Optimization of *Trans*-Vinylene Index Measurements for Orthopaedic UHMWPE

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Statement of Purpose:

The *trans*-vinylene index (TVI) of orthopaedic ultra high molecular weight polyethylene (UHMWPE), measured by infrared (IR) spectroscopy[1], gives an estimate of the ionizing radiation dose level the UHMWPE has received during crosslinking. This measurement can be hampered, particularly at low radiation doses, by waviness or rippling in the infrared spectrum. This rippling, or interference fringing, results from internal reflection of some of the incident infrared radiation within the UHMWPE film during transmission IR measurements. Roughening the microtomed surfaces, of UHMWPE films, with 400 grit sandpaper removes most of the rippling[1].

Surface roughening is time consuming and labor intensive. In addition, variability in surface roughening can be expected based upon preparers, applied pressures, and length of sanding time, and could potentially yield thickness variations within individual films. The experimental parameters necessary to measure TVI values of UHMWPE films without surface preparation (roughening) were investigated in this study. Using p-polarized radiation and orientation of the UHMWPE film at Brewster's angle (54º for polyethylene) was expected to allow the radiation to pass through the film without reflection, therefore eliminating interference fringing.

Methods:

Infrared spectra of "low" and "high" TVI films were acquired using a Vertex 70 Fourier Transform IR (FTIR) spectrometer and Hyperion 2000 FTIR Microscope (Bruker Optics, Inc.) following ASTM Method F 2381-04. Spectra of 200 µm thick UHMWPE microtomed film slices were acquired in transmission mode at 4 cm^{-1} resolution, 32 scans per spectrum, using a 100 µm x 100 µm knife edge aperture every 100 µm along the length of the films. The following variations to the ASTM method were investigated: film orientation (54º and 36º), IR radiation polarization angle (90º (p), 45º, 0º (s), and no polarization (np)), and UHMWPE film preparation (roughened and nonroughened). A triangular block sample holder enabled the film to be oriented either at 54º (Brewster's angle for UHMWPE) or 36º off-axis from the incident IR beam. Non-crosslinked GUR 1050 UHMWPE was utilized as the "low" TVI sample and a sample crosslinked at 100 kGy was utilized as the "high" TVI sample.

Results / Discussion:

Infrared spectra acquired from UHMWPE films oriented within the plane of the microscope stage, at slight angles from the microscope stage, and at 36º off-axis from the incident IR beam, showed the characteristic rippling patterns for films that had not undergone surface roughening. Figure 1 shows that the intensity of the rippling varies with film orientation and incident radiation.

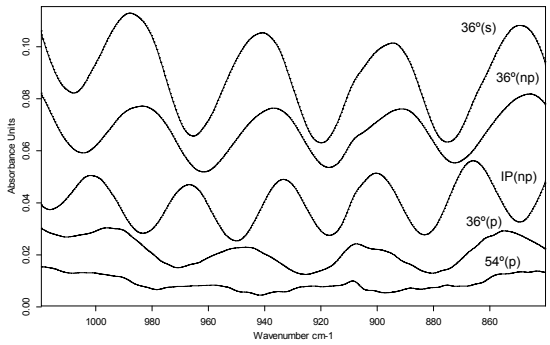

Figure 1. Interference fringing patterns observed near the TVI region (965 cm^{-1}) for an unroughened low TVI film at various selected film orientations (36º, 54º, and in-plane (IP)) and polarization angles (s, p, and no polarization (np)).

Orienting the films at Brewster's angle (54º) eliminated the fringes (Figure 1) and allowed comparison of roughened and non-roughened films for both the low and high TVI samples. Using Brewster's angle and p-polarized IR radiation resulted in lower variations in TVI values than for TVI values obtained using 45º or 0º polarization. Using Brewster's angle eliminated the need for polarizing the radiation. At Brewster's angle, comparable TVI values, but slightly higher standard deviations, were obtained for unroughened films as compared to roughened films. Less variability in TVI values was observed for the roughened low TVI film oriented at Brewster's angle than when maintained in the stage plane, whereas comparable variability was observed for the high TVI film at the two orientations.

Conclusions:

Orienting the orthopaedic UHMWPE film at Brewster's angle enables TVI values comparable to those obtained via the ASTM method, without having to roughen the film's surfaces. Avoiding the film roughening step saves time in sample preparation and minimizes potential sanding differences between preparers.

References:

(1) ASTM Method F 2381-04