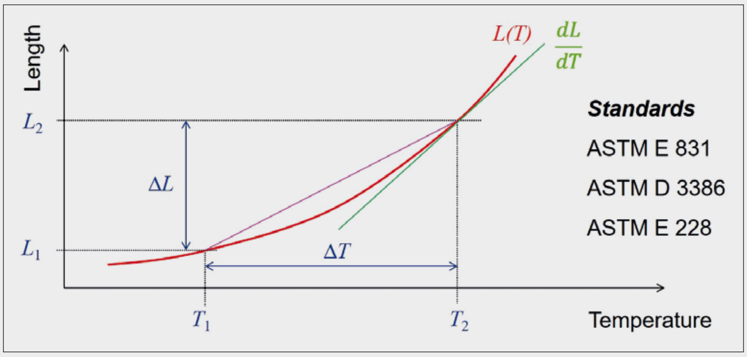
TMA Evaluation

Thermomechanical Analysis

In thermomechanical analysis (TMA), dimensional changes of a sample are measured as a function of temperature or time. The dilatometry mode determines changes in a sample's length using a very small load (force). The deformation of a sample can also be recorded with a higher force (penetration) and under a dynamic load (DLTMA). Depending on the type of sample and the selected measurement program, the curve profile can be used to characterize material properties.



dL = Infinitesimal length change
dT = Infinitesimal temperature change
L_0 = Initial length
ΔL = Change of length
ΔT = Change of temperature
Δt = Change of time

Local coefficient of expansion $\alpha = \frac{dL}{dT} \cdot \frac{1}{L_0}$

Mean coefficient of expansion $\alpha = \frac{\Delta L}{\Delta T} \cdot \frac{1}{L_0}$

One of the main uses of thermal mechanical analysis is to measure the coefficient of thermal expansion (CTE). Expansion and contraction occur in all samples with a change in temperature. The CTE of a sample can be calculated with high accuracy in all measurement modes.

Features and benefits

- **Glass transition evaluation** – TMA specific T_g calculation
- **Coefficient of thermal expansion** – CTE results as a curve and numerically in tabular form
- **Modulus determination by DLTMA** – get elasticity information and accurate glass transition temperature

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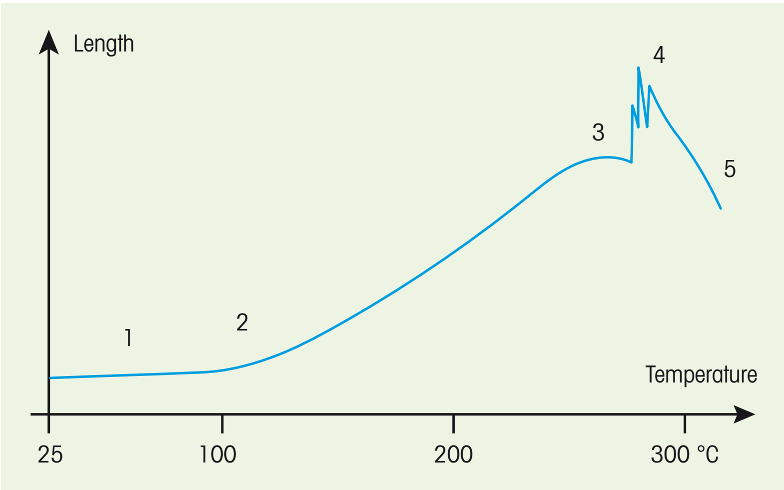
TMA Evaluation
Dimension Changes of a Samples

The TMA curve of a glass-fiber reinforced epoxy resin is a good example for the use of the TMA evaluation software option, as this class of materials tends to demonstrate the most important effects that appear when using this instrument.

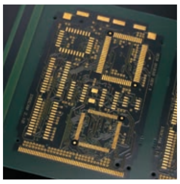


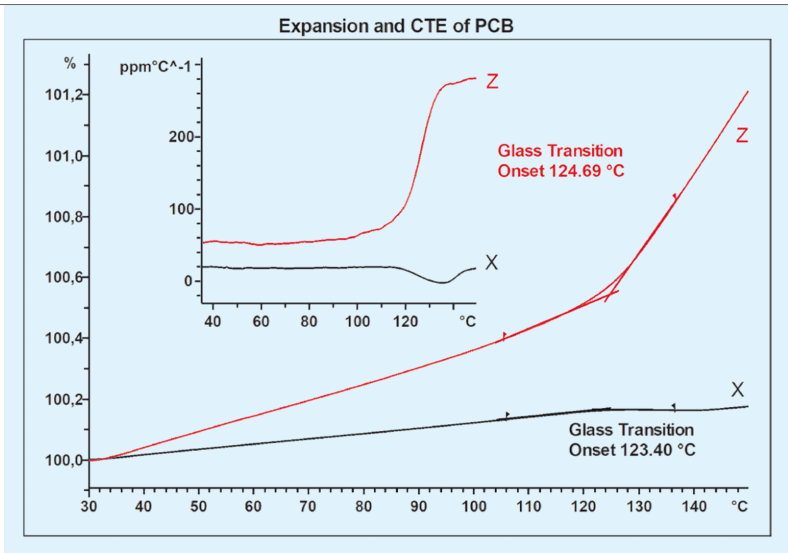
1 = Thermal expansion
2 = Glass transition (change in the coefficient of expansion)
3 = Softening, penetration
4 = Degassing, delamination
5 = Plastic deformation

This software option offers you the following evaluations specific to TMA:

1. **Glass transition temperature** – Intersection point of the tangents to the TMA curve before and after T_g
2. **Coefficient of thermal expansion** – Local and mean value α, in tabular or graphical form
3. **Conversion** – Ratio of the partial length change to the total length change over a temperature or time interval, e.g. in thermal decomposition of a surface coating
4. **Young's modulus** – Based on tensile measurements of films and fibers as well as 3 point bending
5. **CTE with sapphire** – Determine the expansion coefficient by comparison with sapphire
6. **Stress-stain curve** – Calculate and display a stress-strain curve
7. **DLTMA evaluations** – Detailed information about viscoelastic properties (modulus)

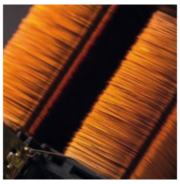
Application Examples

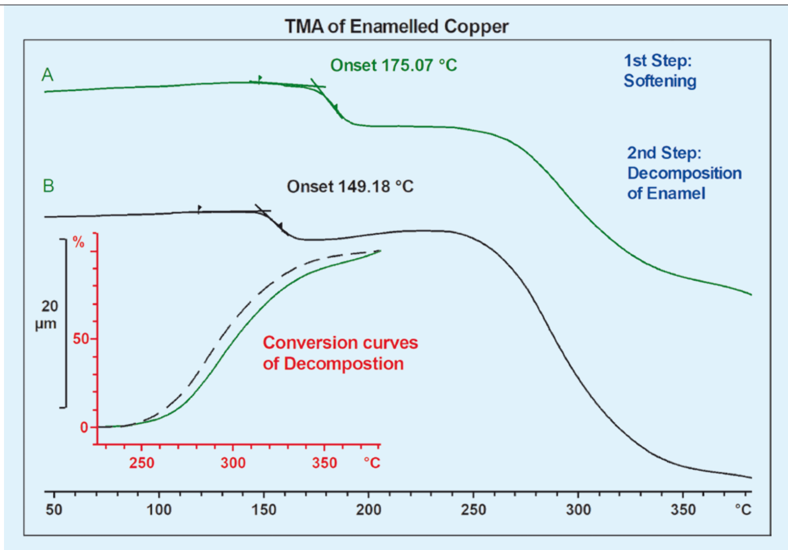




Printed circuit board

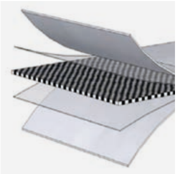
The expansion behavior of composites helps to define the possible application field of the material. The diagram shows the expansion behavior of a glass-fiber reinforced epoxy resin sample. The sample was measured in both the fiber direction (x-axis) and perpendicular to the fibers (z-axis). There is a clear difference in expansion behavior when comparing these different measurements. The material expands more along the z-axis, as indicated by both graphs. Evaluating the glass transition is therefore more easily determined when evaluating along the z-axis.

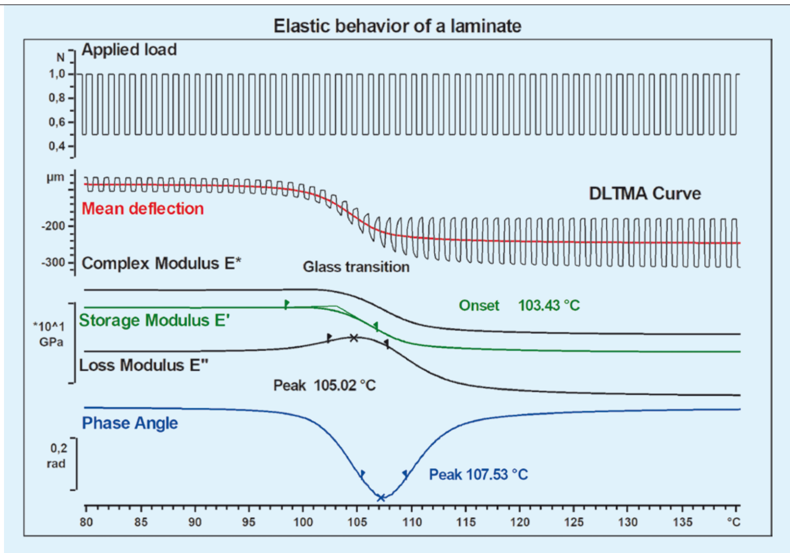




Insulated copper wire

The thermal and mechanical stability of copper wire insulation is an important characteristic of magnetic wire coils. The diagram shows the TMA curves of two copper wires (A and B) insulated with different enamels. Both samples exhibit similar behavior (i.e. curve shape), but have different softening and thermal decomposition temperatures. Both effects are shifted to higher temperatures with Sample A, thus demonstrating a greater thermal stability of this enamel. The conversion curves of decomposition are shown for both samples to further emphasize the improved thermal stability of Sample A.





Metal laminate

To improve damping properties of sheet metal laminates, they are often sandwiched together by energy absorbing layers. Using DLTMA (dynamic load TMA) in 3-point bending, the viscoelastic and damping behavior of materials can be easily characterized.

The evaluation of the experimental curve with TMA Evaluation Option yields valuable insight into the material:

- Mean deflection shows softening is visible around 100 °C.
- Storage modulus (E′) is proportional to the material's elasticity.
- Phase angle curve provides dampening behavior.
- Storage modulus (E′) and loss modulus (E′′) can both be used to calculate the glass transition temperature.
- Complex modulus (E*) is the addition of the storage and loss modulus.

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