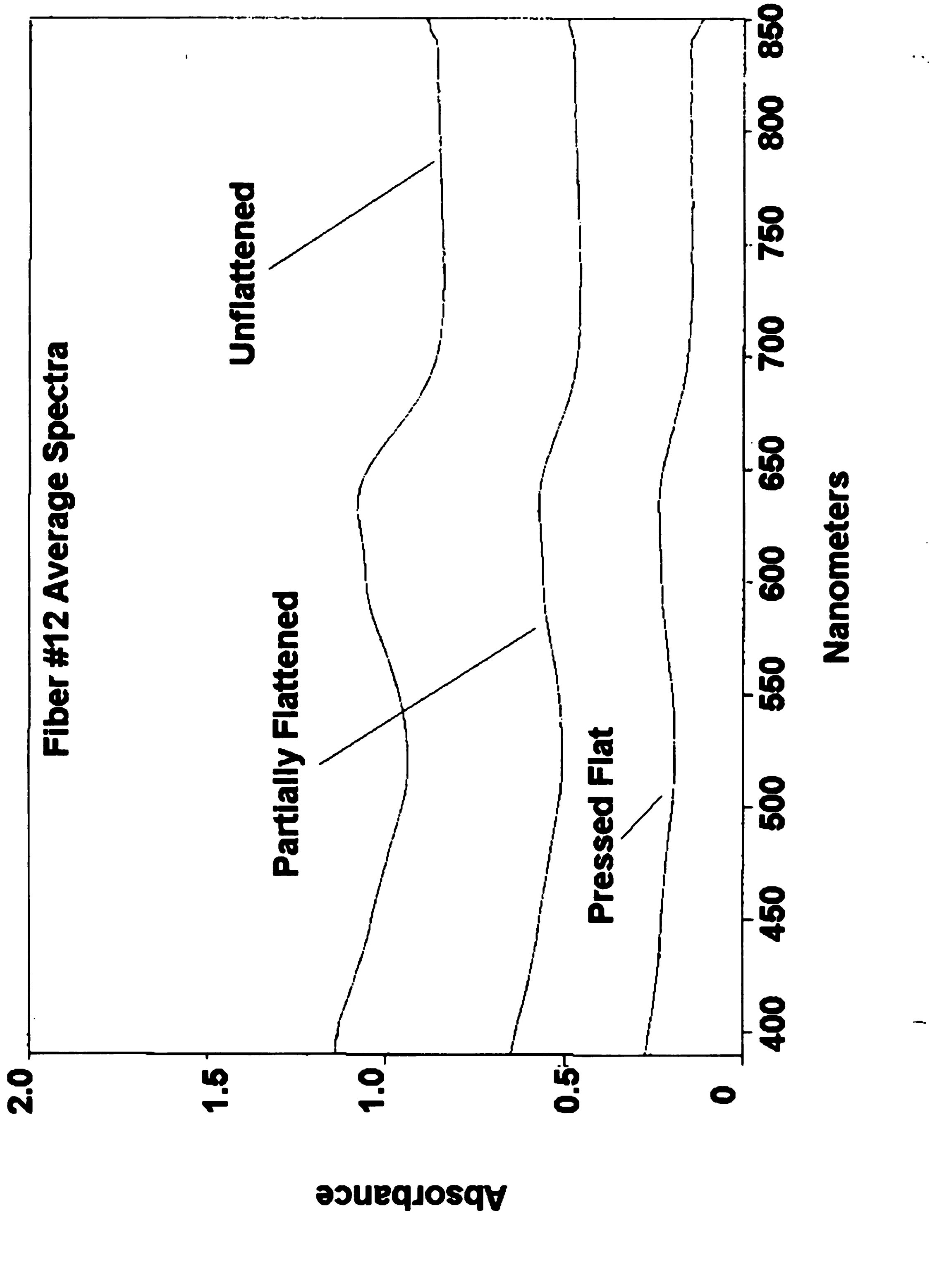


Figure #16-Comparison Spectra of Fiber #13

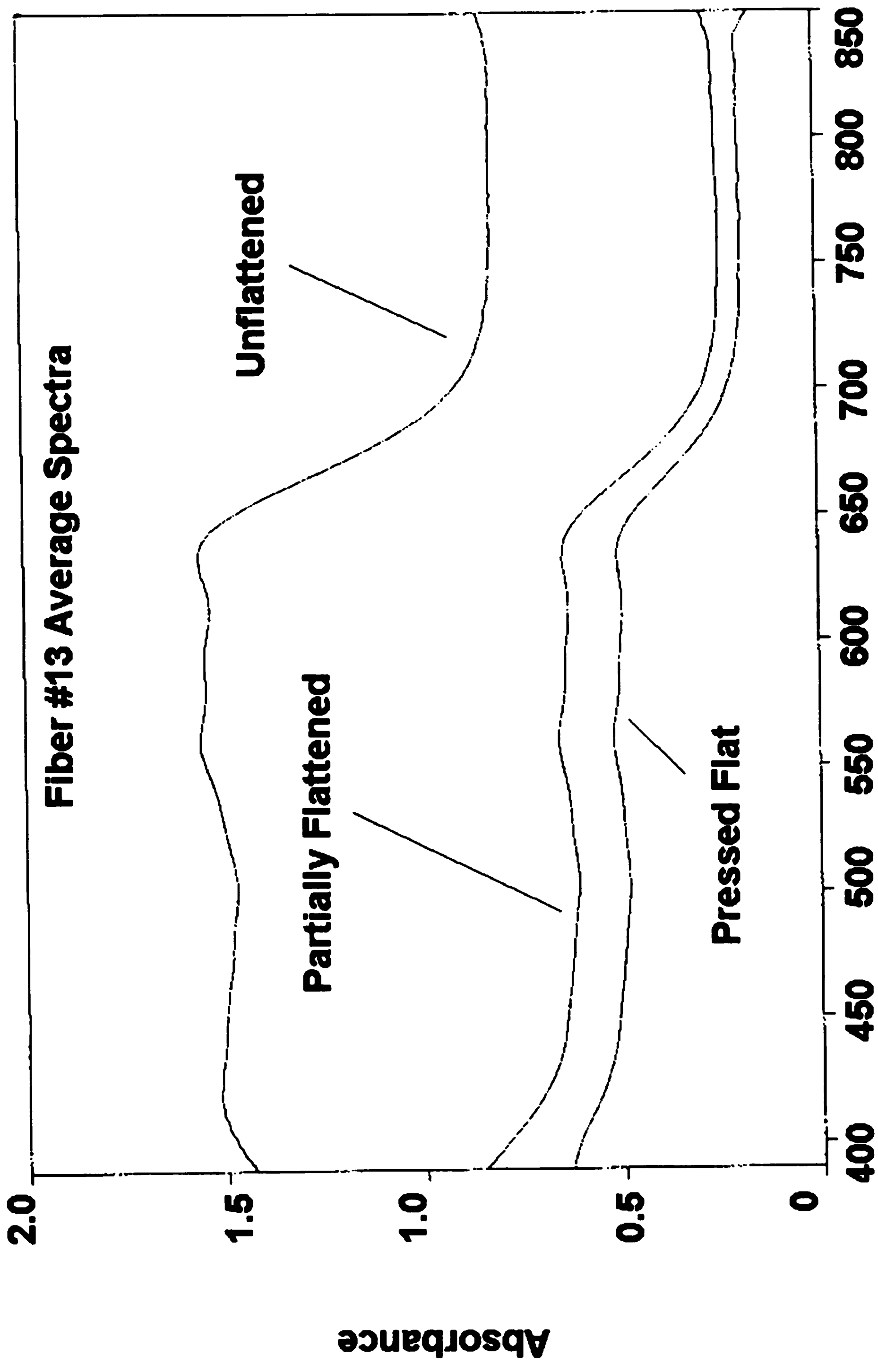


Figure #17-Comparison Spectra of Fiber #14

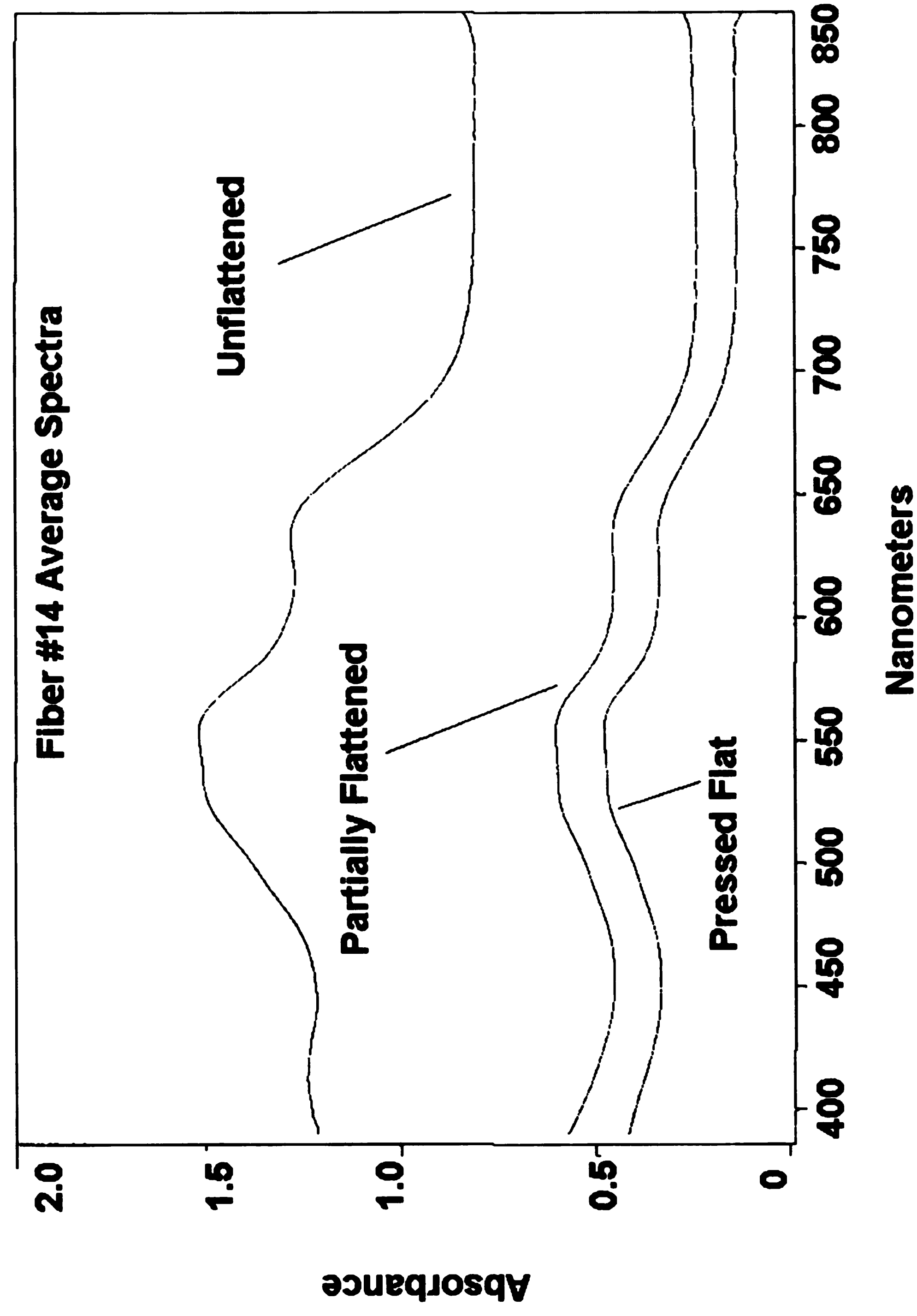


Figure #18-Comparison Spectra of Fiber #15

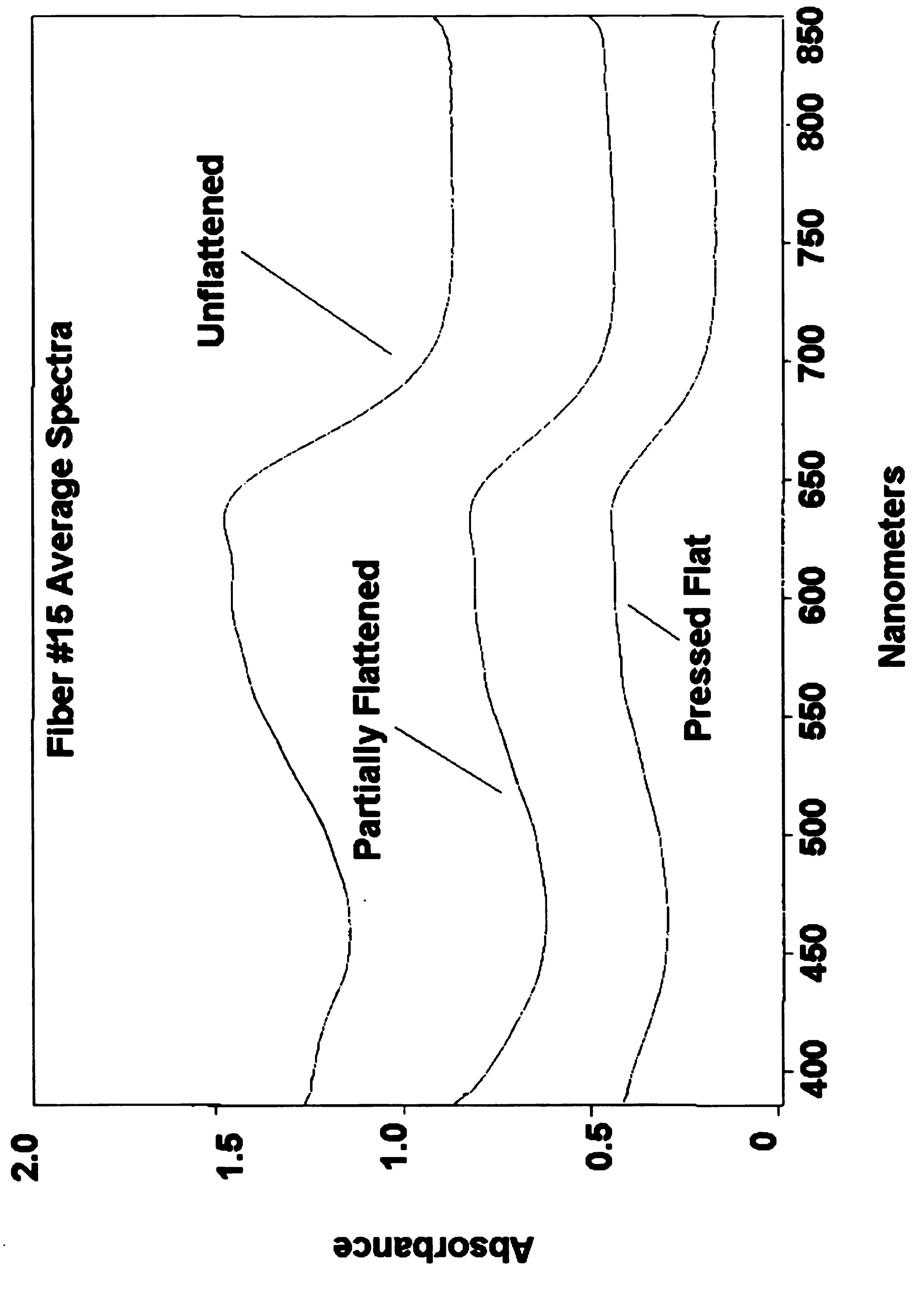


Figure #19-Comparison Spectra of Fiber #16

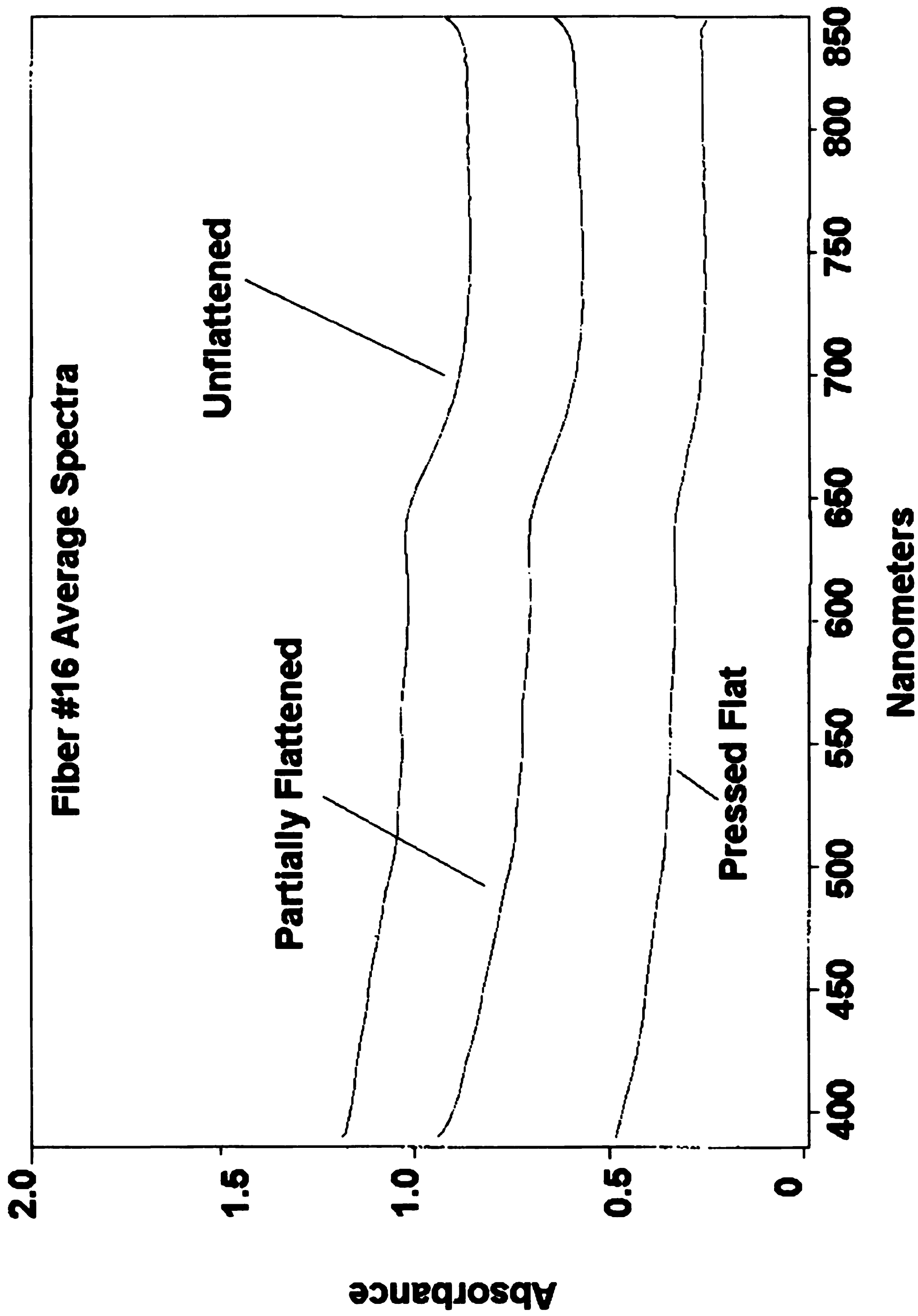


Figure #20-Comparison Spectra of Fiber #17

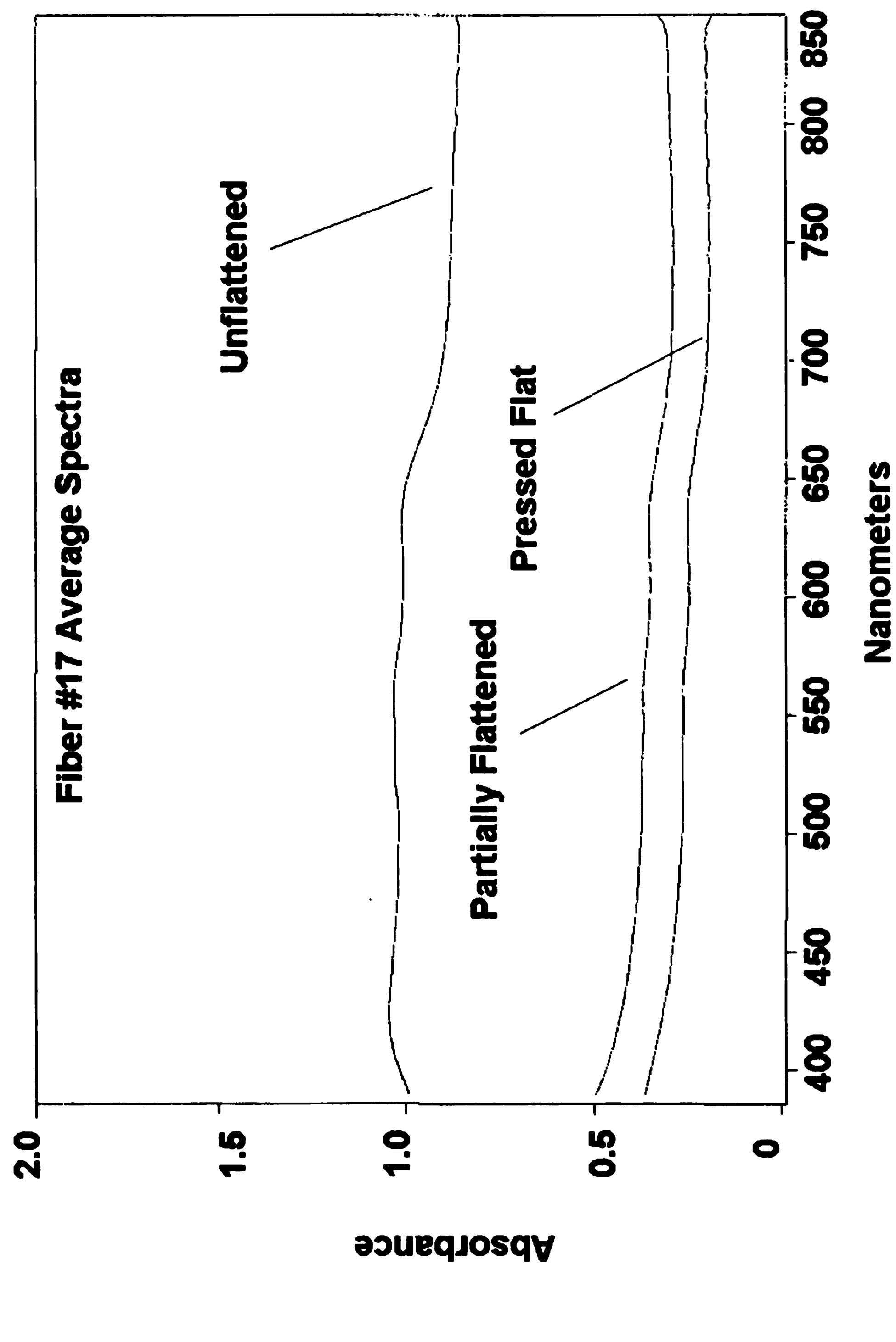


Figure #21-Comparison Spectra of Fiber #18

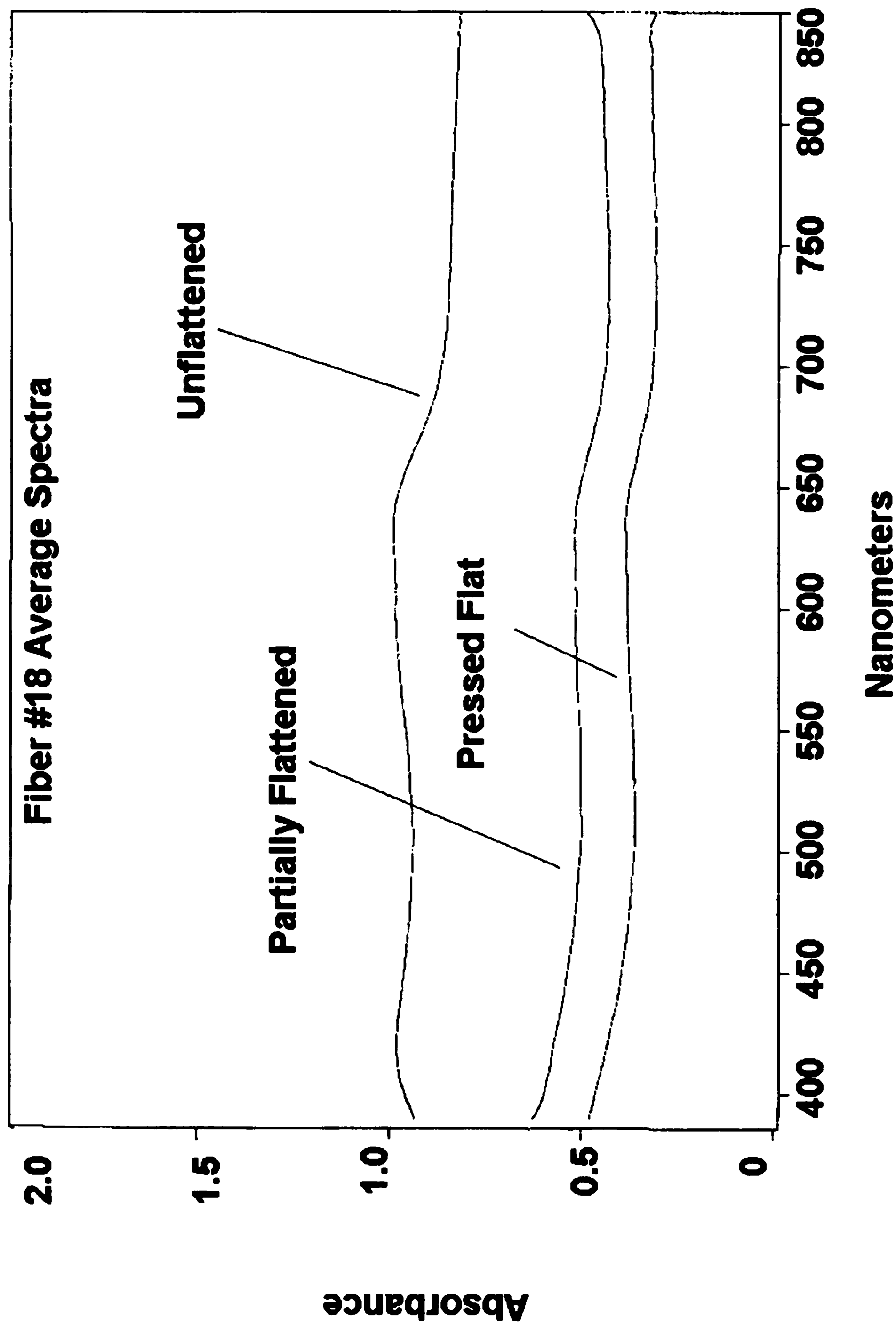


Figure #22-Comparison Spectra of Fiber #19

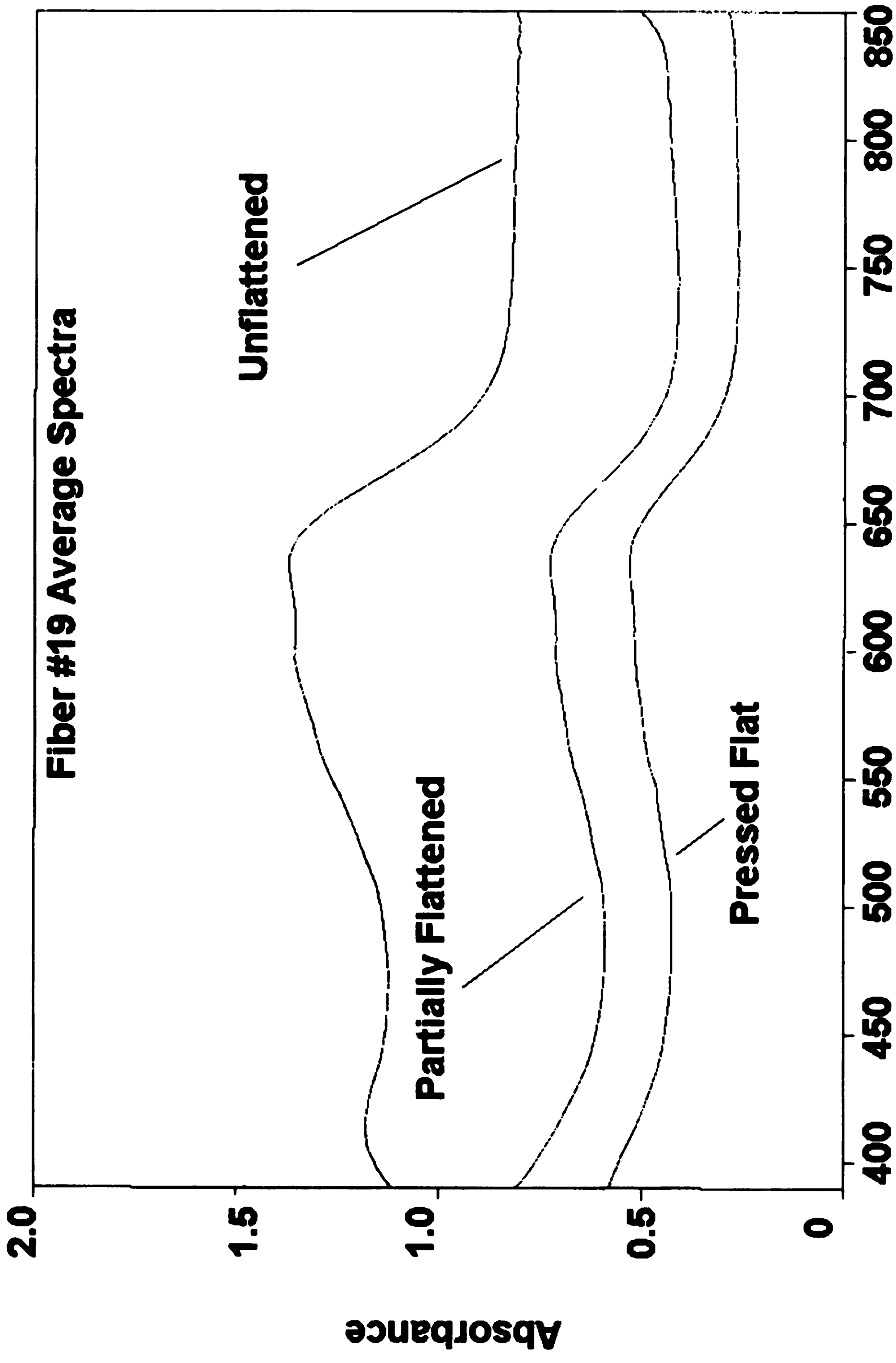


Figure #23-Comparison Spectra of Fiber #20

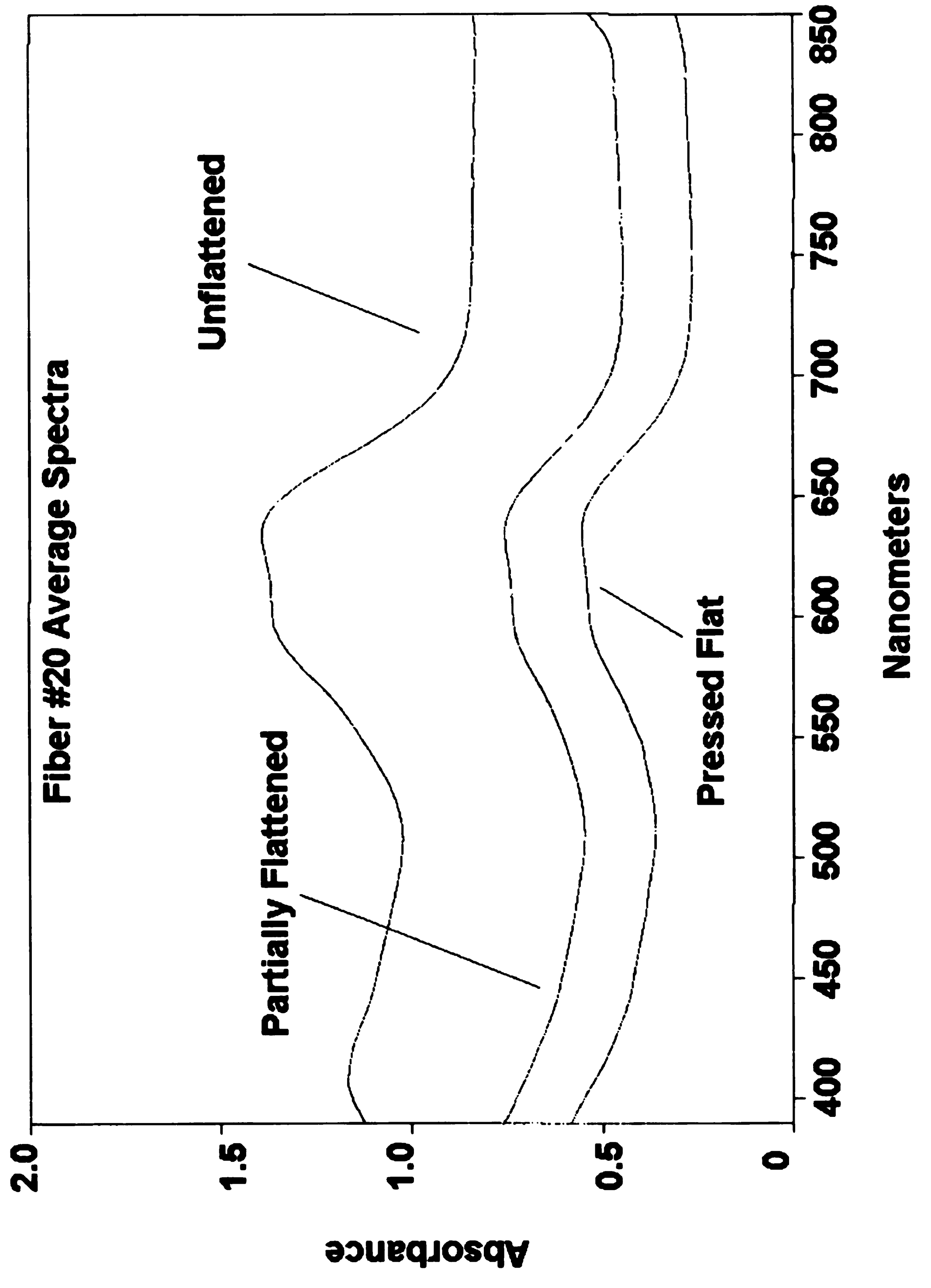


Figure #24-Comparison Spectra of Fiber #21

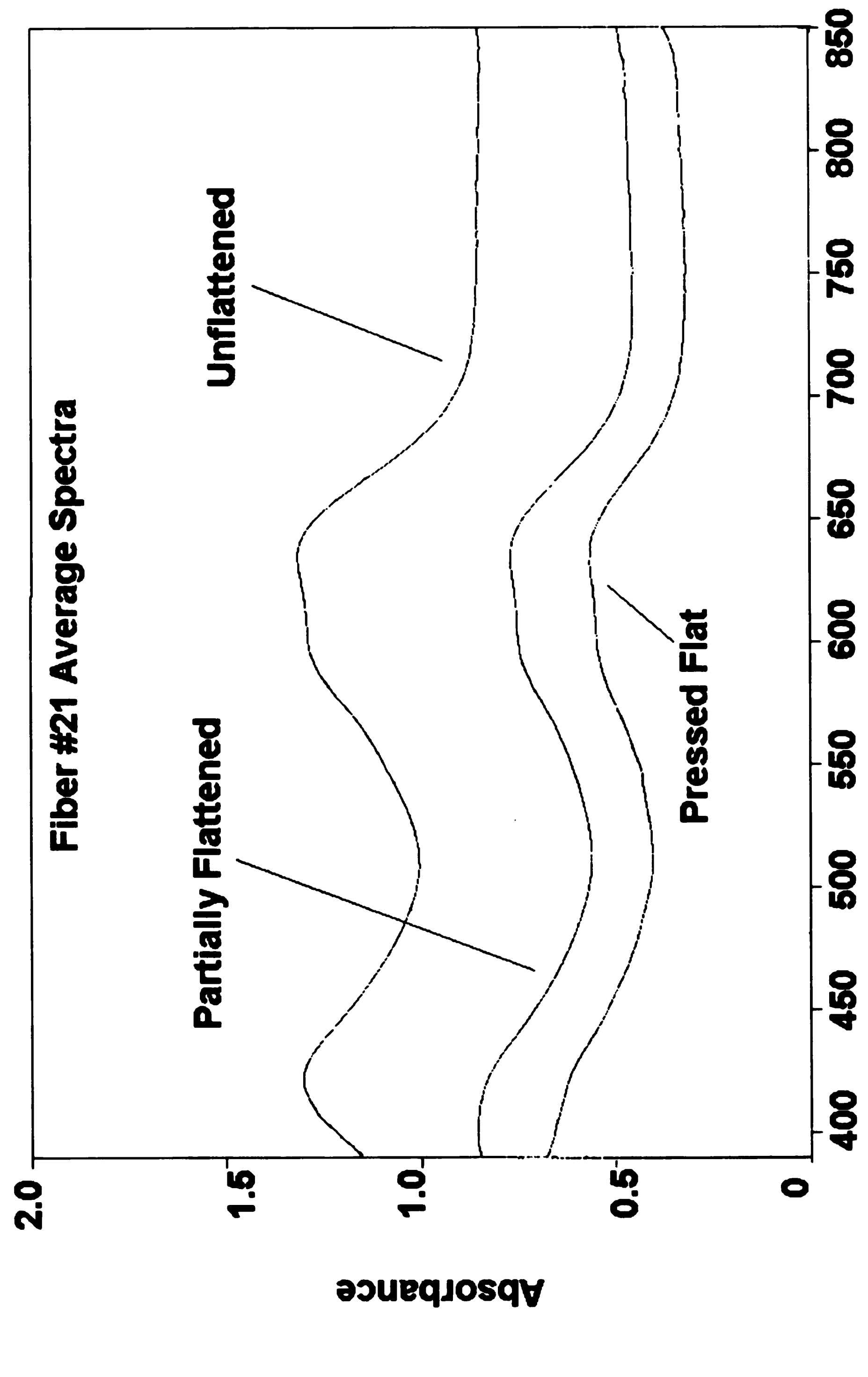


Figure #25-Comparison Spectra of Fiber #22

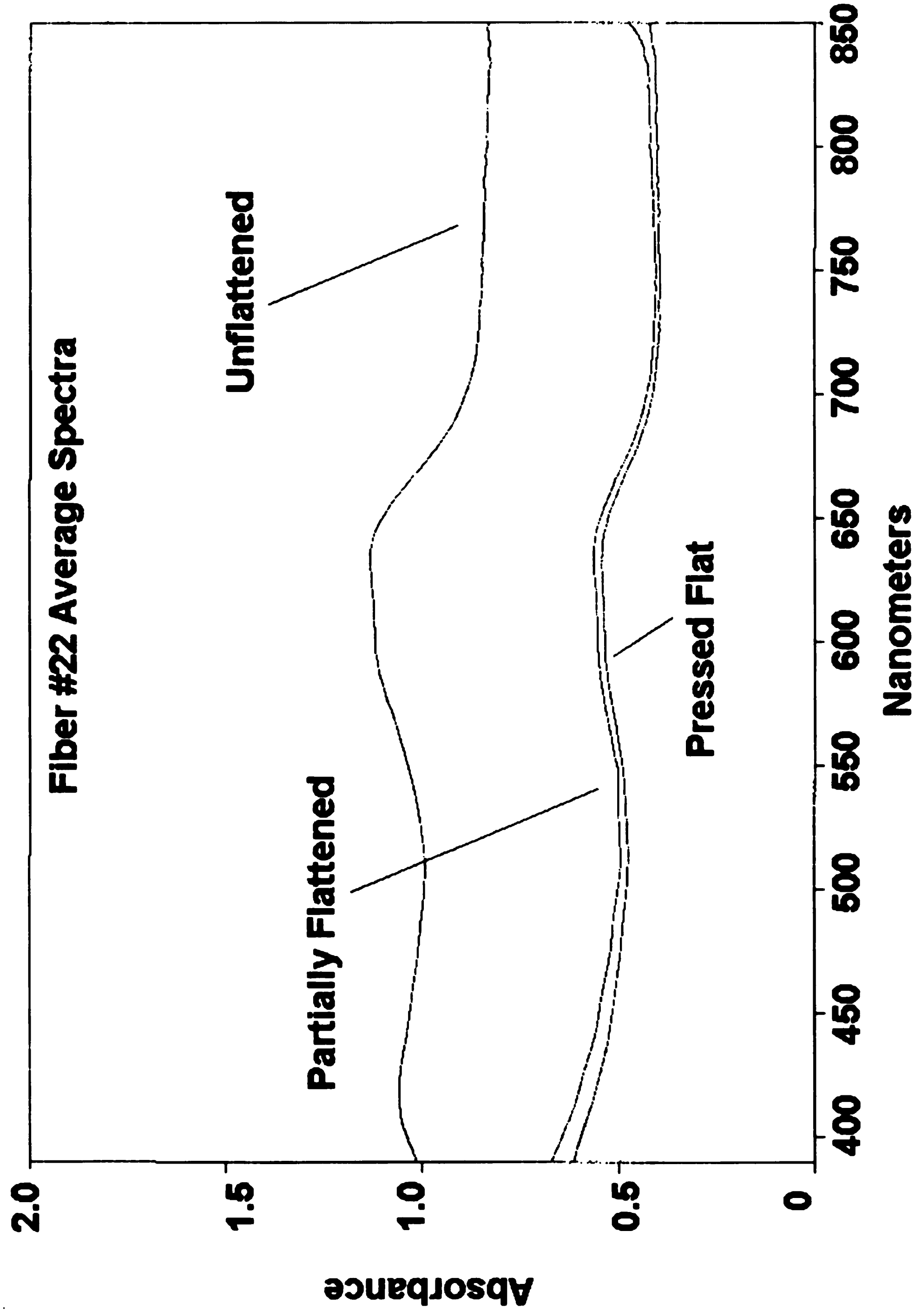


Figure #26-Comparison Spectra of Fiber #23

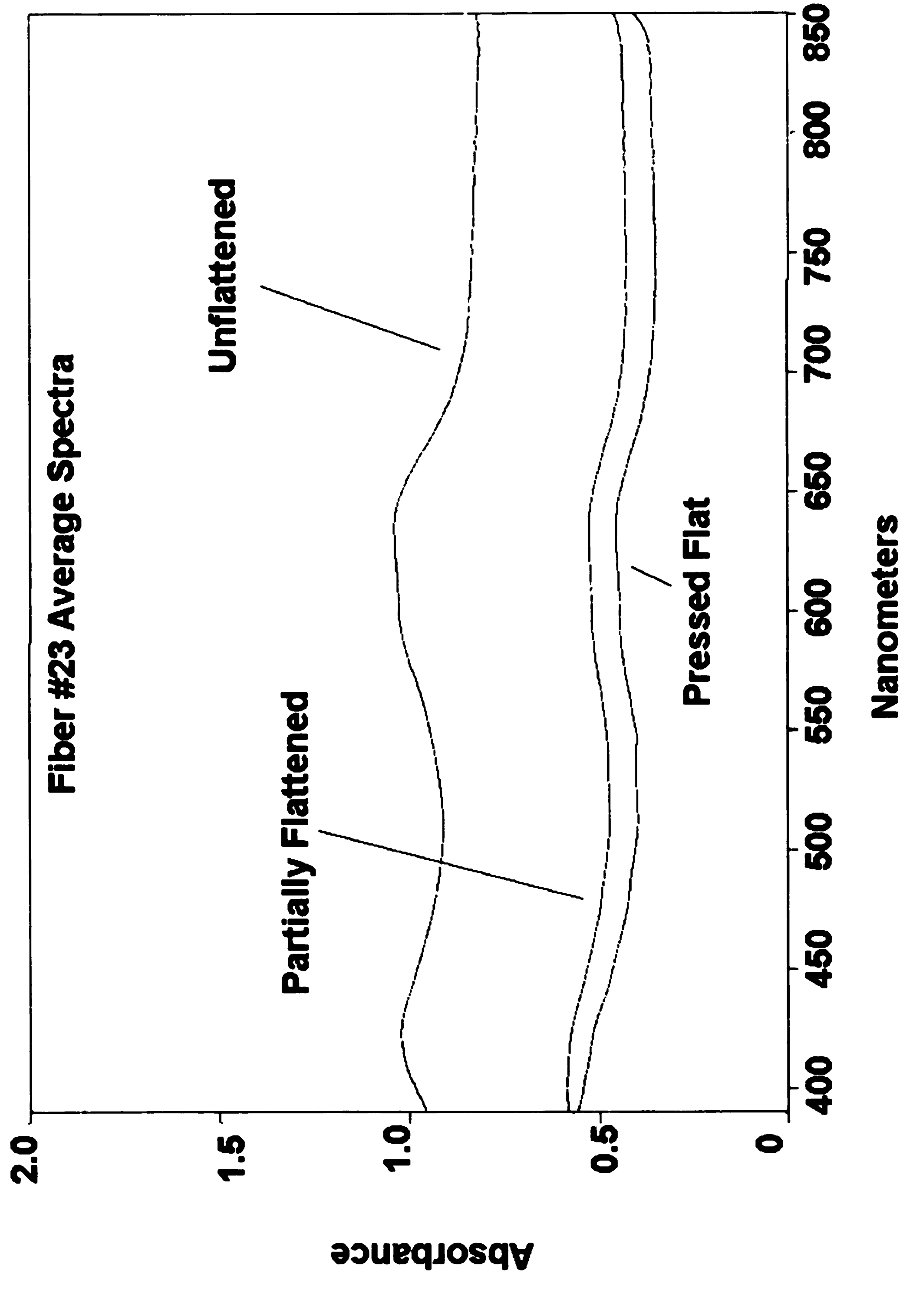


Figure #27-Comparison Spectra of Fiber #24

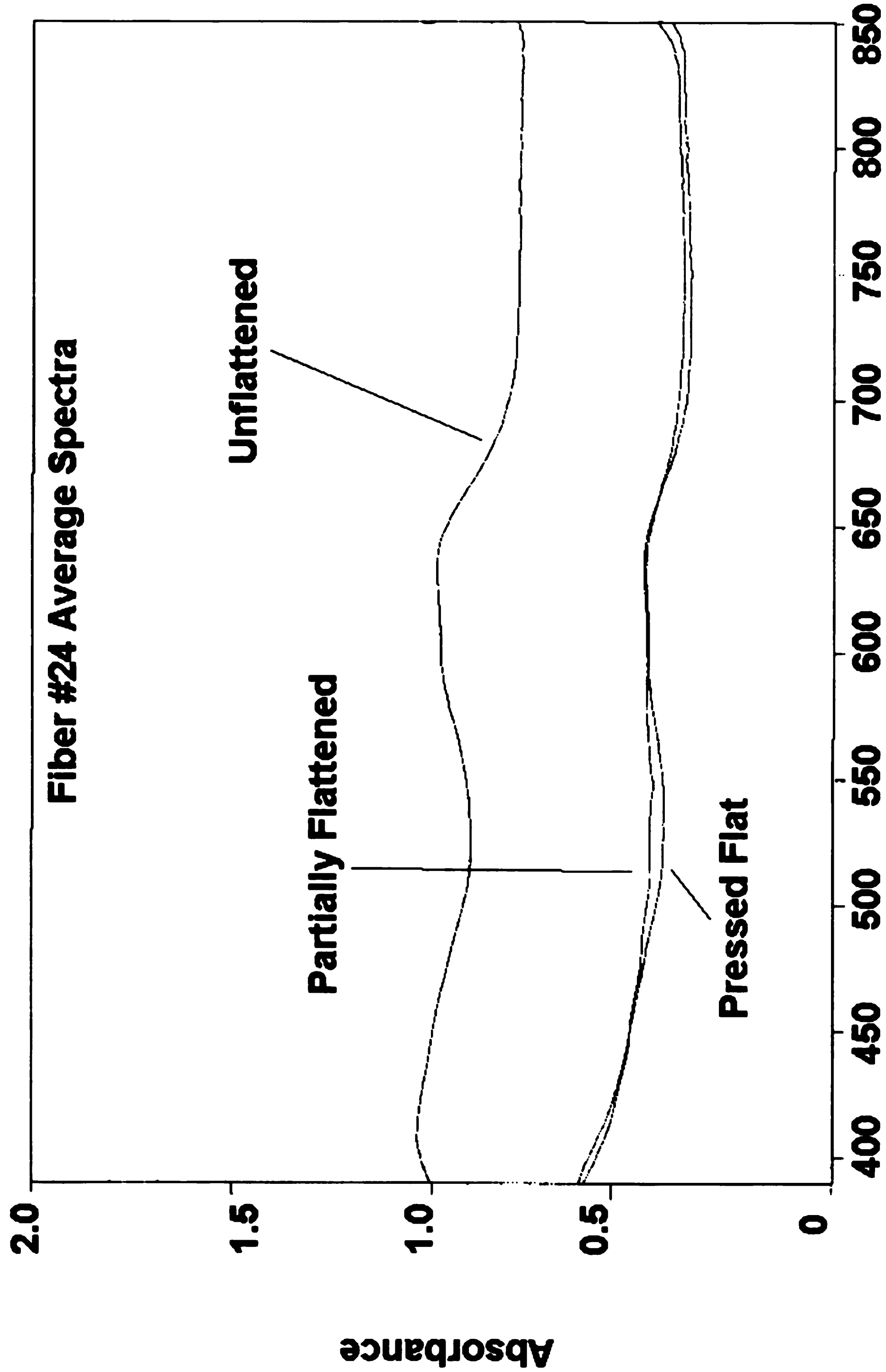


Figure #28-Comparison Spectra of Fiber #25

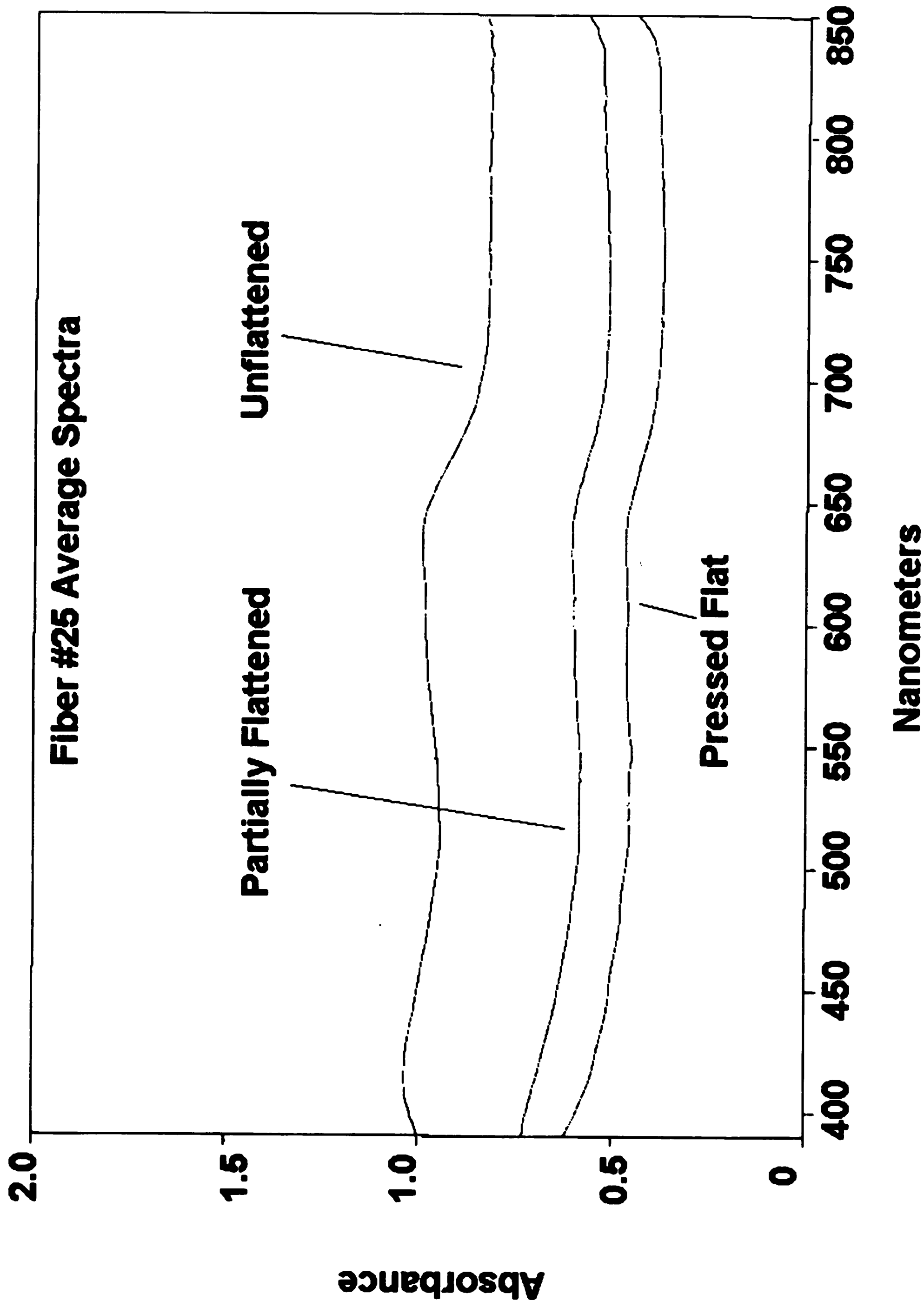


Figure #29-Comparison Spectra of Fiber #26

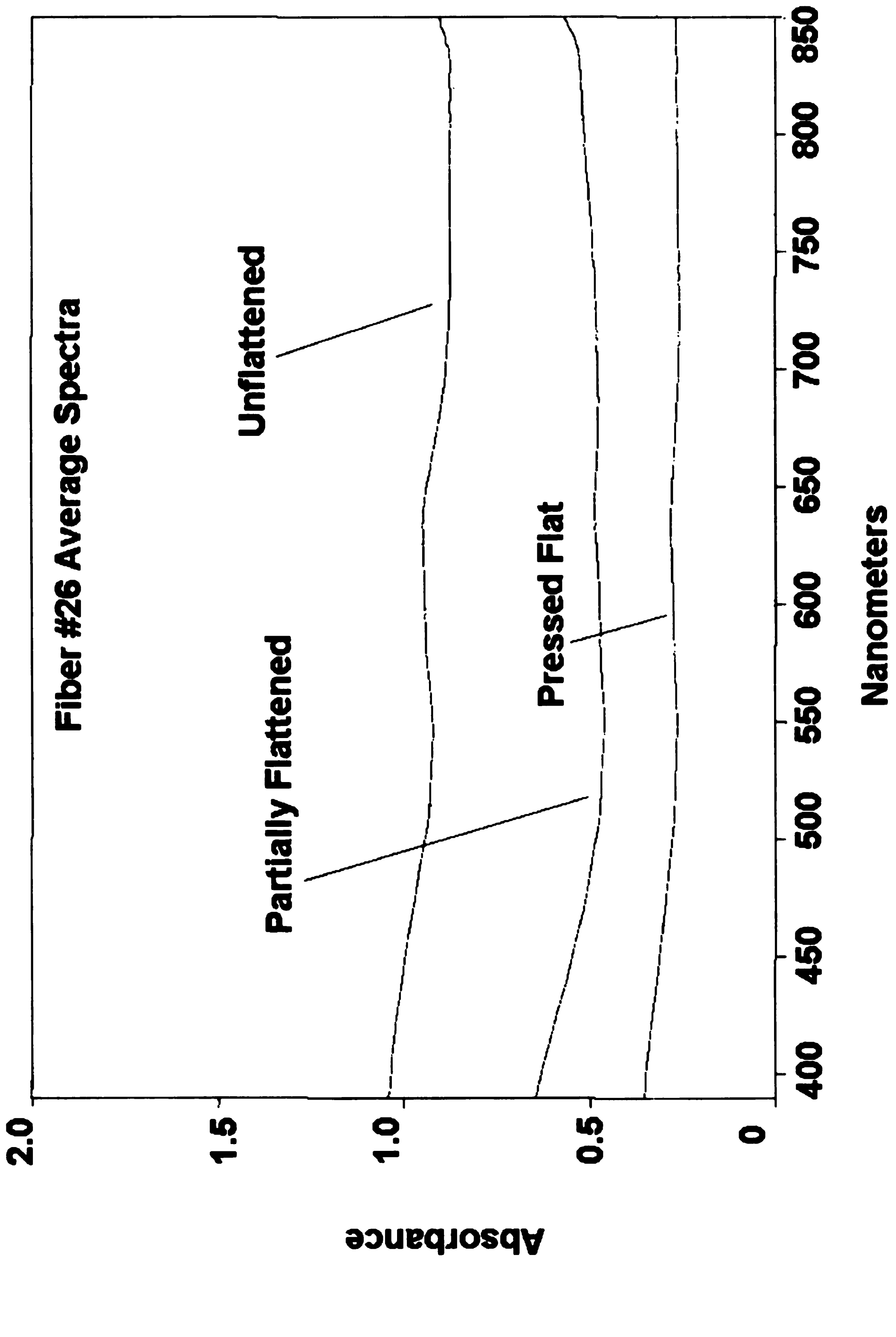


Figure #30-Comparison Spectra of Fiber #27

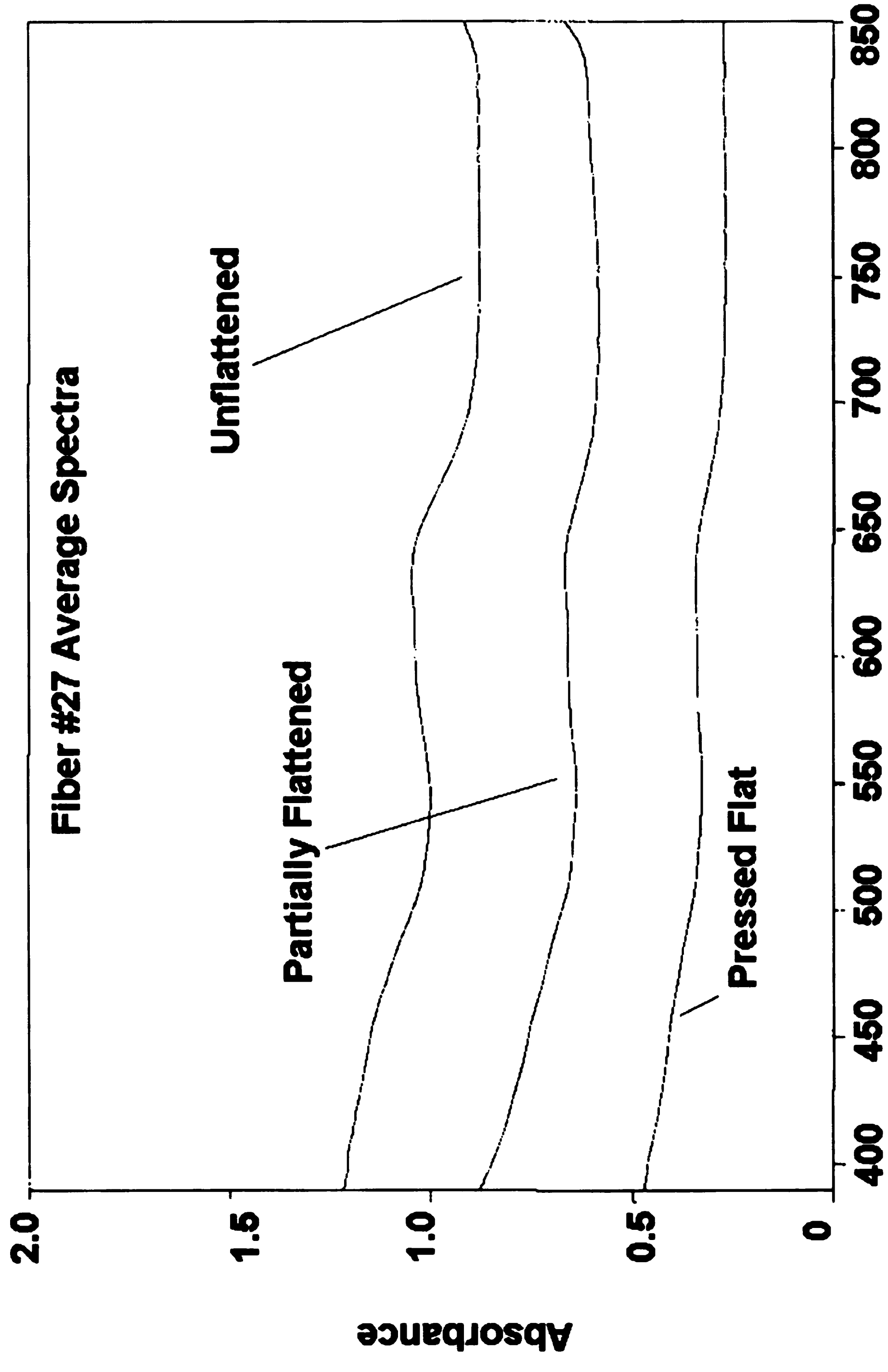


Figure #31-Comparison Spectra of Fiber #28

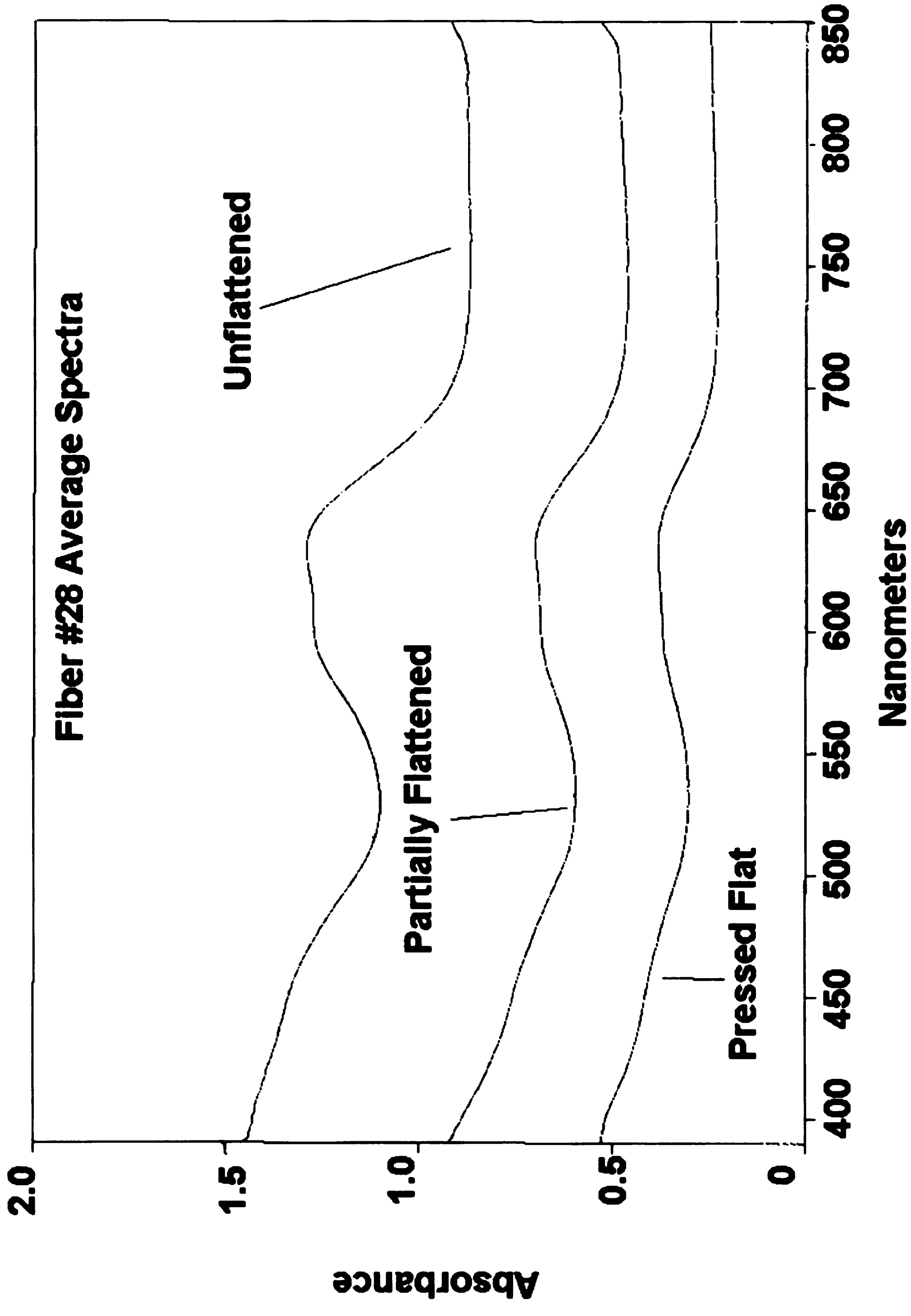


Figure #32-Comparison Spectra of Fiber #29

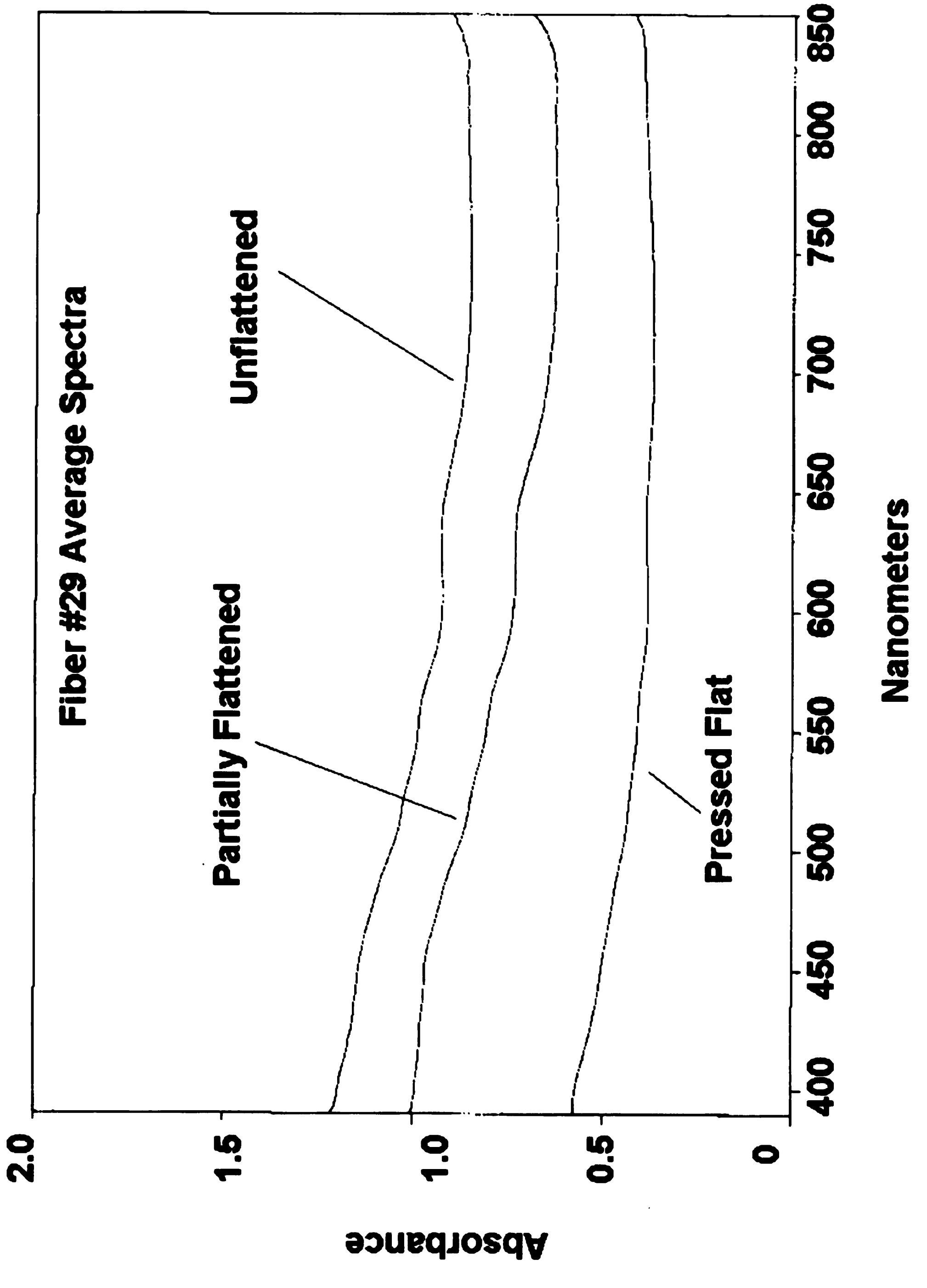


Figure #33-Comparison Spectra of Fiber #30

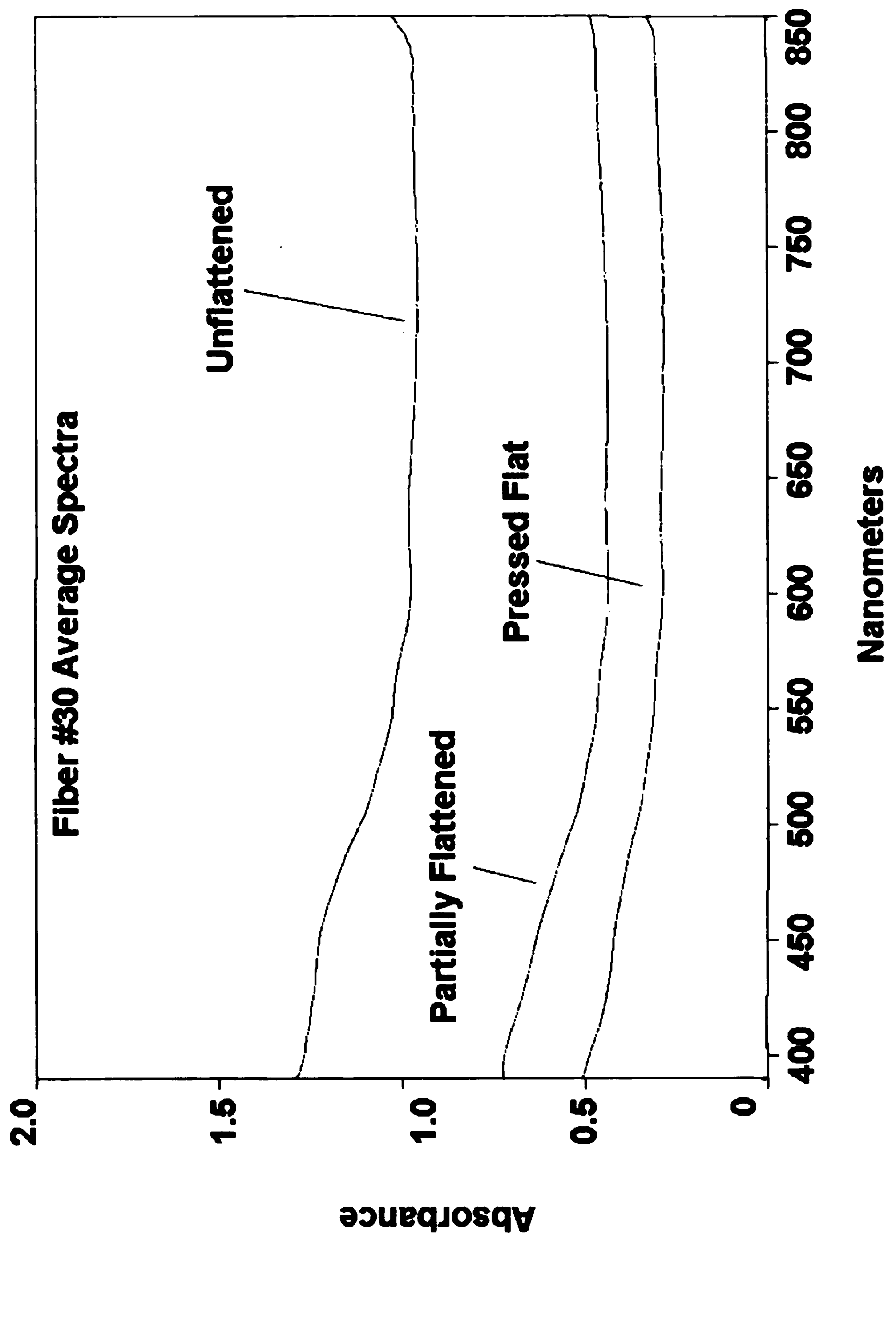


Figure #34-Comparison Spectra of Fiber #31

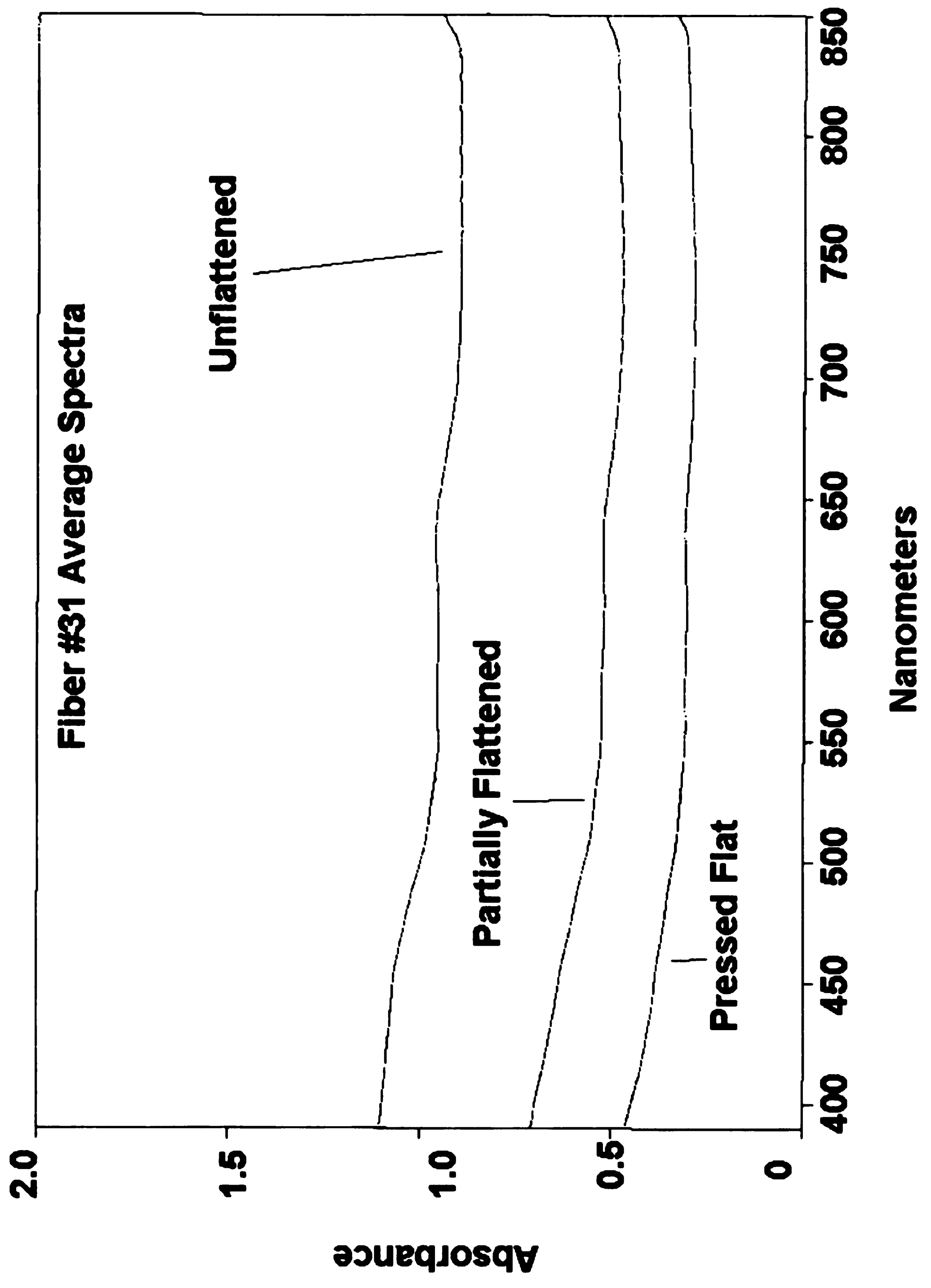


Figure #35-Comparison Spectra of Fiber #32

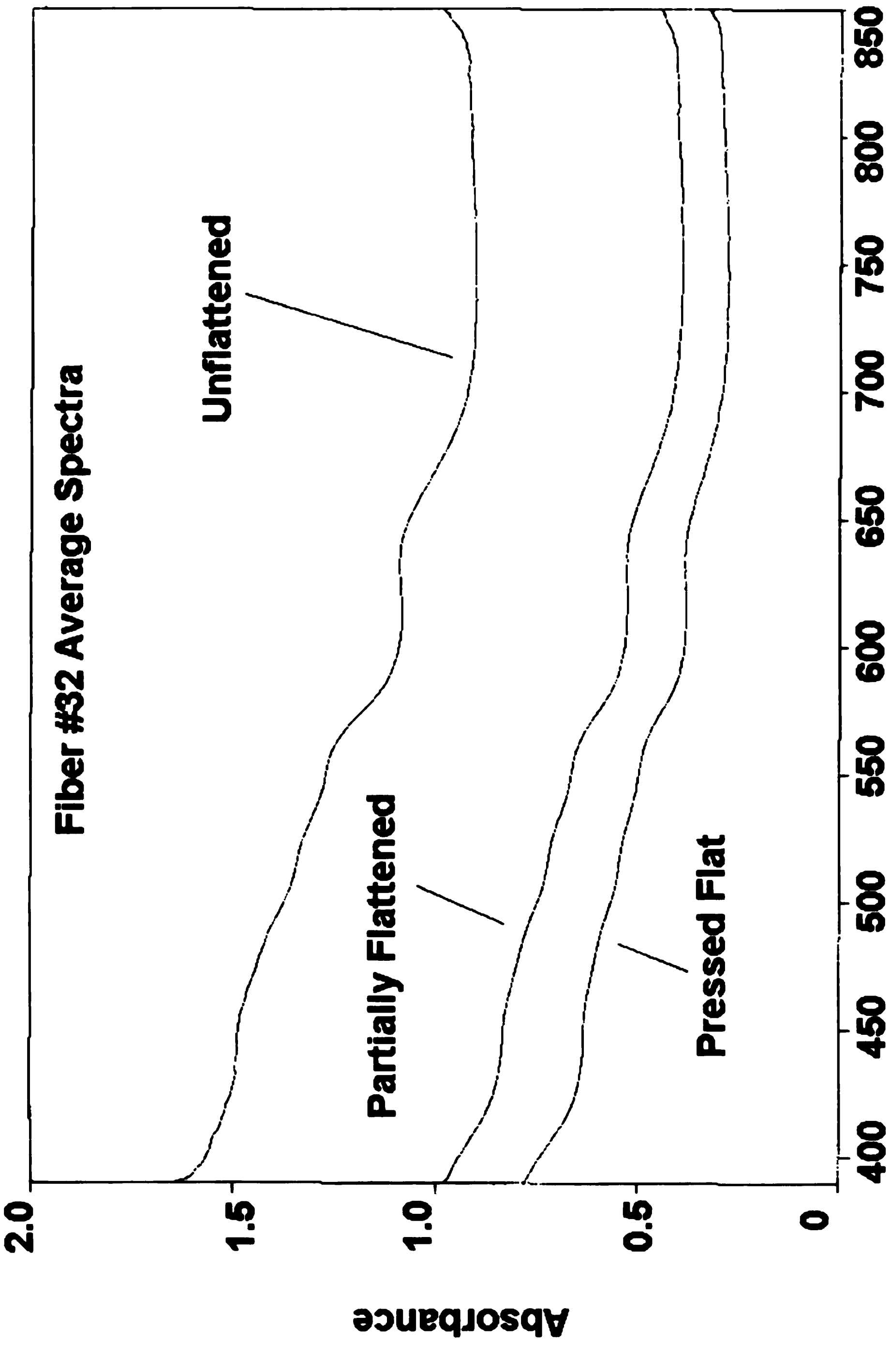


Figure #36-Comparison Spectra of Fiber #33

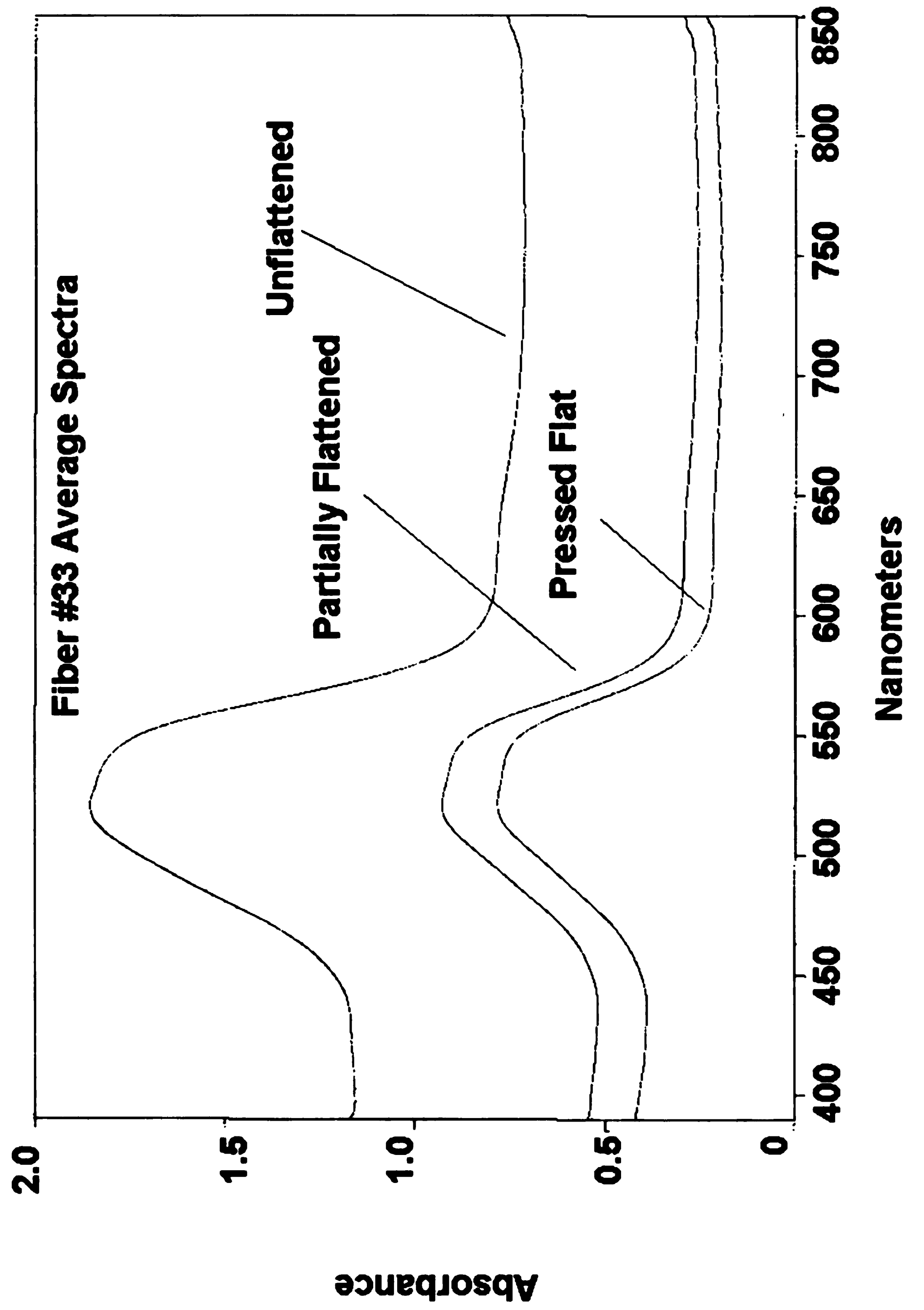


Figure #37-Comparison Spectra of Fiber #34

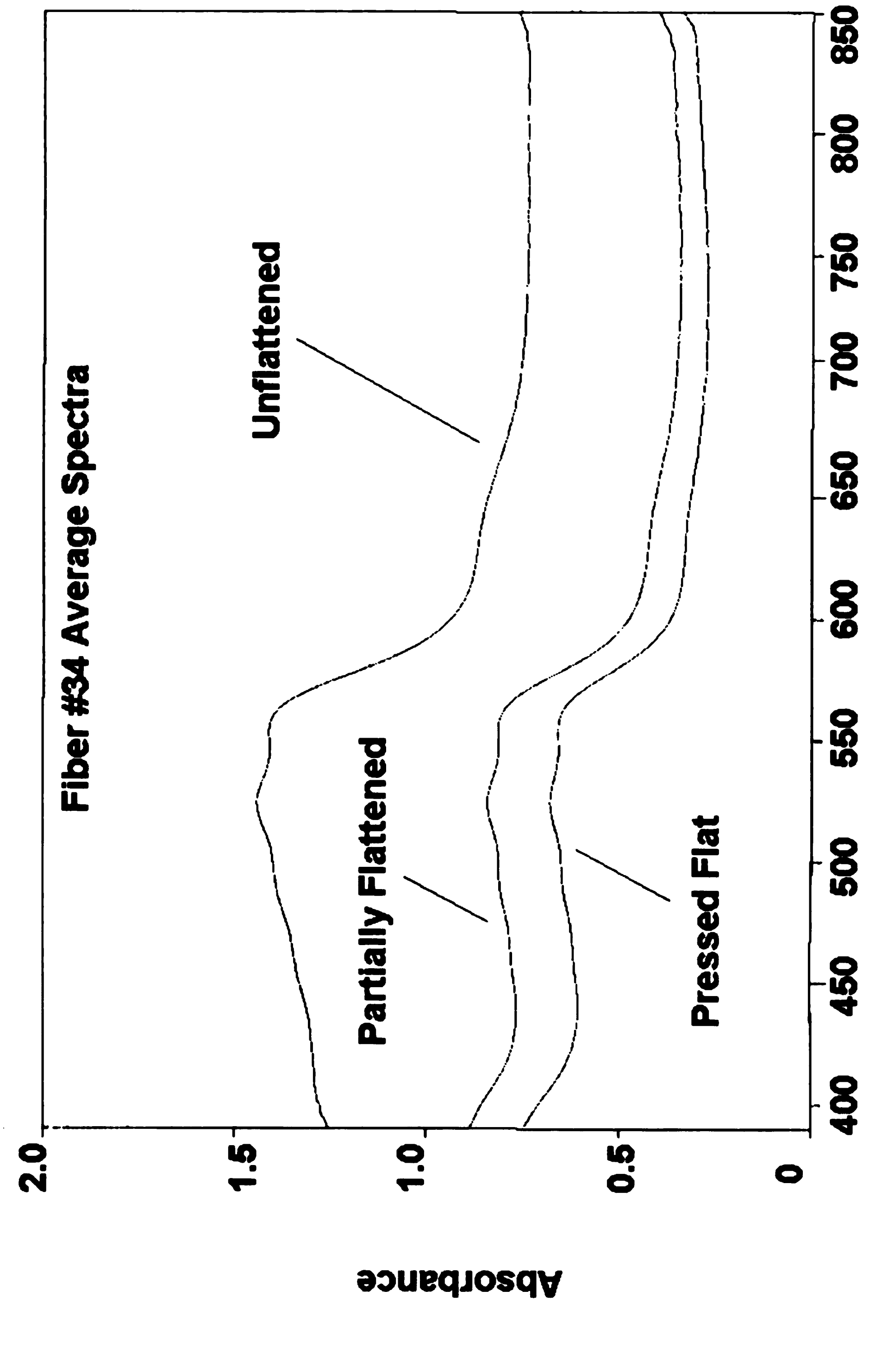


Figure #38-Comparison Spectra of Fiber #35

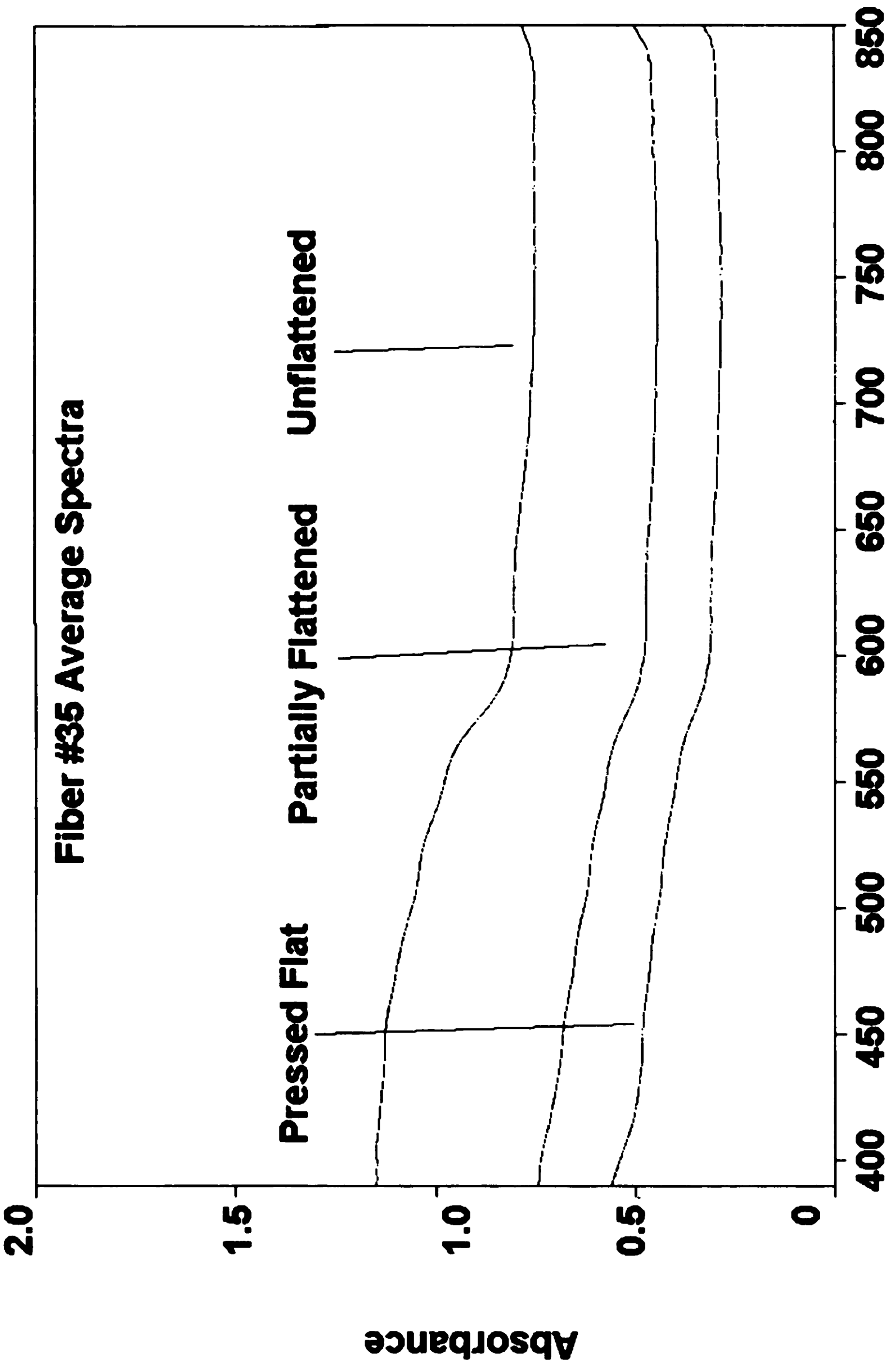


Figure #39-Comparison Spectra of Fiber #36

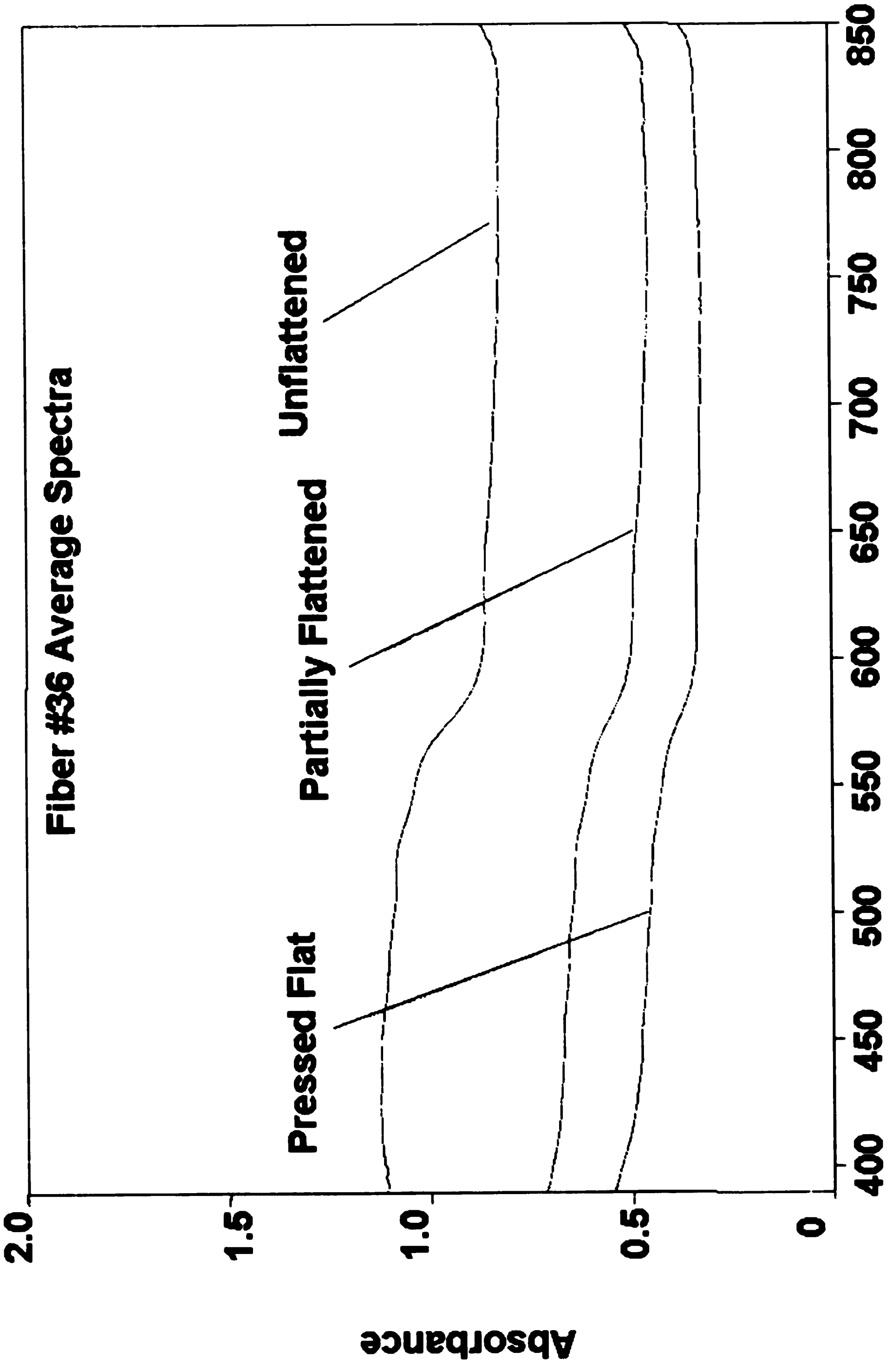


Figure #40-Comparison Spectra of Fiber #37

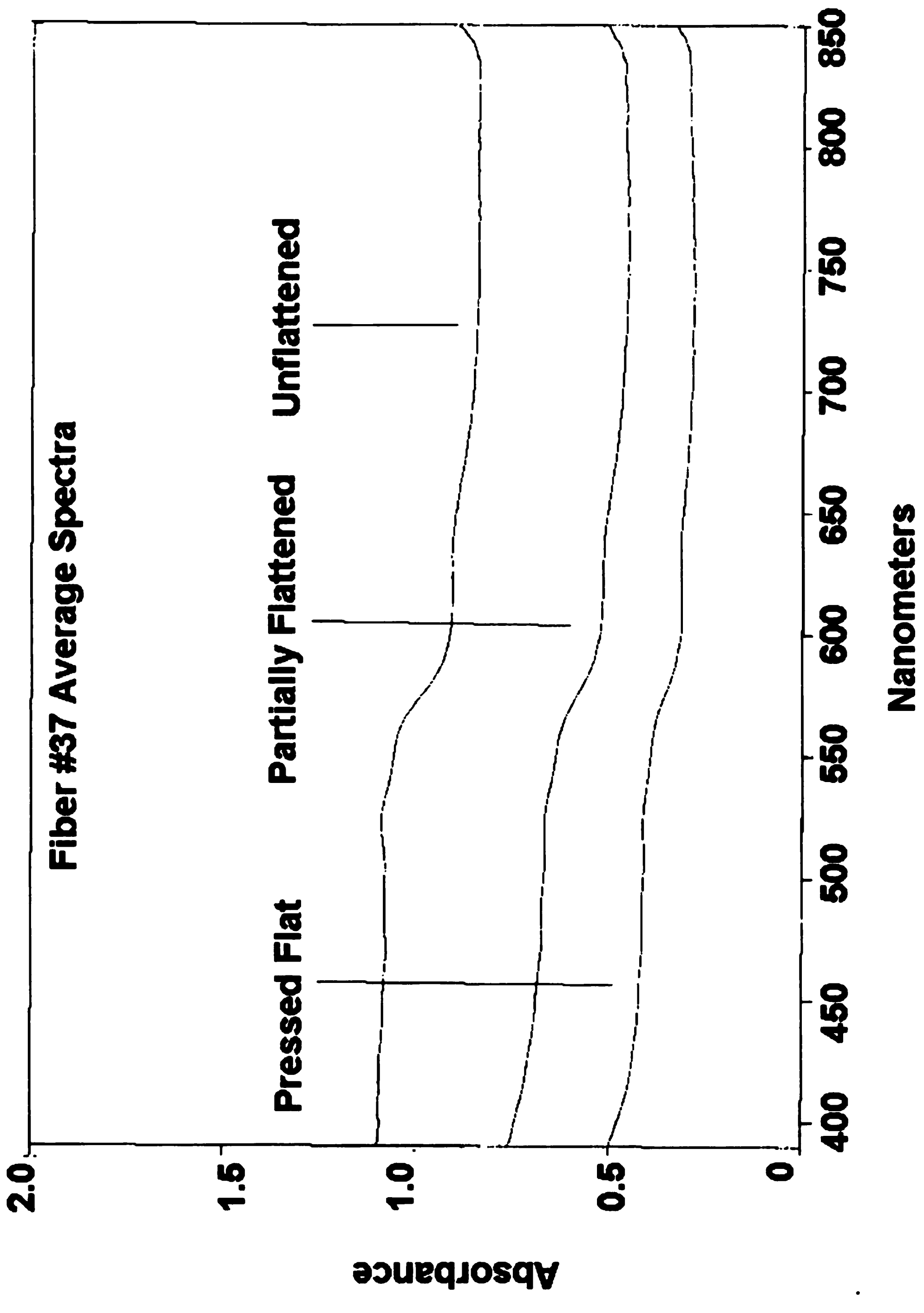


Figure #41-Comparison Spectra of Fiber #38

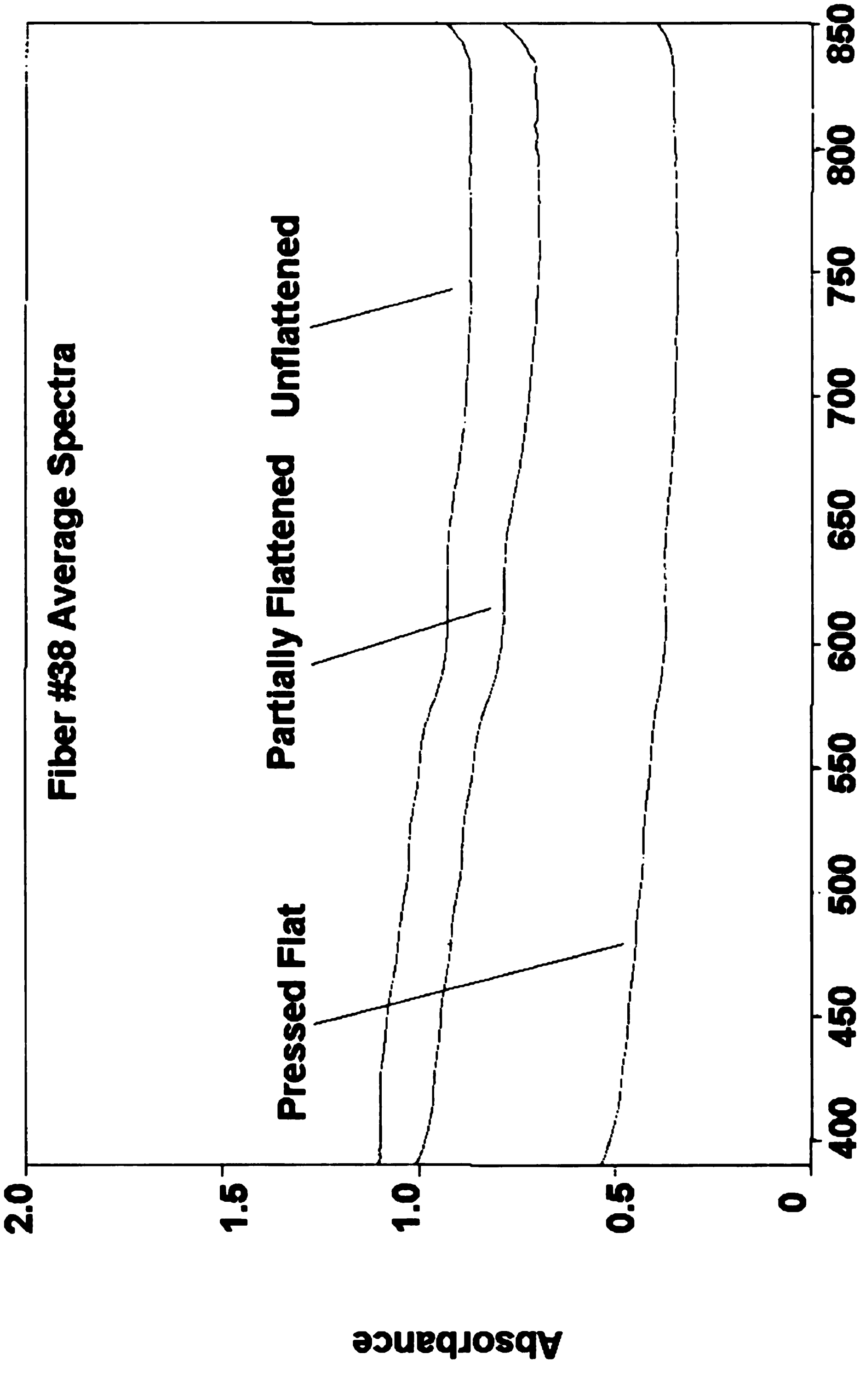


Figure #42-Comparison Spectra of Fiber #39

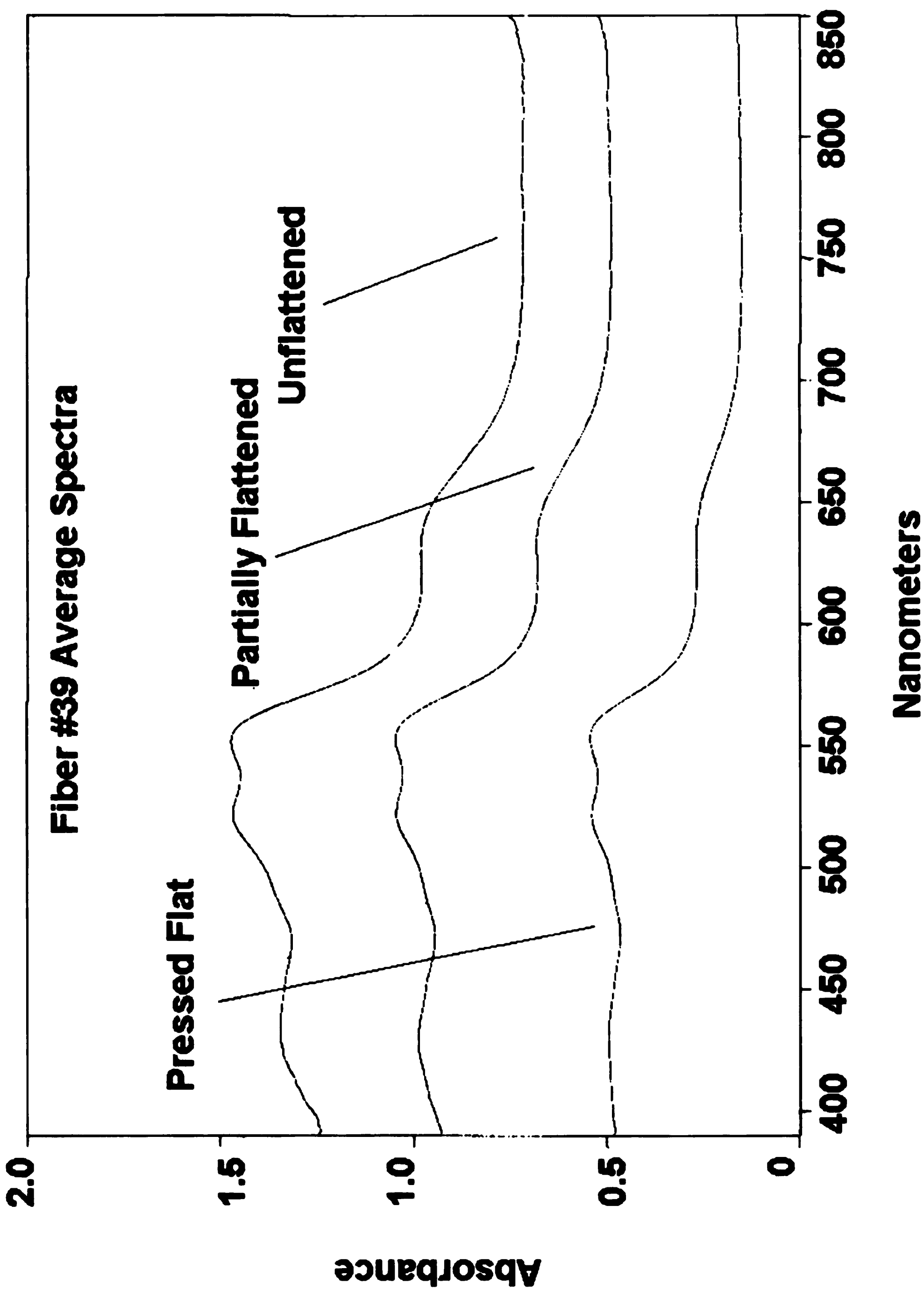


Figure #43-Comparison Spectra of Fiber #40

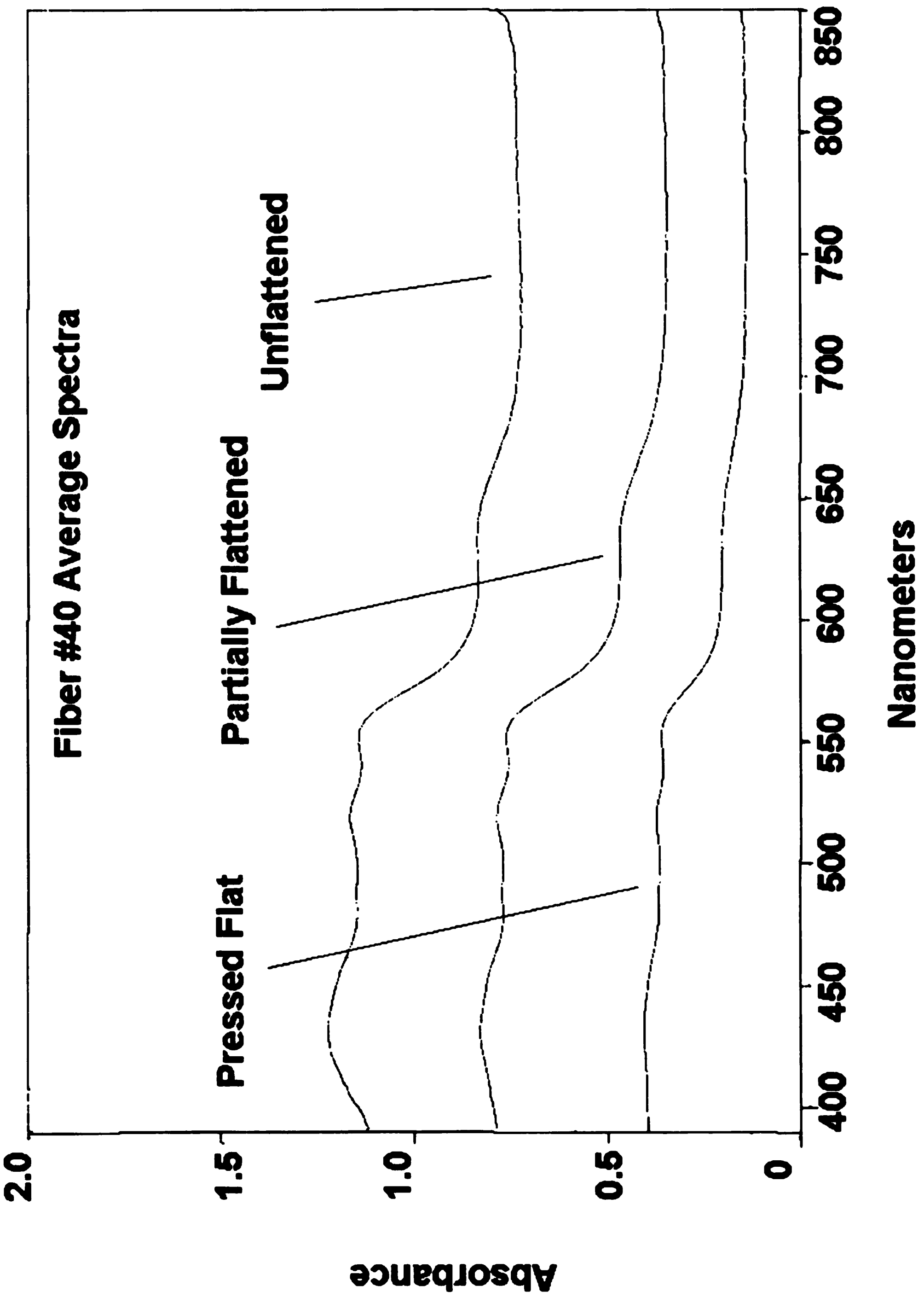


Figure #44-Comparison Spectra of Fiber #41

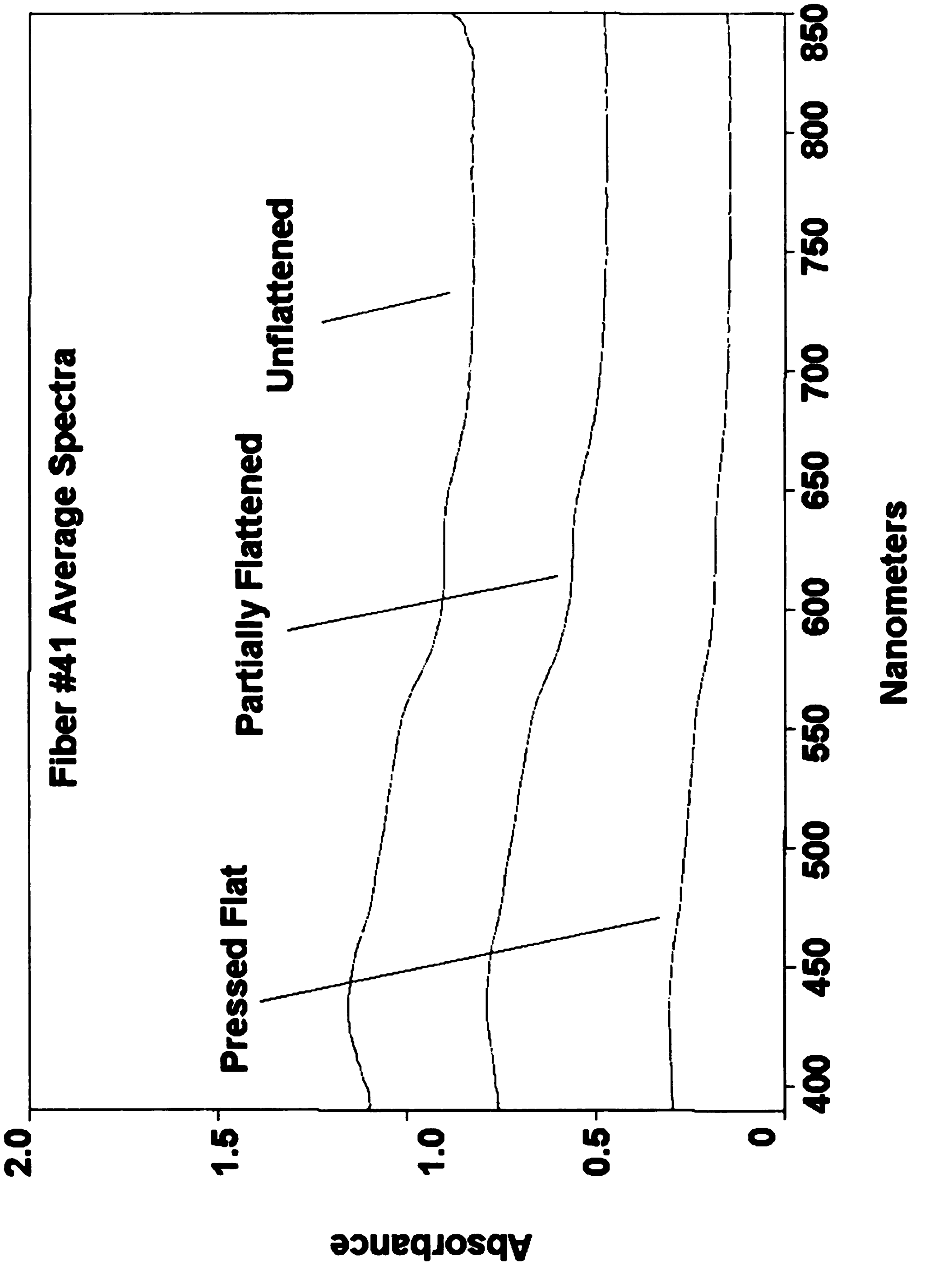


Figure #45-Comparison Spectra of Fiber #42

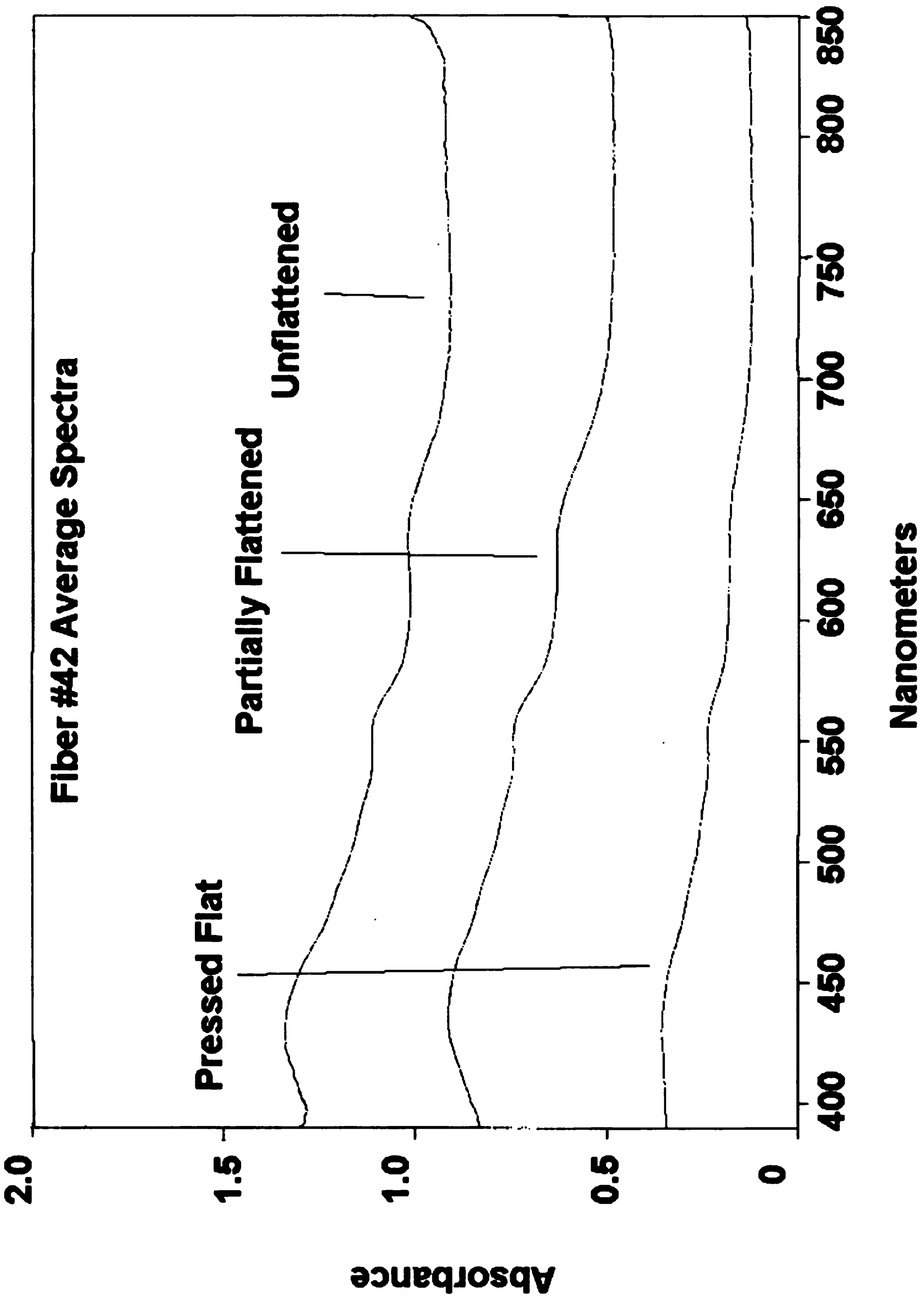


Figure #46-Comparison Spectra of Fiber #43

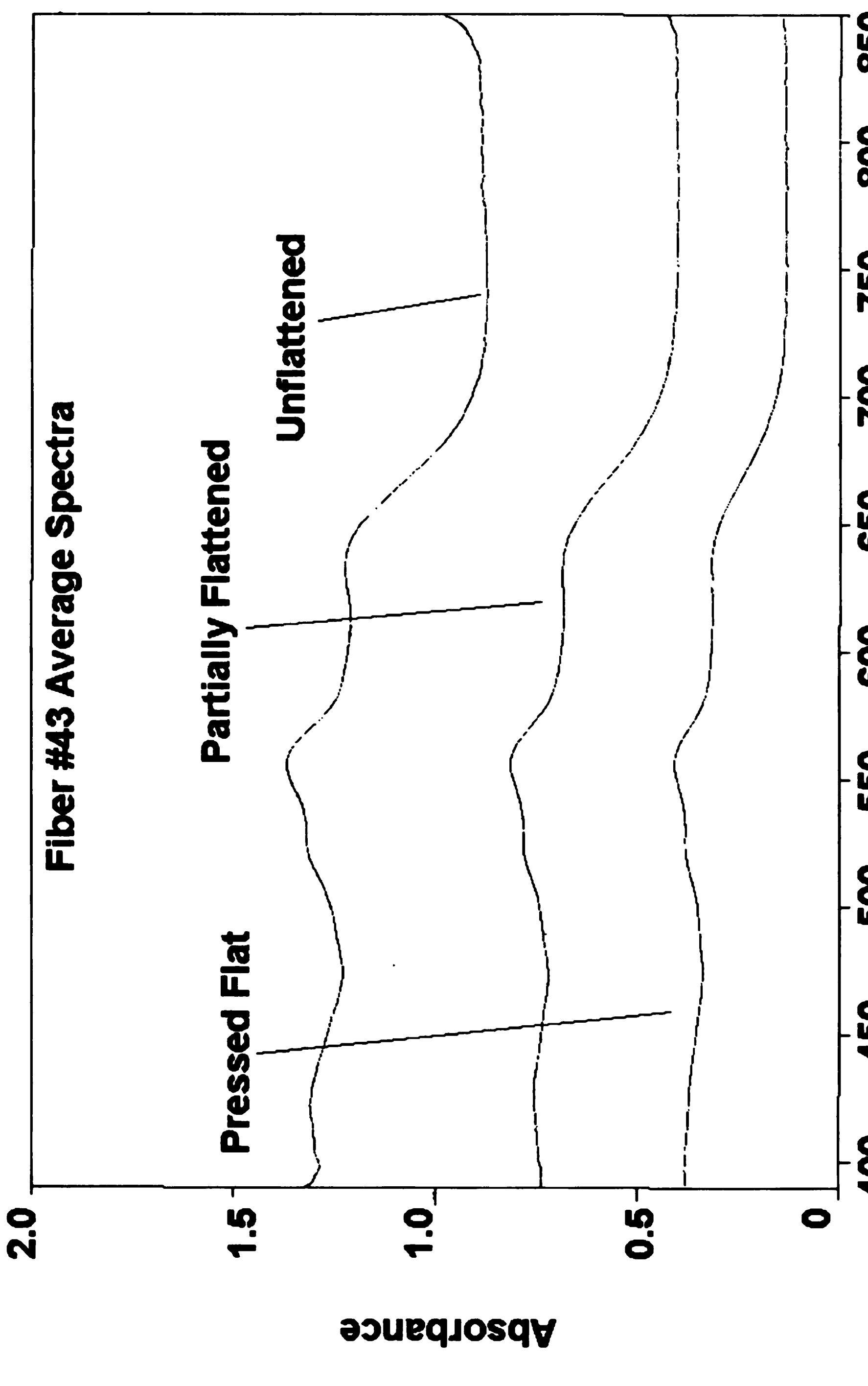


Figure #47-Comparison Spectra of Fiber #44

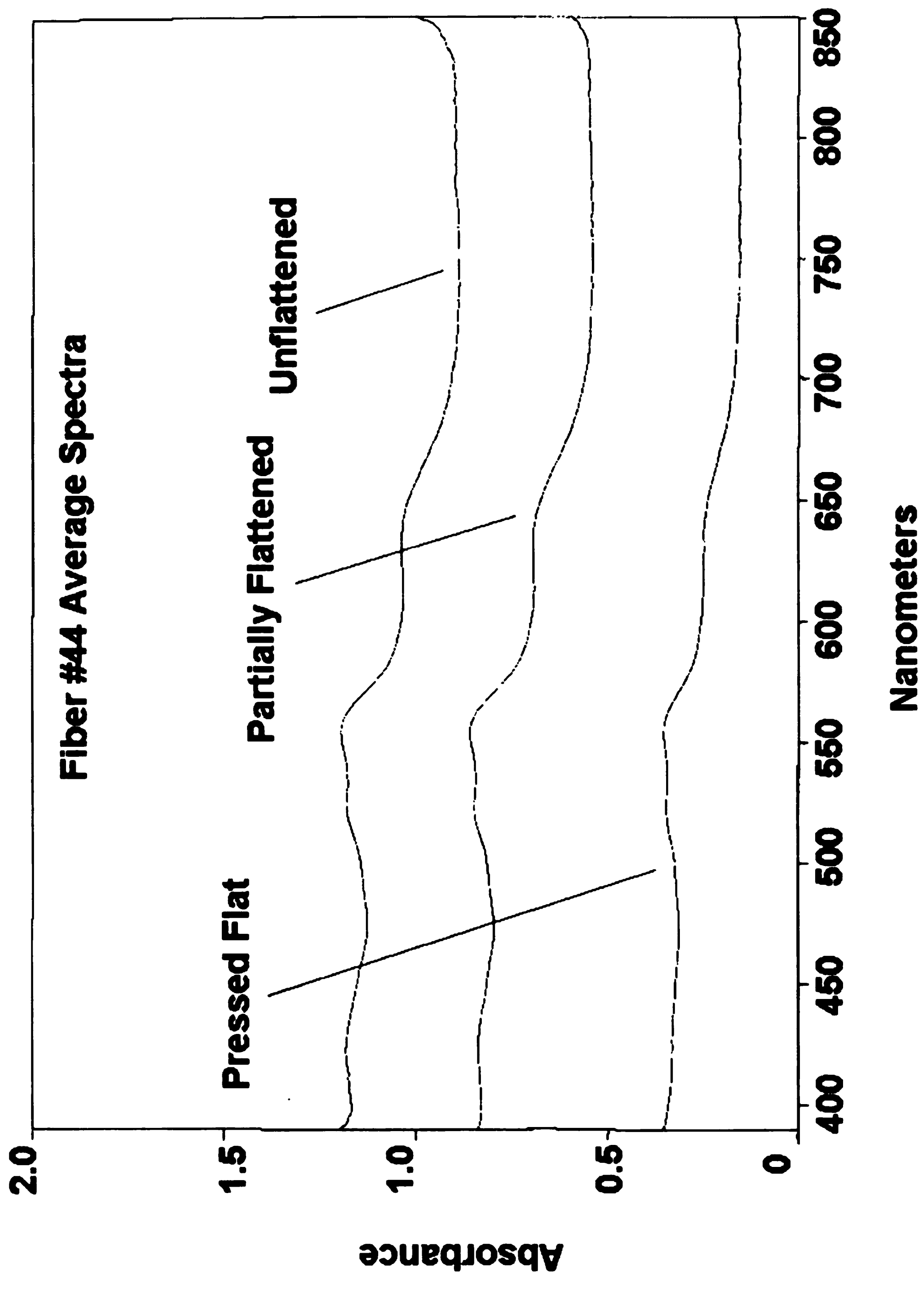


Figure #48-Comparison Spectra of Fiber #45

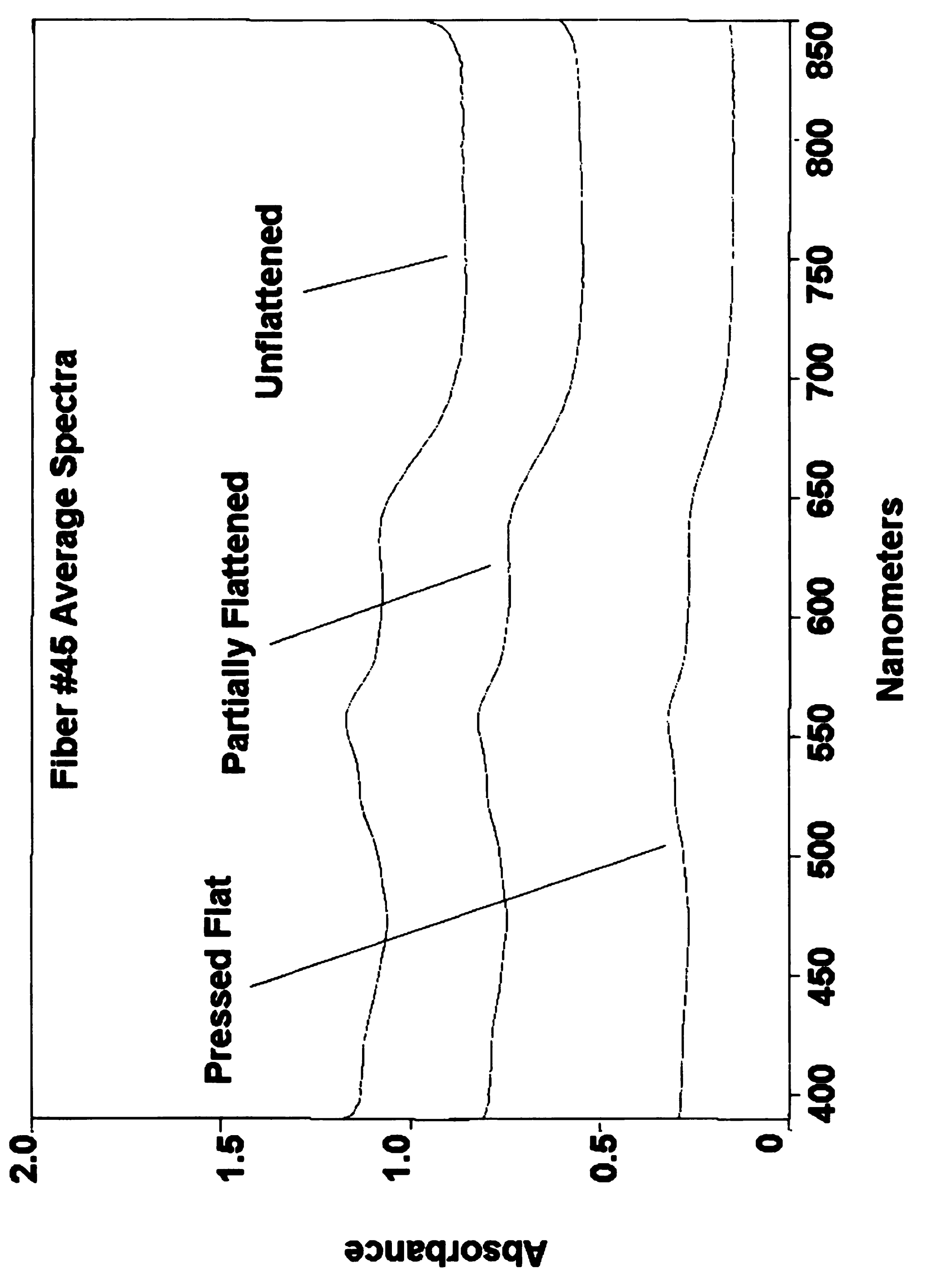


Figure #49-Comparison Spectra of Fiber #46

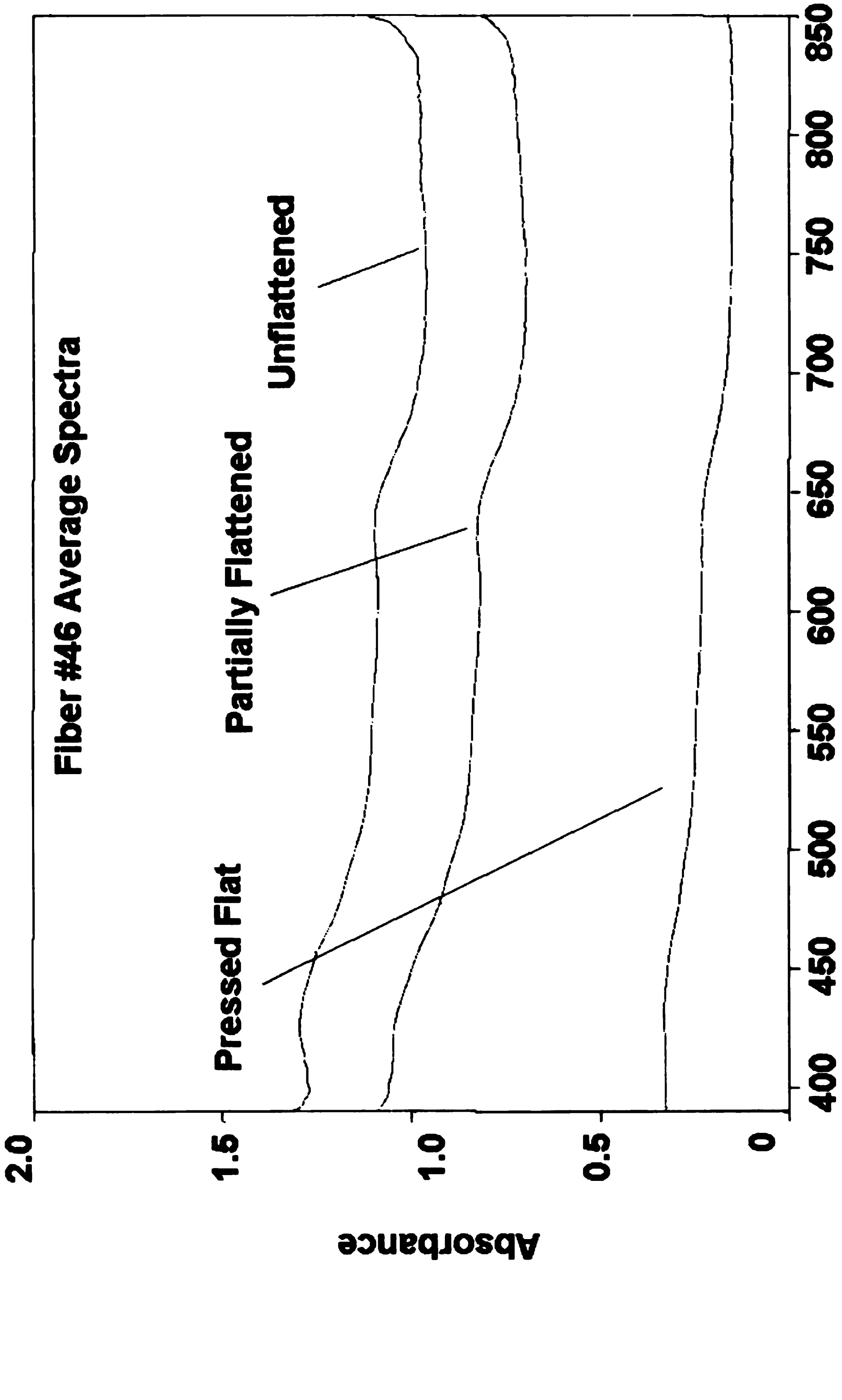


Figure #50-Comparison Spectra of Fiber #47

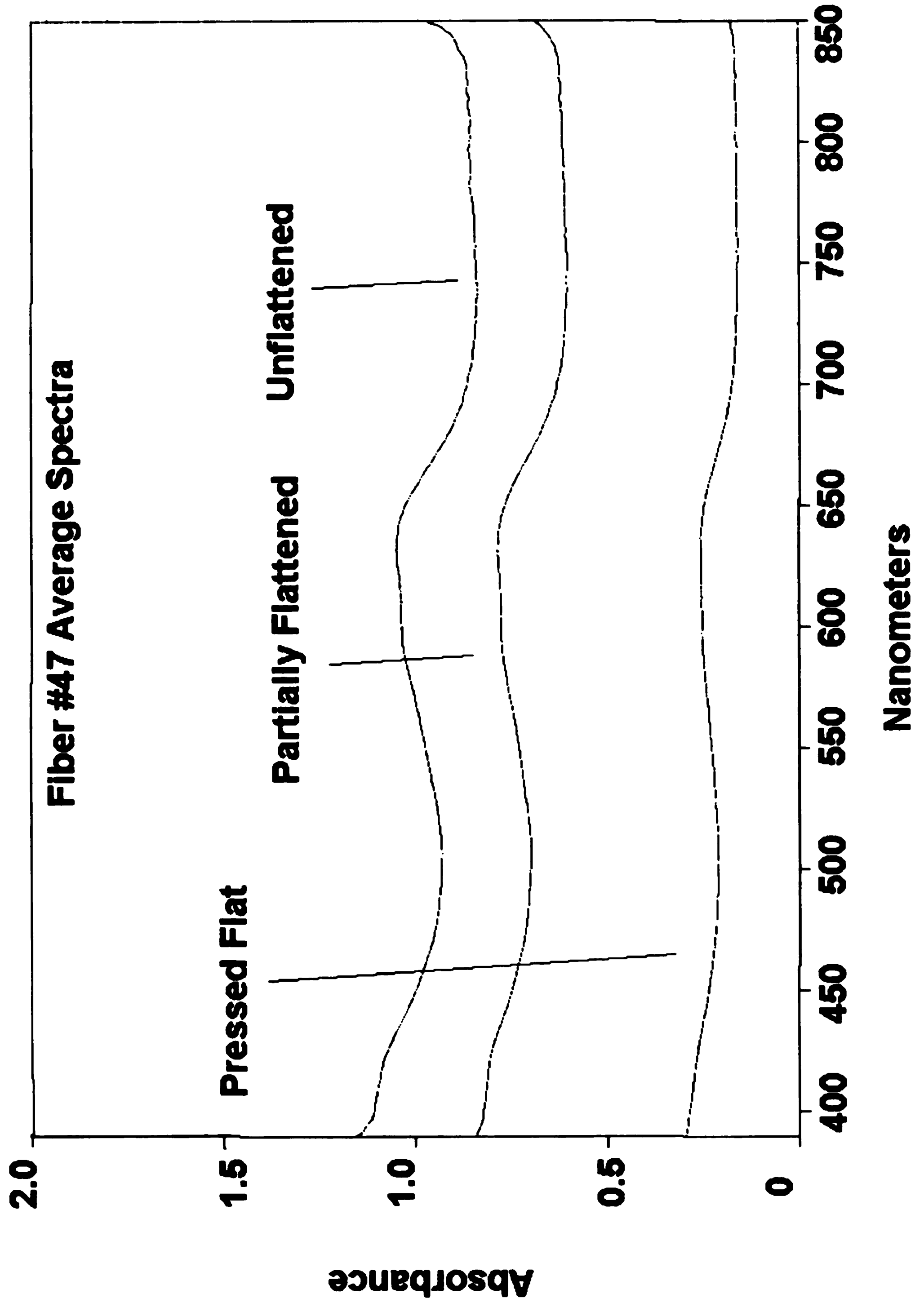


Figure #51-Comparison Spectra of Fiber #48

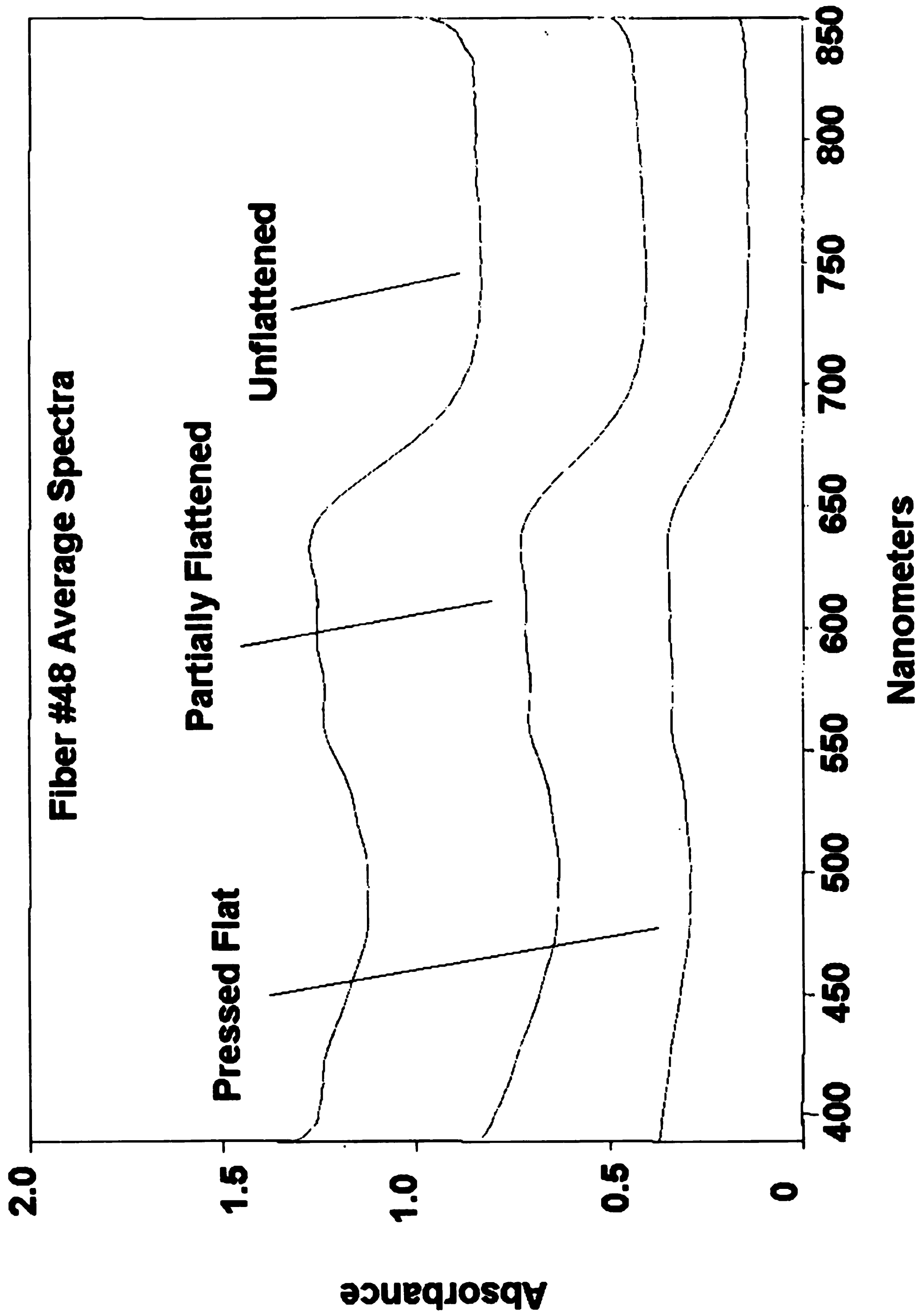


Figure #52-Comparison Spectra of Fiber #49

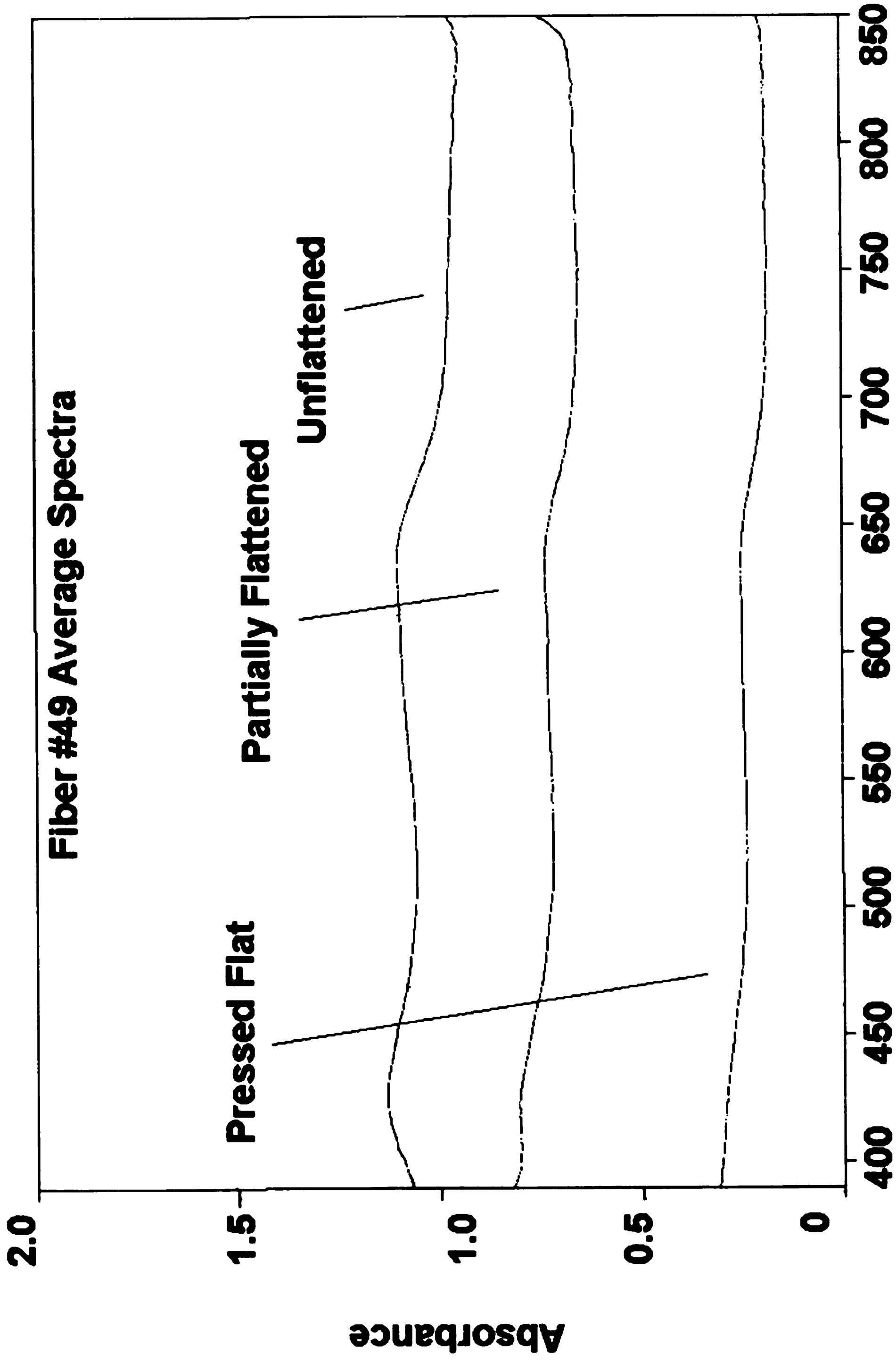


Figure #53-Comparison Spectra of Fiber #50

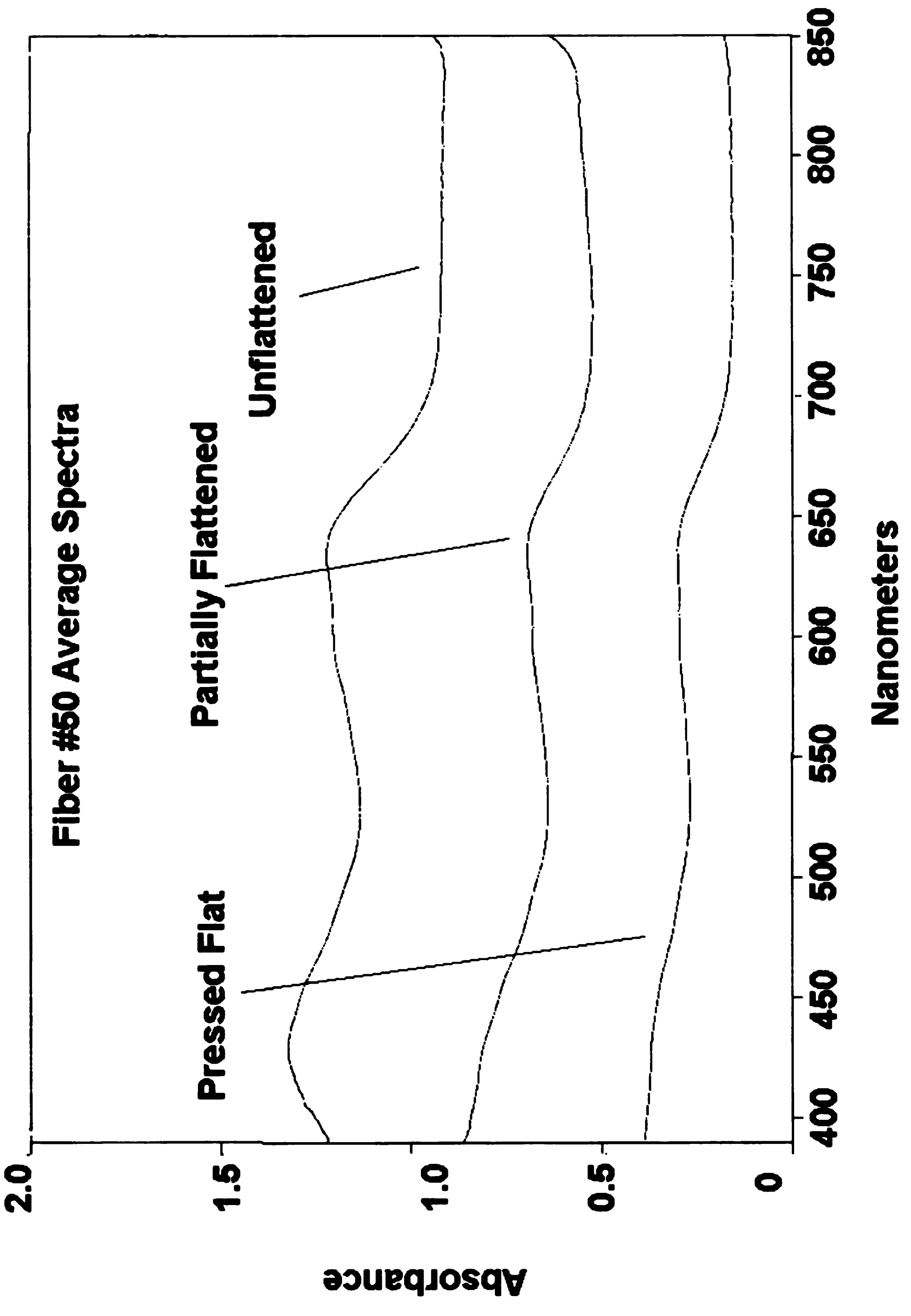
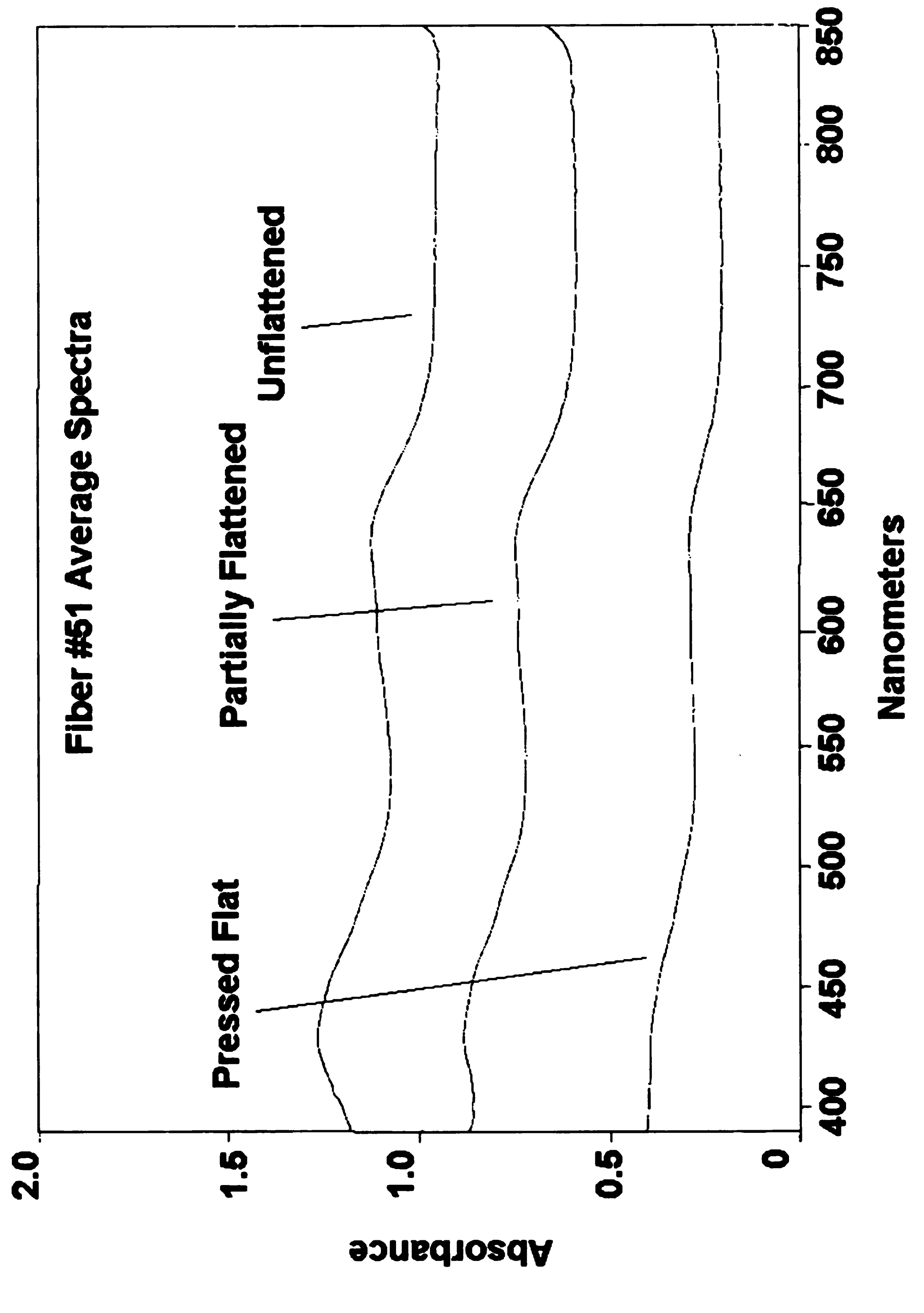


Figure #54-Comparison Spectra of Fiber #51



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