A Study of the Far-infrared Optical Properties of Rexolite™

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As interest grows in optical and quasi-optical systems operating at terahertz frequencies, materials which may provide alternative solutions to the design of system components come under close scrutiny. In response to evaluating prospective materials for window and lens applications, the far-infrared optical properties of Rexolite™ 1422 were characterized at the University of Lowell Research Foundation (ULRF) using Fourier transform spectroscopy (FTS). The Rexolite™ used in this study was acquired from C-Lec Plastics, Inc. of Beverly, NJ and a sample was machined to a thickness of t = 0.0236"±0.0002". Spectroscopic transmission measurements were performed on the sample over a wavelength region of 10 cm^{-1} to 360 cm^{-1} with a 0.1 cm^{-1} wave number resolution. See Figure 1.

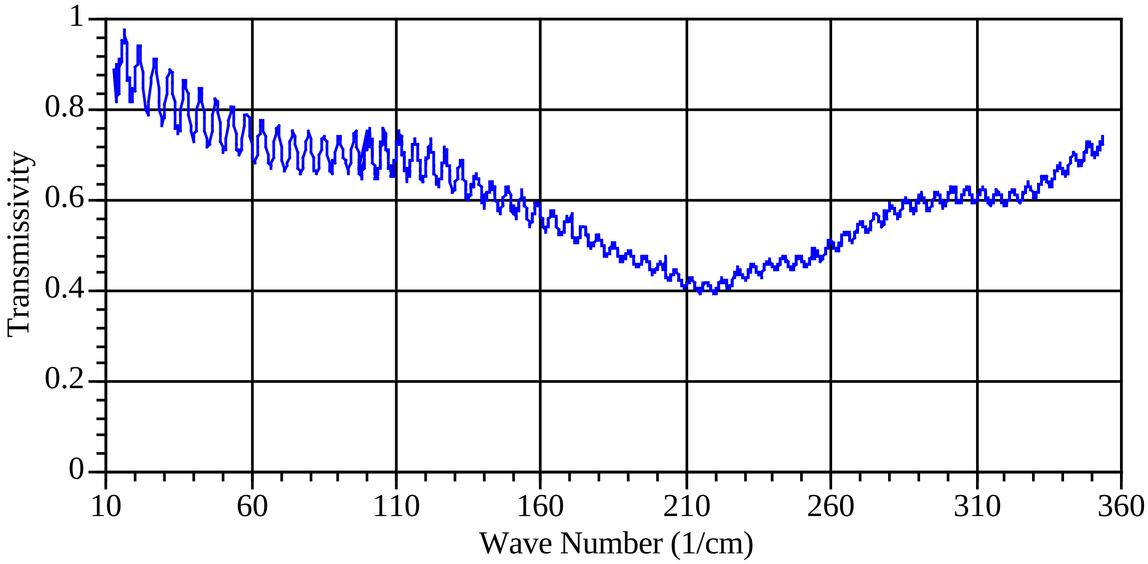

Figure 1. The FTS transmission data for a 0.0236" thick sample of Rexolite™.

The data's transmission peak location as a function of wave number was used to determine the material's refractive indices knowing the phase thickness(β)[1] relationship:

$$\beta = 2\pi(N\, t / \lambda)\cos\theta_1 \qquad \text{eqn. 1}$$

The internal refraction angle, θ_1, is zero since the measurement was made at normal incidence. Each peak corresponds to a phase thickness of $\beta = m\pi$ where m is an integer. $N = n - ik$ is the complex refractive index where, during the determination procedure for n, the extinction coefficient, k, may be treated as negligible (i.e. $n >> k$ for Rexolite™ in the far–infrared).

Measuring the wavelength at locations of two different transmission peaks allows calculation the refractive index using equation 1 in the following manner,

$$\beta' - \beta = 2\pi t \left\{ 1/\lambda' - 1/\lambda \right\} n \qquad \text{eqn. 2}$$

For example, Figure 1 allows evaluation of equation 2 over the measured wavelength region using values with a five peak separation. This calculation yields an average value of n = 1.58±0.02 for the refractive index. Uncertainty in these calculations stem from the interferometer's maximum resolution, 0.1 cm^{-1}, point to point location of the transmission peaks and the material's thickness tolerance ±0.0002".

Table 1. The extinction coefficient for Rexolite™ as a function of wave number.

1/λ(1/cm)	k	1/λ(1/cm)	k	1/λ(1/cm)	k
21.2	0.0028	132.4	0.0034	242.6	0.0038
26.2	0.0036	137.5	0.0036	248.2	0.0037
32.0	0.0043	142.6	0.0038	253.2	0.0034
37.0	0.0045	147.8	0.0039	259.1	0.0032
42.5	0.0047	152.9	0.0039	264.7	0.0029
47.8	0.0049	158.1	0.0040	270.3	0.0027
53.1	0.0049	163.5	0.0041	274.7	0.0025
58.4	0.0048	169.1	0.0041	279.7	0.0023
63.8	0.0049	173.5	0.0043	285.3	0.0021
68.9	0.0047	178.7	0.0044	290.4	0.0020
74.1	0.0047	184.6	0.0045	296.0	0.0020
79.7	0.0045	189.7	0.0046	301.8	0.0019
85.1	0.0044	194.9	0.0047	306.8	0.0019
90.3	0.0041	200.7	0.0047	312.0	0.0019
95.9	0.0037	205.6	0.0048	317.2	0.0018
100.0	0.0034	211.0	0.0050	322.8	0.0018
104.4	0.0032	216.5	0.0049	328.0	0.0017
111.0	0.0032	222.1	0.0048	333.0	0.0016
116.5	0.0032	227.2	0.0044	338.3	0.0014
122.1	0.0032	232.4	0.0041	343.5	0.0012
127.2	0.0033	237.5	0.0039	349.0	0.0010

With the refractive indices' real component (n) determined, calculations were performed to evaluate the far–infrared absorption of Rexolite™ using the Fresnel equations[1]. The theoretical transmissivity which models the material's multiple reflection behavior:

$$T = \left| \frac{1 - r^2 e^{-i\beta}}{1 - r^2 e^{-2i\beta}} \right|^2 \qquad \text{where} \qquad r = \frac{N-1}{N+1}$$

was evaluated at ≈ 60 different frequencies across the submillimeter wavelength regime and matched to the measured data through adjustment of the extinction coefficient (k). The calculated values of k ±0.0002 are given in Table 1 and have been depicted graphically in Figure 2. While precision of this analysis may not be adequate for all FIR design applications, the refractive index model generated can be used to determine the general optical behavior of FIR devices fabricated from Rexolite™ 1422.

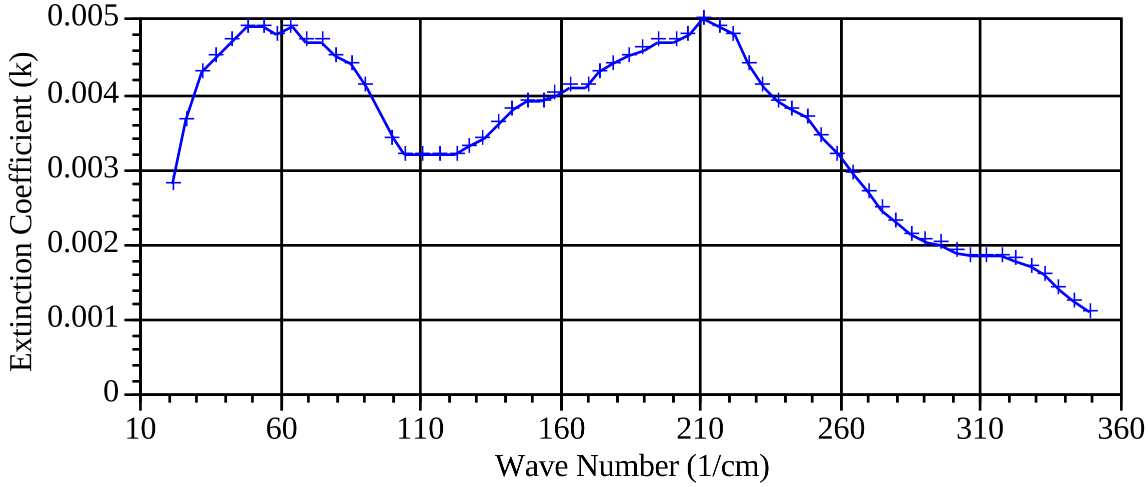

Figure 2. The extinction coefficient for Rexolite™ as a function of wave number.

References

1. R.M.A. Azzam and N.M. Bashara, Ellipsometry and Polarized Light, North-Holland 1979, Section 4.3