Dielectric Cure Monitoring for the Study of Thermosets

Materials, formulations, viscosity, gelation, full cure and end of cure

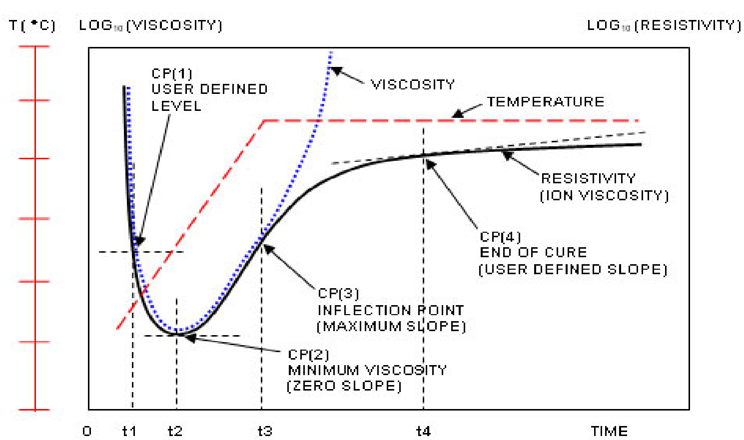
Instruments, sensors and software
http://www.lambient.com

LT-451 / LTF-631 Dielectric Cure Monitors with CureView Software

Dielectric cure monitoring saves time, effort and expense with a simple method of observing the effects of chemistry, reaction rate, formulation and process parameters on the cure of thermoset materials.

Dielectric cure monitoring measures the electrical properties of a material. It is the only method that can be used in Research and Development, Quality Assurance/Quality Control, and manufacturing, making quantitative information readily applicable and readily transferable to every aspect of polymer processing.

Lambient Technologies' instruments, sensors and software are designed for flexibility and ease of use. Together these products form an integrated system for studying polymers and using the results for optimizing the final product.



Viscosity and resistivity in a curing material.
Note correlation between viscosity and resistivity.
The cure curve is characterized by four Critical Points.

Instruments

- **LT-451 Dielectric Cure Monitor**
  Wide frequency range, versatile, optimized for research applications
- **LTF-631 High Speed Dielectric Cure Monitor**
  Cost effective, optimized for QA/QC and studies of rapidly curing materials

Software

- **CureView for the LT-451/LTF-631**
  For instrument control, cure monitoring and data analysis

Applications

- Formulation, reaction rate and cure studies
- Diffusion studies
- Cure and process development/monitoring
- Materials testing
- Statistical quality control

Materials

- Epoxy
- Acrylic
- Silicone
- Polyester/polyurethane/polystyrene
- Composites and laminates
- Bulk molding compound/Sheet molding compound
- Paints, coatings and adhesives

Processing Environments

- Ovens
- Presses
- Autoclaves
- Pultruders and extruders
- Batch reaction vessels

Rugged Reusable Dielectric/Conductivity Sensors

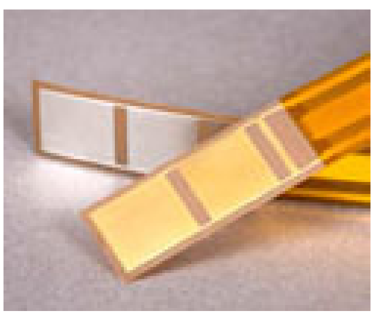
CeramiComb Ceramic Sensor

The **Ceramicomb-1"** is designed for use in presses, molds or harsh environments where a rugged, reusable dielectric/conductivity sensor is desired. It may be mounted so the electrodes are flush with a platen or mold surface, insuring no interference with the flow of material during processing. The sensor is constructed with silver-palladium electrodes embedded in an alumina substrate, protected by a stainless steel sheath with a nominal 1.0" (2.54 cm) diameter. A thermocouple is positioned in the ceramic just below the surface to allow measurement of process temperatures. The maximum operating temperature of the **Ceramicomb-1"** sensor is 250 °C.

Single Electrode Sensors
(Right—8mm unsheathed, left—0.5" sheathed)

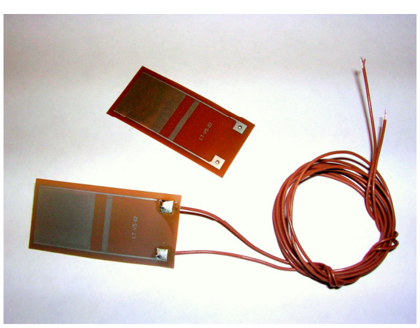
Single Electrode sensors are designed for use in locations where a tiny reusable dielectric/conductivity sensor is required. They may be mounted so the electrode is flush with a press or mold surface. The surrounding platen or opposing face of a mold acts as the second electrode, enabling these sensors to measure through the bulk material. The electrode is stainless steel surrounded by a polyimide insulator. The unsheathed version is a nominal 8 mm in diameter. The sheathed version, with stainless steel sheath for high pressure applications, is a nominal 0.5" (12.5 mm) in diameter. The maximum operating temperature of the **Single Electrode** sensor is 200 °C for the unsheathed version and 250 °C for the sheathed version.

Flexible Disposable Dielectric/Conductivity Sensors



Varicon Selectable Sensitivity Sensor

The **Varicon** sensor is designed for use in presses, molds, bulk materials or laminates where a thin, flexible dielectric/conductivity sensor is necessary. Patterned on a polyimide substrate, the electrode array is designed to allow a choice of three sensitivities, which are selected by cutting off portions of the array at designated lines. The **Varicon** sensor is 15" (38 cm) long and only 0.004" (100 um) thick. It is sensitive to the dielectric/conductive properties of materials within approximately 0.004" (100 um) of the electrode surface. The maximum operating temperature of the **Varicon** sensor is approximately 350 °C.



Mini-Varicon Selectable Sensitivity Sensor

The **Mini-Varicon** sensor an inexpensive version of the **Varicon** sensor. Patterned on a polyimide substrate, the electrode array is designed to allow a choice of two sensitivities, which are selected by cutting off portions of the array at designated lines. The **Mini-Varicon** sensor is 1.5" (3.0 cm) long and only 0.004" (100 um) thick. It is sensitive to the dielectric/conductive properties of materials within approximately 0.004" (100 um) of the electrode surface. The **Mini-Varicon** sensor can be provided without leads, or with Teflon insulated leads. When provided with leads, the **Mini-Varicon** sensor has a maximum operating temperature of 200 °C.

Accessories

LTP-350 MicroPress

The **LTP-350 MicroPress** is a small thermal pneumatic press designed for the curing of SMC, BMC, epoxies, polyesters, polystyrenes, polyurethanes, silicones, laminates and other polymeric materials. Providing a portable, easily operated platform to reproduce the time-temperature-pressure processing profiles of most polymers, the **LTP-350 MicroPress** has independent temperature control of both upper and lower platens and can operate in either isothermal or ramp-and-hold modes. The heating temperature range is ambient to 350 Degrees C (660 Degrees F), and maximum applied force is 2000 pounds (909 Kg). Platen area is 3.0” x 3.0” (75 cm x 75 cm).

Brief Dielectric Theory

The dielectric properties of ***conductivity*** σ, and ***permittivity*** ε, arise from ionic current and dipole rotation in the bulk material. For polymers, mobile ions are typically due to impurities and additives, while dipoles result from the separation of charge in the monomers making up the material. When analyzing dielectric properties, it is possible to separate the influence of ions from dipoles, as shown in Figure 1, in order to consider their individual effects.

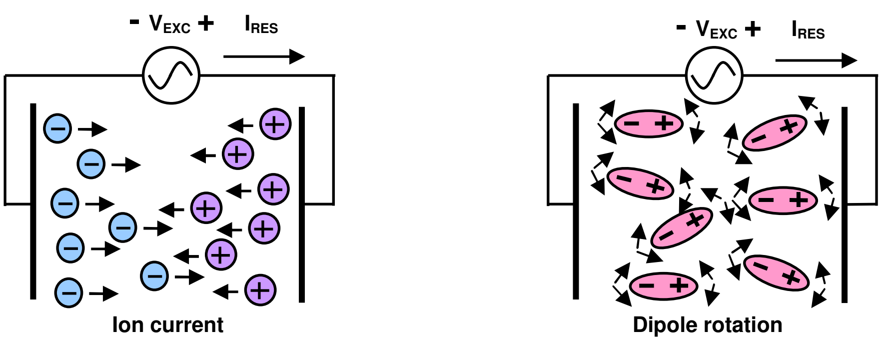


Figure 1

The flow of ions under the influence of an electric field is responsible for conductive current, and therefore for conductivity σ and its inverse, ***resistivity*** ρ. Consequently, the effect of mobile ions can be modeled as a conductance, as shown in Figure 2. This conductance may be frequency dependent, and will change as the bulk material changes. The mobility of ions highly depends on the nature of the medium--ions flow more easily through a material with low viscosity and with greater difficulty as the viscosity increases.

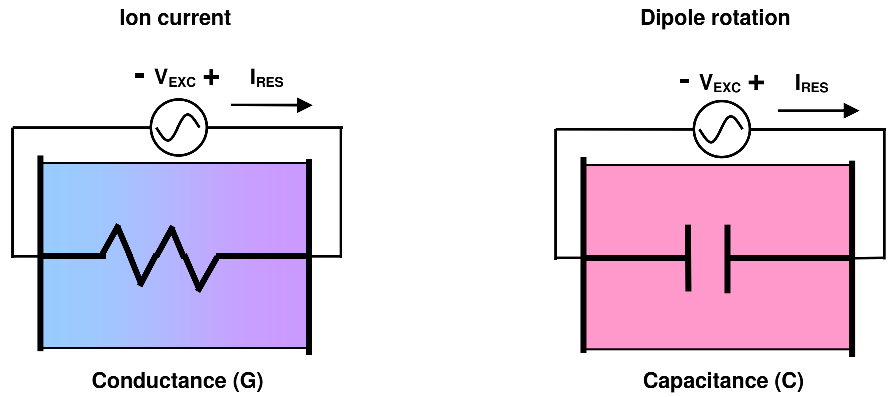


Figure 2

For dielectric cure monitoring, it is convenient to observe the ***ion viscosity***, which is simply the electrical resistivity ρ—i.e the inverse of conductivity. As the physical viscosity of a curing polymer increases, the ion viscosity presented to ion current also increases. This relationship is the principle behind the usefulness of dielectric cure monitoring, and makes possible the observation of cure state.

Researchers studying dielectric properties often use parallel plate electrodes, for which plate separation sometimes cannot be accurately controlled. The distance between the plates may change upon the application of pressure, or as the material between them expands or contracts. For such situations ***tan(δ)*** is used to characterize dielectric properties because ε″/ε′ does not vary with plate spacing. However, tan(δ) alone cannot provide information about either permittivity or loss factor, and therefore is limited in usefulness—especially because permittivity and loss factor are themselves complicated functions of several factors.

Interdigitated electrodes on a substrate can be used instead of parallel plate electrodes, as shown in Figure 3. The planar structure of interdigitated electrodes has a geometry which does not change with pressure or expansion or contraction of the material under test, and therefore has the ability to accurately measure both permittivity and loss factor.

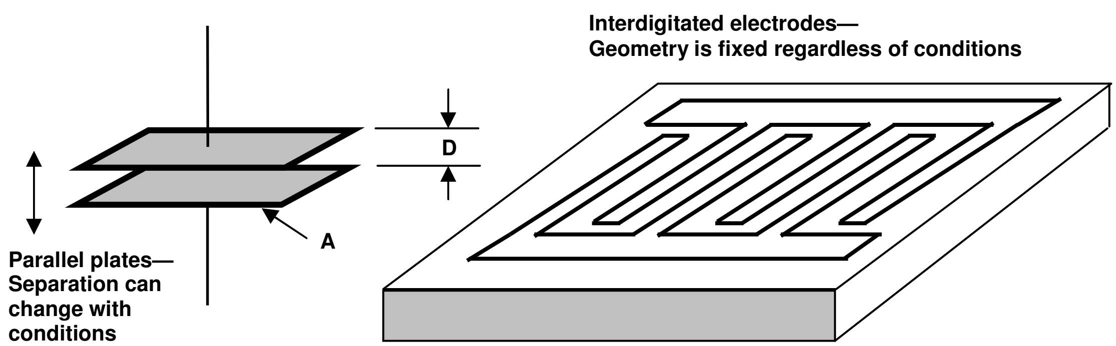


Figure 3

About Lambient Technologies

Lambient Technologies was established in 2007. The principals each have over 25 years experience in the commercialization of dielectric cure monitoring technology developed at the Massachusetts Institute of Technology.

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