Dynamic Mechanical Analysis (DMA):

- Shows how the modulus (stiffness) $E'$ or $G'$ varies with temperature.
- Identifies mechanical transitions in solid polymers ($T_g$, $T_m$).
- Defines useful thermal range for property retention.
- Indicates degree of crystallinity by the value of $E'$ above $T_g$.
- Allows prediction of heat distortion and softening temperatures.
- Gives an easy comparison of material performance over a range of temperatures.
- Measures the elastic and viscous response of a material to an oscillating mechanical load over a broad temperature range and a fixed frequency.

Storage modulus ($E'$ or $G'$) - Also called the elastic modulus. The recoverable portion of applied mechanical energy. It is a measure of the stiffness of a plastic material. Reported in pounds per square inch (psi) or mega Pascals (MPa).

Loss modulus ($E^*$ or $G^*$) - The viscous damping modulus. The portion of applied mechanical energy that is dissipated or lost to heating. Reported in psi or MPa.

Tan delta - Ratio of the loss modulus to the storage modulus $E^*/E'$ or $(G^*/G')$. A sensitive measure of the magnitude and temperature of transitions (Tan Delta is the tangent of the phase angle between the input and response waves).

Melt temperature ($T_m$) - The temperature where a crystalline polymer changes from an elastic solid to a viscous liquid.

Glass transition temperature ($T_g$) - The temperature at which amorphous segments change from a glassy to a rubbery state upon heating. Evidenced by a peak in Tan $\Delta$. (In amorphous polymers $E'$ or $G'$, becomes smaller than $E^*$ or $G^*$). The elastic modulus in tension ($E'$) and elastic modulus in shear ($G'$) are related by the following equation $E' = 2(1 + v)G'$ where $v$ is Poisson’s ratio.

**Typical amorphous polymer**

*Based on internal SABIC Innovative Plastics test data. Figure 1 shows the change in modulus and Tan Delta with temperature for a typical amorphous polymer.

**These plots are based on internal SABIC Innovative Plastics test data.**
- The storage modulus gradually decreases with increasing temperature up to $T_g$.
- Heat Distortion Temperature (HDT) is close to $T_g$. 

![Figure 1](Lexan* 141 resin frequency = 1 Hertz)

**Figure 1**
Typical crystalline polymer

A typical crystalline polymer shows temperature dependence of the kind shown in Figure 2.

- Storage modulus drops significantly at Tg, but material stiffness is maintained through Tm.
- Magnitude of drop in E' through Tg indicates the degree of crystallinity (small drop indicates high crystallinity).
- The degree of crystallinity affects the magnitude of drop in E' through Tg. (higher crystallinity, smaller drop).

Effect of glass on dynamic mechanical response

Figure 3 shows the change in elastic modulus with temperature for unreinforced Valox* resin and for resins with 30% and 40% glass reinforcement.

- Storage modulus increases as the glass content increases.
- The thermal transition temperatures depend on the resin and do not change with glass content.

*Based on internal SABIC Innovative Plastics test data.

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