Insight — Application Note 3.12

Guidelines for Making Good Dielectric Measurements

Making good measurements

Following are some guidelines for successful dielectric cure monitoring. Although the method of DEA is simple, care and good practice are very helpful for making good measurements.

Preparing the sensor and sample

- Do remove oils or other contaminants by cleaning sensors with acetone, alcohol or other solvent
  - Remove adsorbed solvents, which might interfere with test measurements in air, by heating sensors above 60 °C for a short time
- Do prevent material from adhering to ceramic or reusable sensors by applying silicone or non-conductive mold release, as shown in Figure 12-1

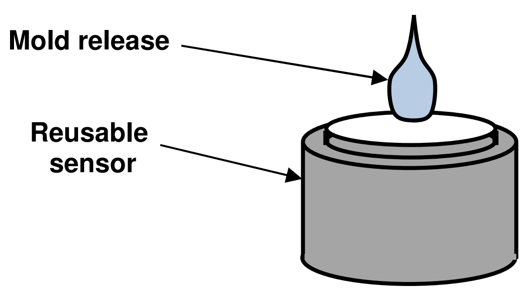

Figure 12-1
Apply mold release to reusable sensors

- Do prevent short circuits by avoiding contact between sensor bond pads and electrically conductive surfaces
  - Wrap bond pads with Kapton® or polyimide tape, as shown in Figure 12-2
- Do run sensor leads parallel to each other to reduce capacitance between leads
  - Don’t use twisted leads, which increase cable or base capacitance

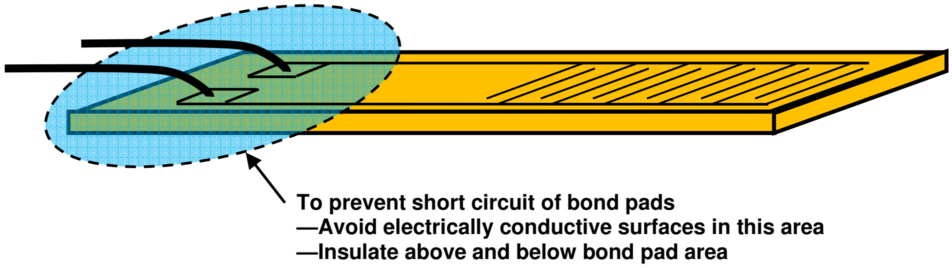

Figure 12-2
Insulating bond pad area

- Do place sample over entire electrode area, as shown in Figure 12-3

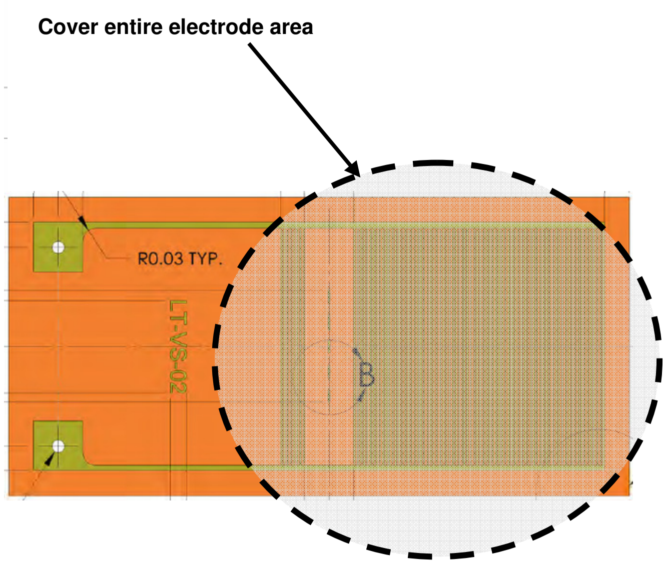

Figure 12-3
Sample application area on sensor

- Do use samples thicker than the separation between interdigitated electrodes
    - When the sample is thinner than the electrode separation, the sensor will also detect air or material on the top side of the sample
- Do stack at least two or three layers of prepreg on top of a sensor to ensure enough resin for good measurements
- Do use a filter between the sensor and materials containing graphite or conductive fibers, as shown in Figure 12-4
    - Fiberglass felt or laboratory filter paper are good filter materials

- Do use aluminum foil or release film above and below the lay-up, as shown in Figure 12-4, to prevent the sample from adhering to platen or mold surfaces
- Do apply pressure to solid samples, or solid samples that melt during processing, for good contact with the sensor

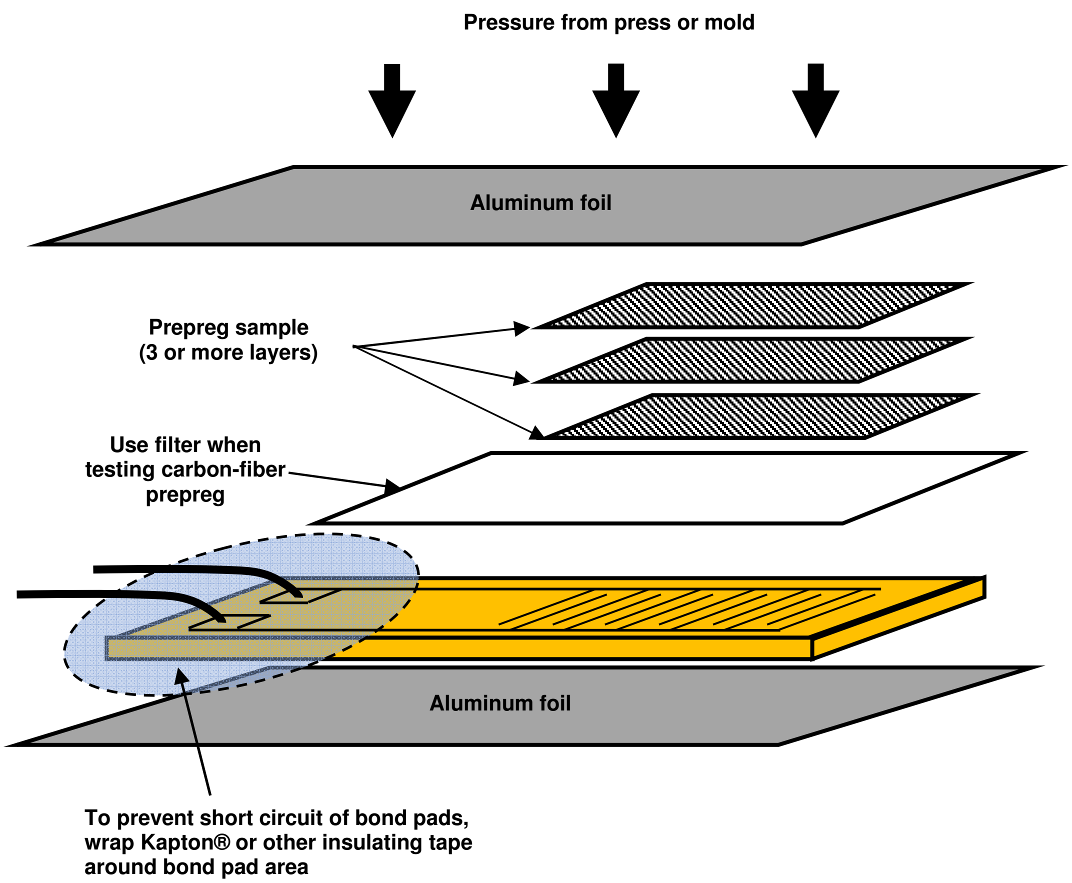

Figure 12-4
Suggested lay-up for prepregs

Reducing noise in leads, extension cables and sensors

- Don't use long, unshielded leads, which act like antennas and can pick up interference
    - Signal levels at the end of cure are low and measurements are more susceptible to noise at this time
    - Use coaxial cable with guarded or grounded shields for long leads
- Don't place the sensor on or near large ungrounded metal surfaces

  - Ungrounded metal acts like an antenna that can pick up noise, which the sensor detects
  - Ground metal surfaces around the sensor
- Don't place power cords near the sensor
  - AC mains voltages are around 100 – 240 VAC but sensor signals may be in the range of only 10 mV

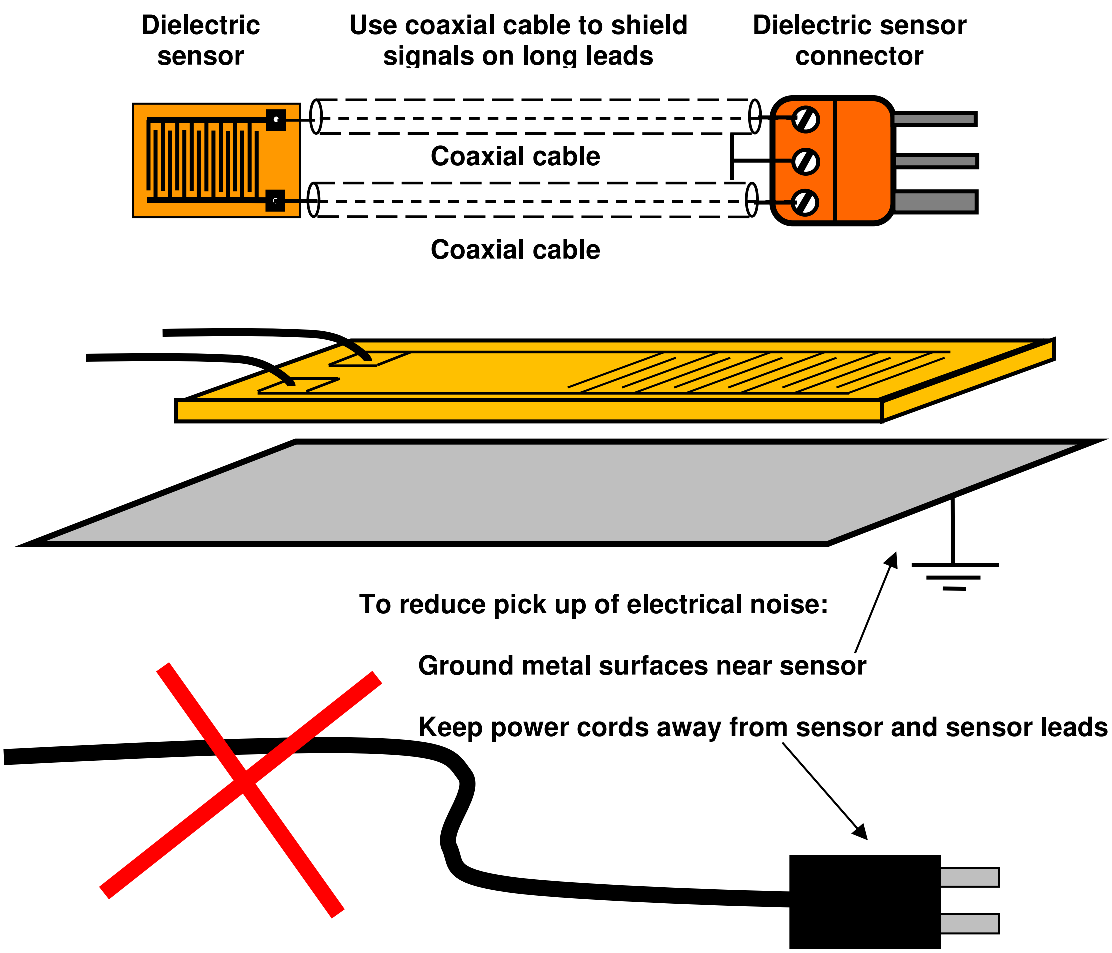

Figure 12-5
Ways to reduce noise in dielectric sensors

If an instrument measures a response voltage from the dielectric sensor, then a guarded cable is usually more suitable. Figure 12-6 shows a typical configuration for guarded cables. Note that the shields around the leads connect to a x1 amplifier that outputs the guard signal. This guard signal drives the shields with a reproduction of the response, reducing capacitive interaction between the sensitive response line and the outside world.

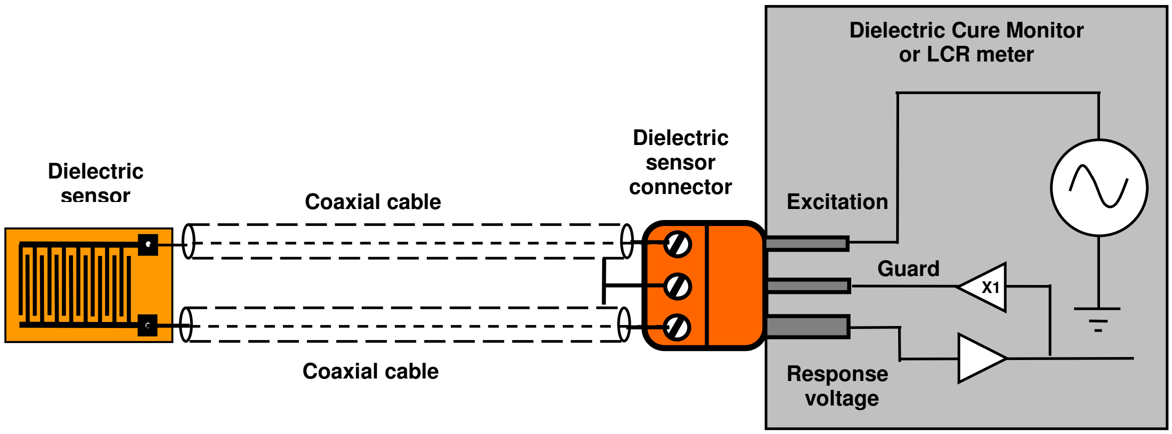

Figure 12-6
Connecting a dielectric sensor using coaxial cable with guarded shields

If an instrument measures a response current from the dielectric sensor, then this current typically goes into a virtual ground. In this case a grounded shield is more suitable, as shown in Figure 12-7.

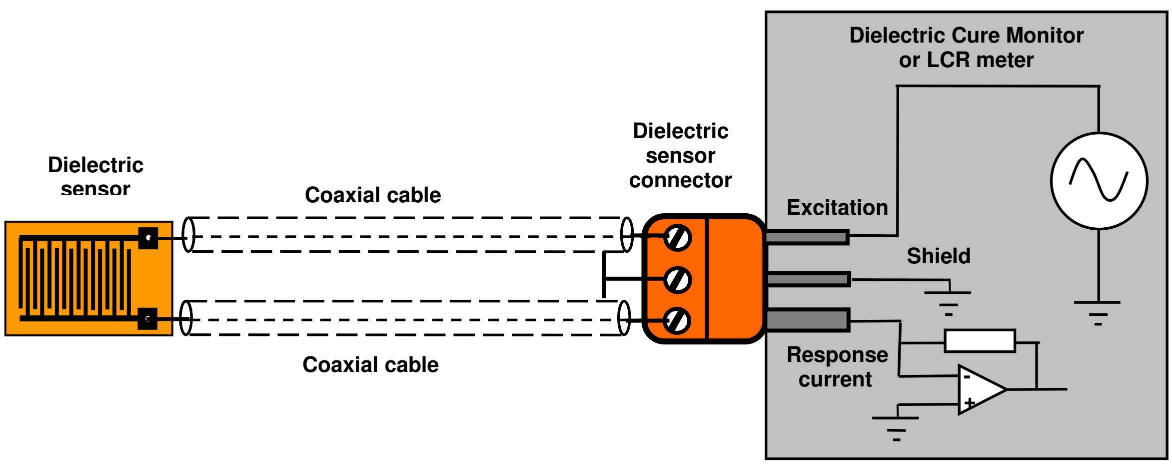

Figure 12-7
Connecting a dielectric sensor using coaxial cable with grounded shields

Interpreting dielectric data

- Do look at loss factor, as in Figure 12-8, when studying the dipole response

- Total loss factor is the sum of loss from the flow of mobile ions and the loss from dipole rotation
- Using loss factor makes it easier to see and separate the mobile ion response from the dipole response
- Loss factor is inversely proportional to frequency when mobile ions dominate response

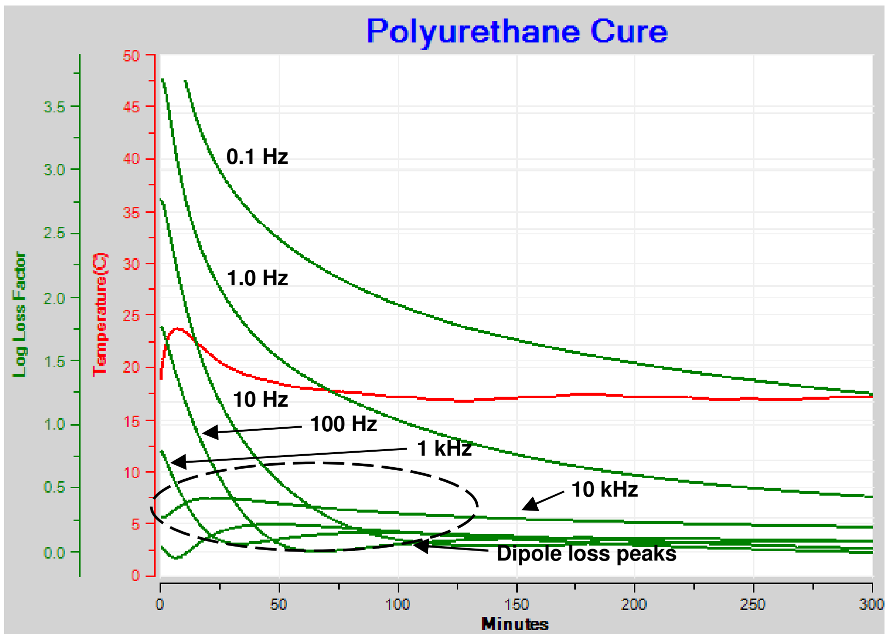

Figure 12-8
Loss factor of curing polyurethane

- Do look at resistivity from multiple frequencies, as in Figure 12-9, to determine ion viscosity
  - Change of ion viscosity indicates cure state
    - Often proportional to change of viscosity before gelation
    - Often proportional to change of modulus after gelation
  - Ion viscosity is frequency independent resistivity due to mobile ions
  - Ion viscosity dominates where curves from different frequencies closely or completely overlap
  - Dipole response dominates where curves from different frequencies do not overlap

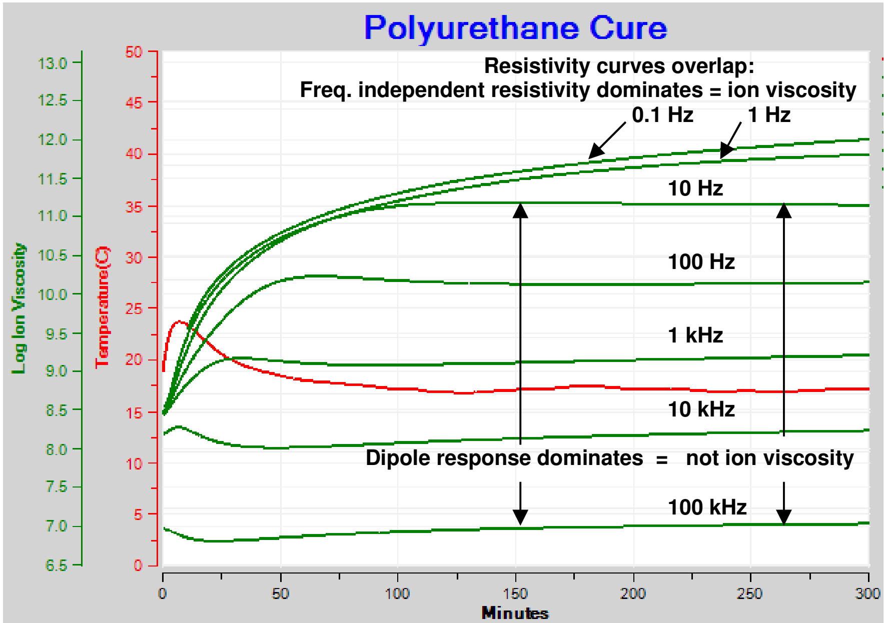

Figure 12-9
Resistivity of curing polyurethane (plotted against ion viscosity axis)

- Do use a single, optimum frequency—if possible—for ion viscosity response for entire cure, as shown in Figure 12-10
    - A single frequency allows calculation of slope for the entire cure

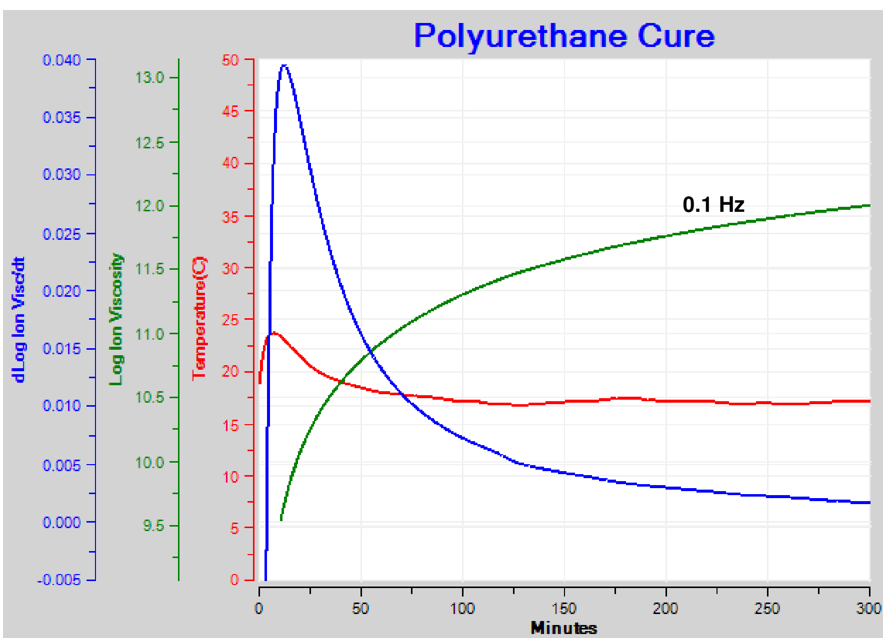

Figure 12-10
Ion viscosity and slope for curing polyurethane

- Do use lower frequencies for better ion viscosity response at end of cure
- Do use higher frequencies for better ion viscosity response at beginning of cure

With proper sample preparation, lay-up, shielding of leads and attention to the electrical environment it is possible to make good, reproducible dielectric measurements for monitoring the cure of thermosets and composites.

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