Insight — Technical Overview 2.03
Guidelines for Dielectric Cure Monitoring

Introduction

Following are some guidelines for successful dielectric cure monitoring. Although the method of DEA is simple—place a sample on the sensor, heat and start data acquisition—care and good practice are very helpful for making good measurements.

Preparing the sensor

- 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 100 °C for a short time
- Do prevent material from adhering to reusable sensors by applying silicone or non-conductive mold release, as shown in Figure 1

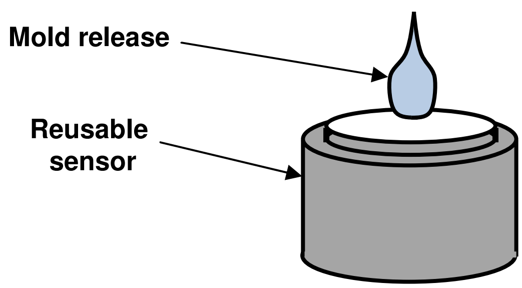

Figure 1
Apply mold release to reusable sensors

- Do prevent short circuits by avoiding contact between sensor bond pads and electrically conductive surfaces
    - Cover bond pads with Kapton® or polyimide tape, as shown in Figure 2

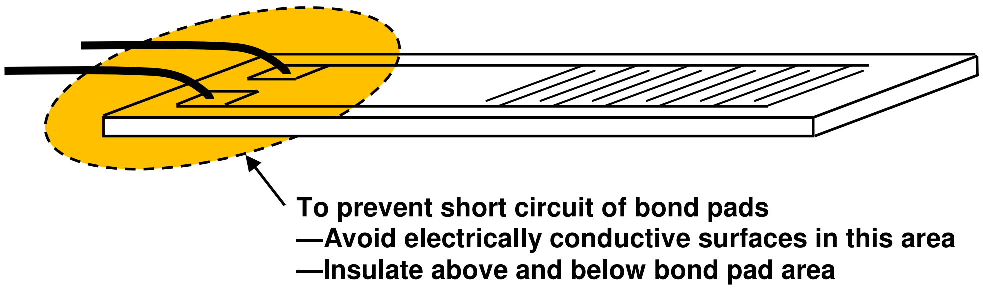

Figure 2
Insulating bond pad area

- Do run sensor leads parallel to each other to reduce capacitance between leads
  - Don't use twisted leads, which increase cable or base capacitance

Laying up the sample

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

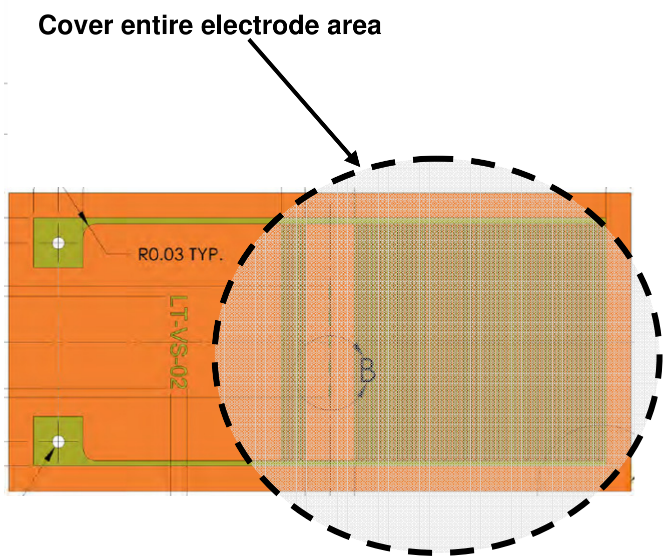

Figure 3
Sample application area on sensor

- 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 4
    - Glass cloth with small pore size, 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 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

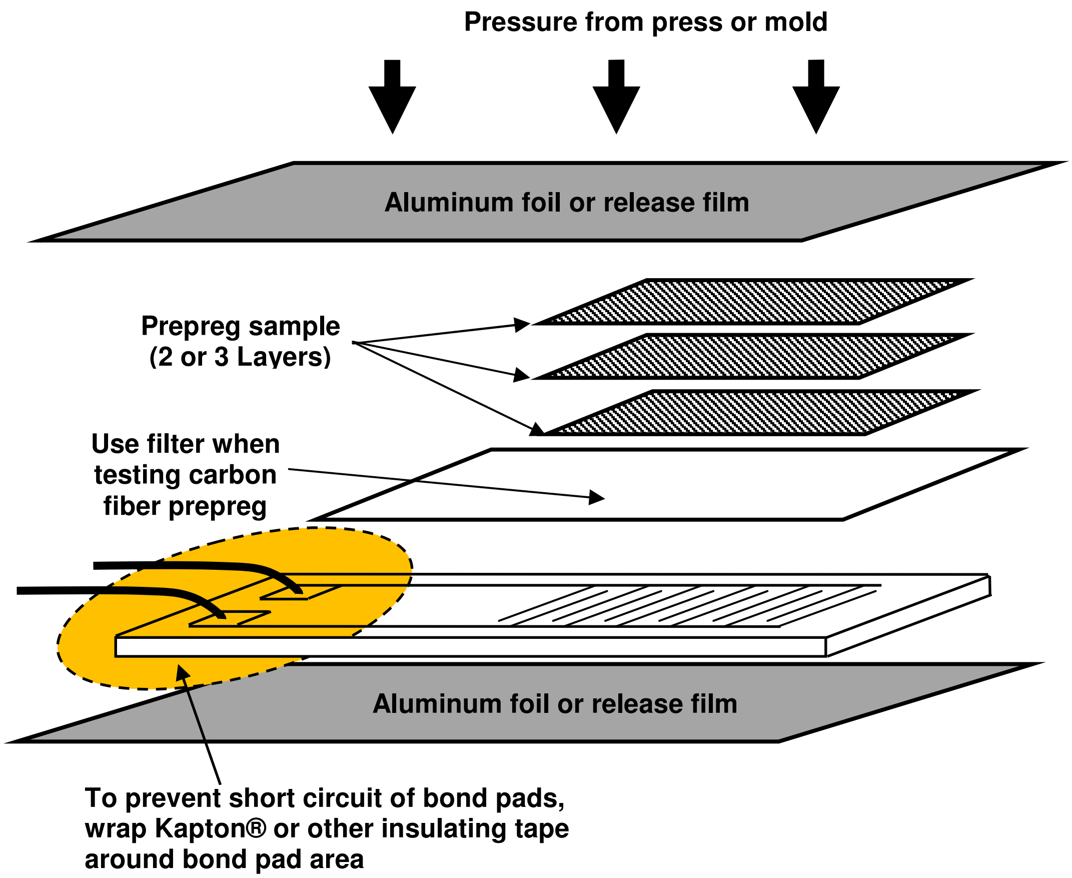

Figure 4
Suggested lay-up for prepregs

Reducing measurement noise

- 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
- 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

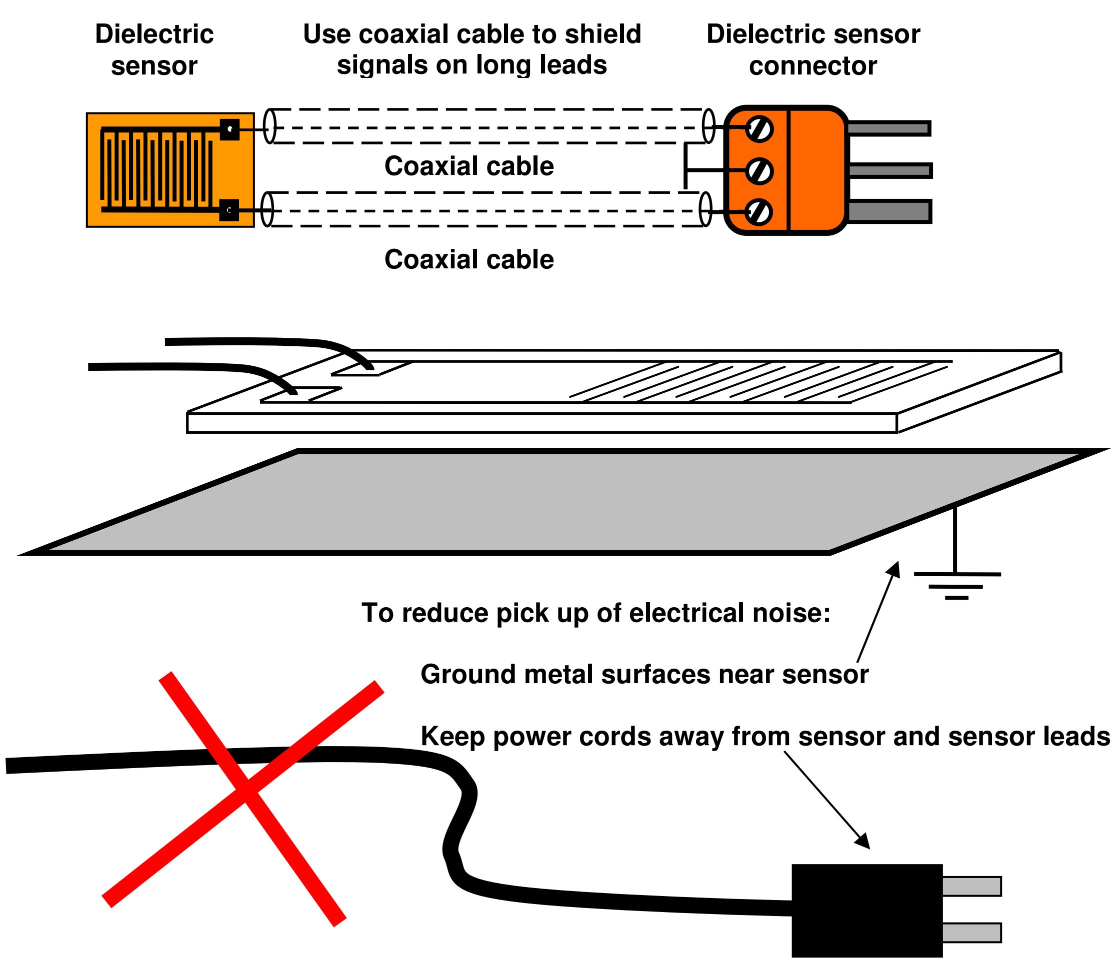

Figure 5
Ways to reduce noise in dielectric sensors

Interpretating dielectric data

- Do look at loss factor, as in Figure 6, 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

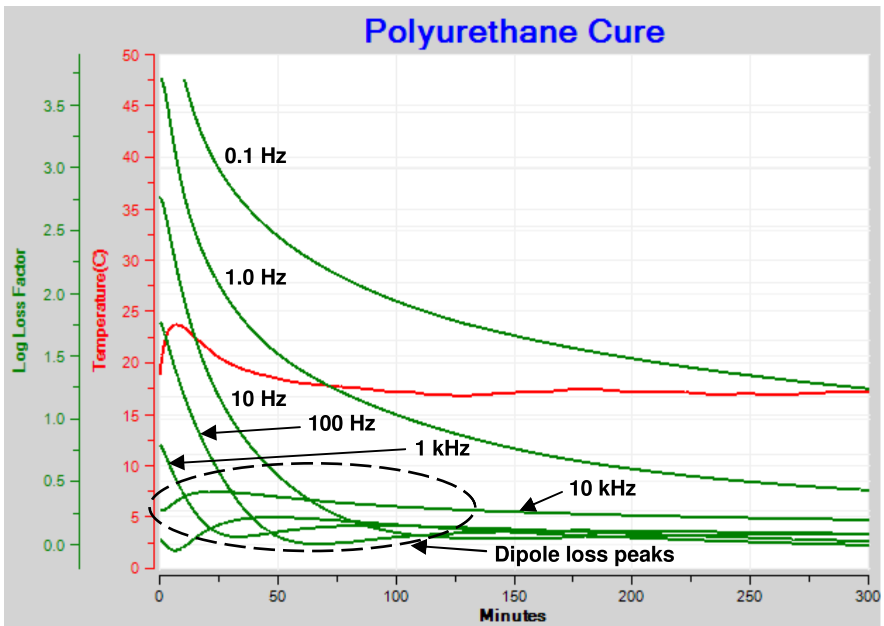

Figure 6
Loss factor of curing polyurethane

- Do look at resistivity from multiple frequencies, as in Figure 7, to determine ion viscosity
  - Ion viscosity indicates cure state
    - Proportional to change in viscosity before gelation
    - Proportional to change in 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

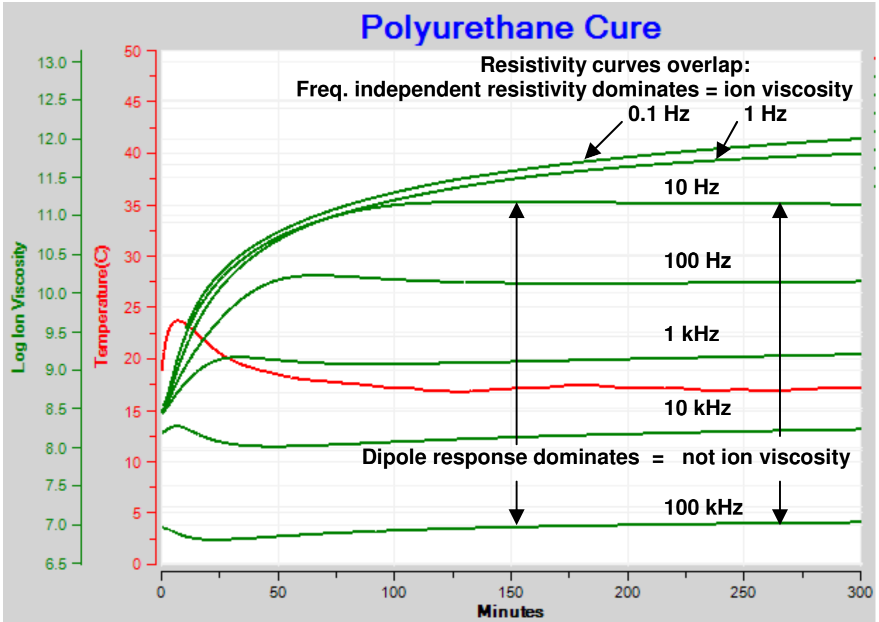

Figure 7
Resistivity of curing polyurethane (plotted against ion viscosity axis)

- Do use ion viscosity from a single, optimum frequency—if possible—to calculate slope, as shown in Figure 8
  - Lower frequencies show ion viscosity response better for whole cure
  - Higher frequencies show dipole response better at end of cure

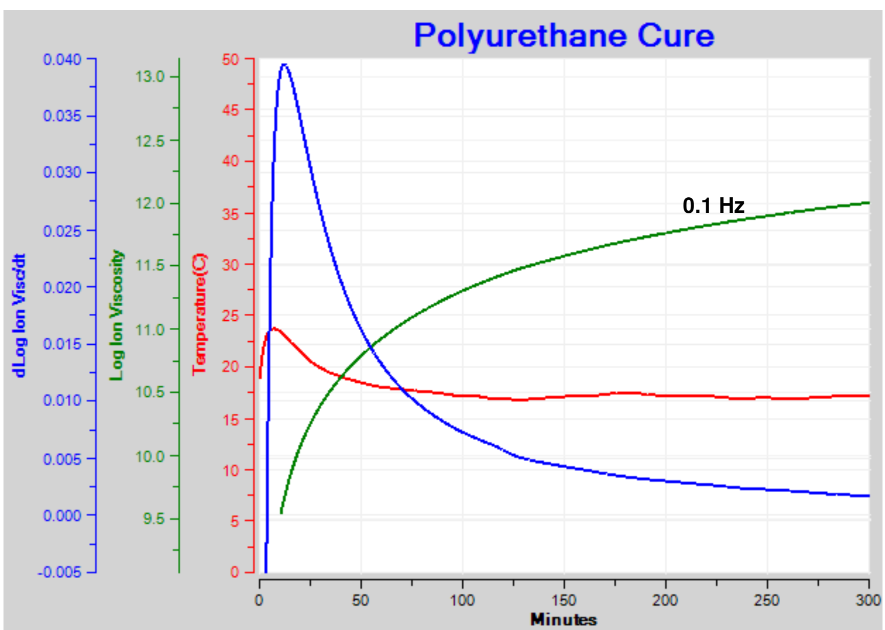

Figure 8
Ion viscosity and slope for curing polyurethane

Conclusion

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

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