AN 11–LT-451 and LCR Meter Comparison

Summary

The Lambient Technologies LT-451 Dielectric Cure Monitor is designed for dielectric measurements of polymeric materials during the curing process, and a typical LCR (Inductance-Capacitance-Resistance) meter such as the QuadTech 1920 is designed for high speed measurements of the electrical parameters of electronic components. Both instruments are suitable for measuring the AC loss characteristics and permittivity of solid electrical insulation per ASTM Standard D150-98, but the Lambient Technologies LT-451 is capable of measuring dissipation, or tanδ, to much lower levels than the QuadTech 1920.

The ability to measure very loss tanδ is necessary for studying cured materials with very low bulk conductivity. A test cell with guard electrodes eliminates fringing electric fields around the sense electrode, allowing accurate calculation of test cell capacitance. Consequently, ASTM D150-98 states that "the guarded electrode (three terminal method) is to be used as the referee method unless otherwise agreed upon."

Lambient Technologies LT-451 Specifications

Direct comparison of QuadTech 1920 and LT-451 specifications is not possible, but LT-451 performance is as follows:

Frequency Range	: 0.001 Hz to 100 KHz
Capacitance Range	: ~20 pF to ~200 pF
Resistance Range	: ~1000 Ω to ~100,000 MΩ

QuadTech 1920 Specifications

Relevant QuadTech 1920 specifications are as follows:

Frequency Range	: 20 Hz to 1 MHz
Capacitance Range	: 1 pF to 9.99 F
Resistance Range	: 10^{-4} mΩ to 100 MΩ

Discussion

Dissipation, or tanδ, at a measurement frequency f is the ratio of a material's relative loss to its relative permittivity, and is given by the relationship:

(eq. 1) $\tan\delta = e'' / e' = 1 / (\omega C_P R_P)$

where $\omega = 2\pi * f$

C_P = Parallel capacitance of material under test

R_P = Parallel resistance of material under test

Dissipation is not determined in isolation, but is measured in a test cell. In the case of a solid composite material which can be fabricated as a laminate or a plaque, a parallel plate electrode configuration is often used. An example of guarded parallel plate electrodes of typical size is shown below.

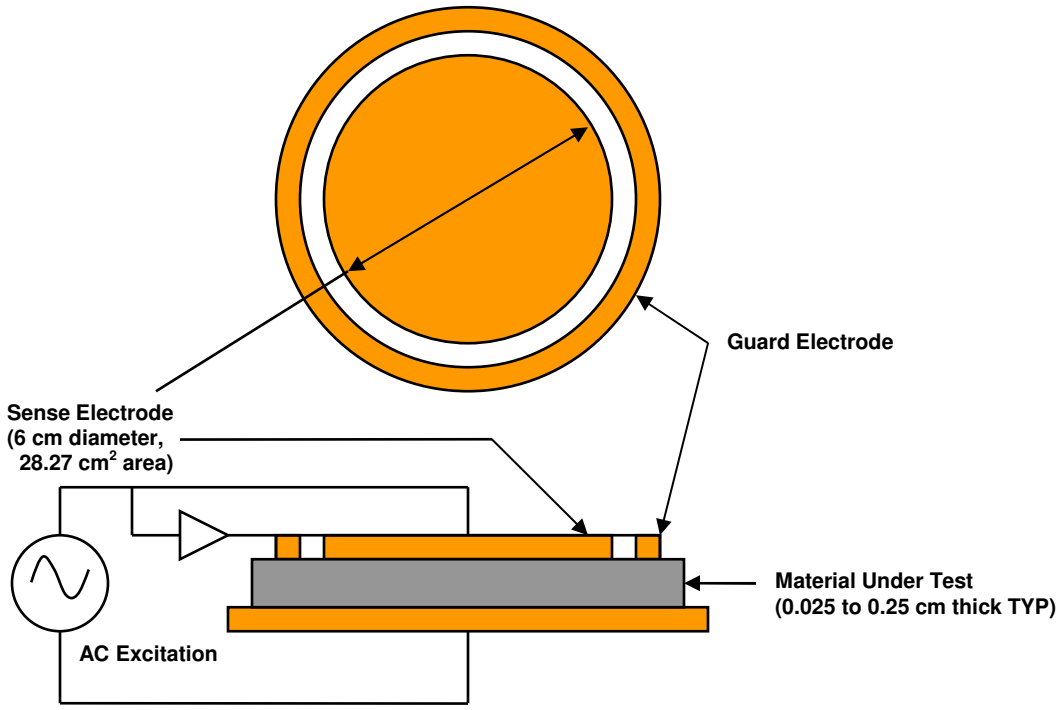

Figure 1
Guarded Parallel Plate Configuration

For the configuration and electrode dimensions of Figure 1, the air capacitance of the test cell, and the capacitance when filled with a material of relative permittivity ε' = 4.0 (typical for polyimide-glass composites) are listed below in Table 1:

Table 1
Parameters of Example Parallel Plate Configuration

Electrode Separation D (cm)	A/D Ratio (cm)	Air Capacitance (ε' = 1.0)	Material Capacitance (ε' = 4.0)
0.025	1130	100 pF	400 pF
0.25	113.0	10.0 pF	40.0 pF

The QuadTech 1920 likely uses a variant of the grounded electrode method of dielectric measurement, which is discussed in the Lambient Technologies Application Note 3: "*Dielectric Measurement Techniques*." The Lambient Technologies LT-451 uses the floating electrode method, which allows measurement of much higher resistances with less noise at low frequencies.

Dissipation is often measured at the 60 Hz AC mains frequency to determine dielectric loss in power transformers. Given the material capacitance and the maximum resistance which the QuadTech 1920 can measure, it is possible from equation 1 to calculate the smallest dissipation which the QuadTech 1920 can measure at a given frequency. A similar though somewhat more complex analysis can be performed for the Lambient Technologies LT-451. Details of the analysis for the LT-451 are available upon request. The results are shown in Table 2.

Table 2
Comparison of Minimum Measurable tanδ at 60 Hz

Material Capacitance	1920 Max R_P	1920 Min tanδ		LT-451 Max R_P	LT-451 Min tanδ
30 pF	100 MΩ	0.88		1000 MΩ	0.09
100 pF	100 MΩ	0.27		300 MΩ	0.09
300 pF	100 MΩ	0.09		100 MΩ	0.09
1000 pF	100 MΩ	0.03		20 MΩ	0.13

Note that only in the last row, for a material capacitance of 1000 pF, is the QuadTech 1920 able to measure lower dissipation than the Lambient Technologies LT-451. In this case, to achieve a capacitance of 1000 pF for the example electrodes shown, the film would have to be less than 0.02 cm (8 mil) thick. While achievable, use of films this thin involves complications due to air gaps which can be comparable in thickness to the film itself.

Conclusion

At 60 Hz the Lambient Technologies LT-451 Dielectric Cure Monitor is able to measure dissipation to levels a factor of 10 lower than a typical LCR meter, such as the QuadTech 1920. Parallel plate cells are used to measure AC loss characteristics and permittivity for solid insulators. In addition, the ability of the LT-451 to drive guard electrodes enables use of the guarded electrode (three terminal) test configuration preferred in ASTM Standard D-150-98.

Details of the grounded electrode configuration used in LCR meters, and of the floating electrode configuration used in the Lambient Technologies LT-451, are presented in the Lambient Technologies Application Note 3: "*Dielectric Measurement Techniques*."