

Measuring Coefficient of Thermal Expansion using TMA

When a material is heated, its physical dimensions will change. Typically when heated, the material will expand, although there are some rare exceptions. This expansion is due to increased movement of the constituent atoms at elevated temperature. Elevated temperature forces these atoms to maintain a greater average separation distance than they would at a lower temperature.

The coefficient of thermal expansion (CTE), α , describes how much the size of an object will change with temperature. While the CTE is normally given as just a single number, it will change depending on the temperature. The magnitude of a given materials CTE is strongly related to the bond energy between its constituent atoms. For example, metals and polymers have much higher CTE's than ceramics. This can be illustrated using a schematic plot of bond energy vs. atomic separation, as seen in Figure 1.



Figure 1. Schematic plot of bond energy vs. atomic separation.

As a material is heated, its constituent atoms gain more kinetic energy and vibrate with larger amplitudes. When there are many atoms in close proximity, they will spread out to accommodate the larger amplitude, causing the material to expand. The minimum in potential energy is much lower for ceramics than for polymers, increasing the amount of heat required to melt the material as well as reducing the change in interatomic spacing.

Knowing the precise amount of thermal expansion that will occur within a system is critical for many material applications. The components in an internal combustion engine will expand as the engine warms up to operating temperature. Supersonic jets will stretch during flight because of the heat generated by friction with the air. Casting molds will change dimensions as a molten metal is poured in. Any large-scale structures will experience large dimensional changes with small changes in temperature and must be designed to accommodate them.



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Ebatco NAT Lab uses a Q400 Thermomechanical Analyzer (TMA) from TA Instruments to accurately measure the CTE of materials. This instrument uses a flat, quartz probe to measure the amount of linear expansion in a material as it is heated. With a displacement resolution of 0.5 nm and a temperature range of -150°C to 1000°C, it can measure the CTE of a wide variety of materials across a broad temperature range. The results from thermal expansion tests on aluminum and silicon nitride can be seen in Figures 2 and 3.



Figure 3. Thermal expansion of aluminum block.