



**DISCOVER** the WORLD'S FINEST  
DYNAMIC MECHANICAL ANALYZER

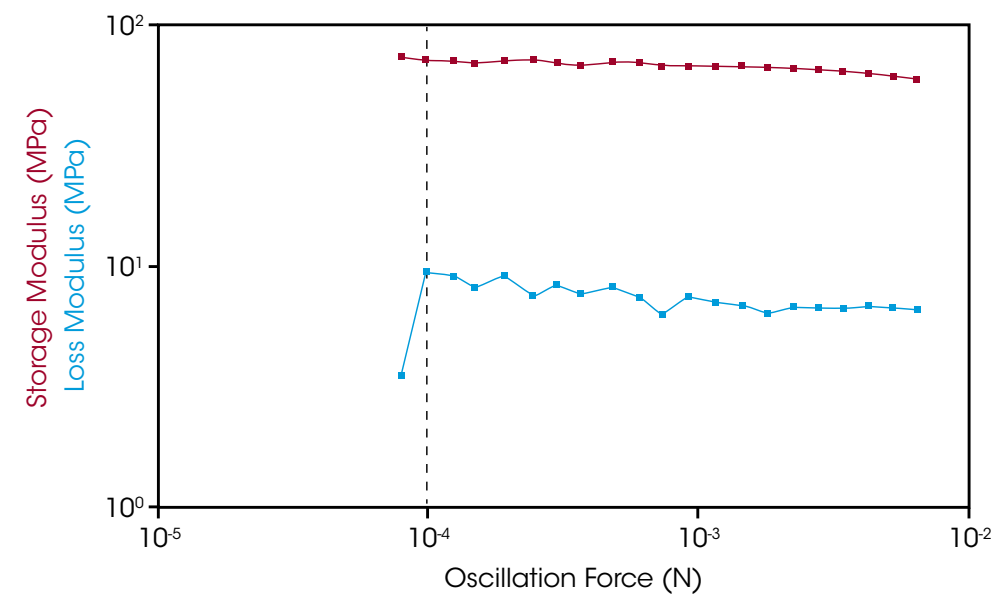
**Discover**  
a new  
**DMA**  
that  
**provides**

Unmatched  
Sensitivity

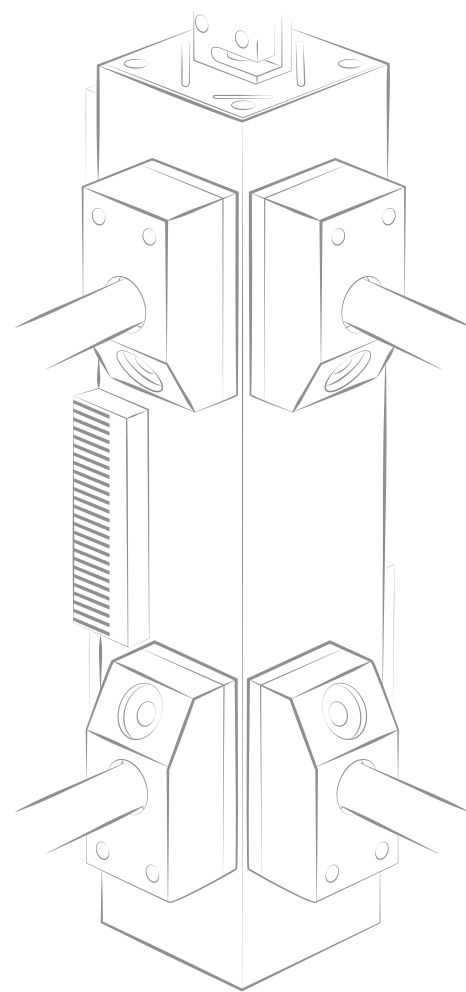
Superior  
Performance

Maximum  
Versatility

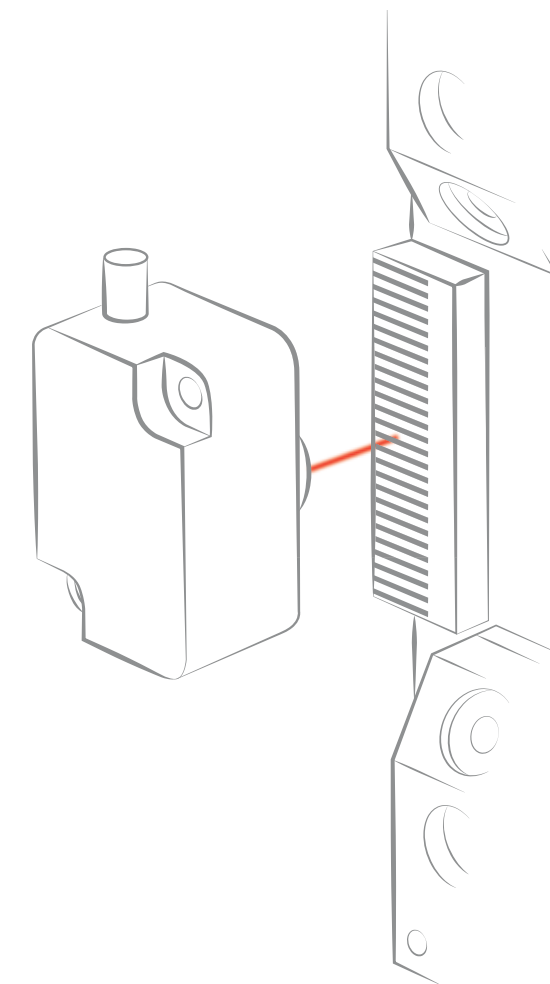
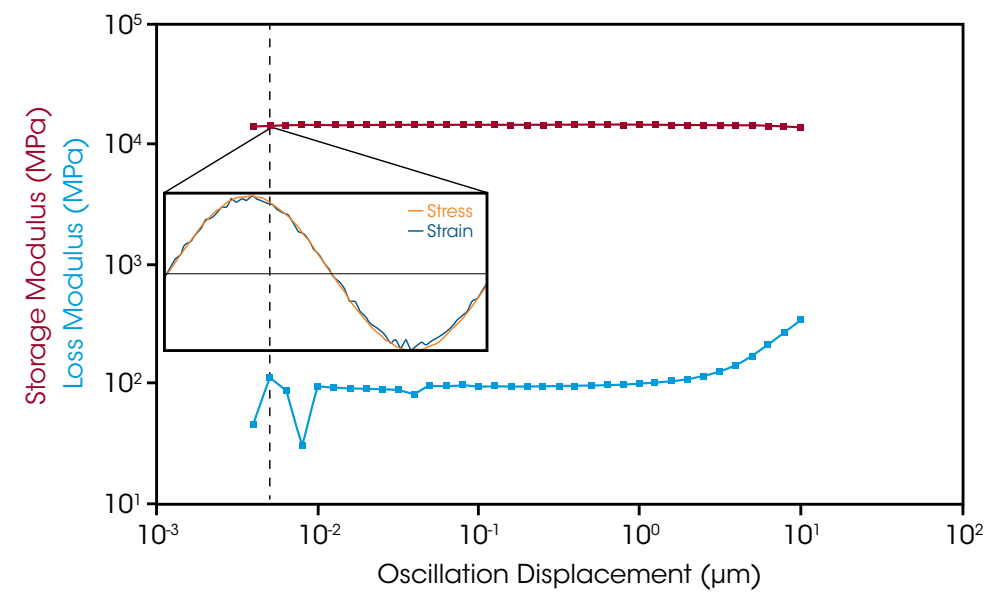
# The World's Most **SENSITIVE DMA** to Measure the **Lowest Forces...**



*0.1 mN Forces*

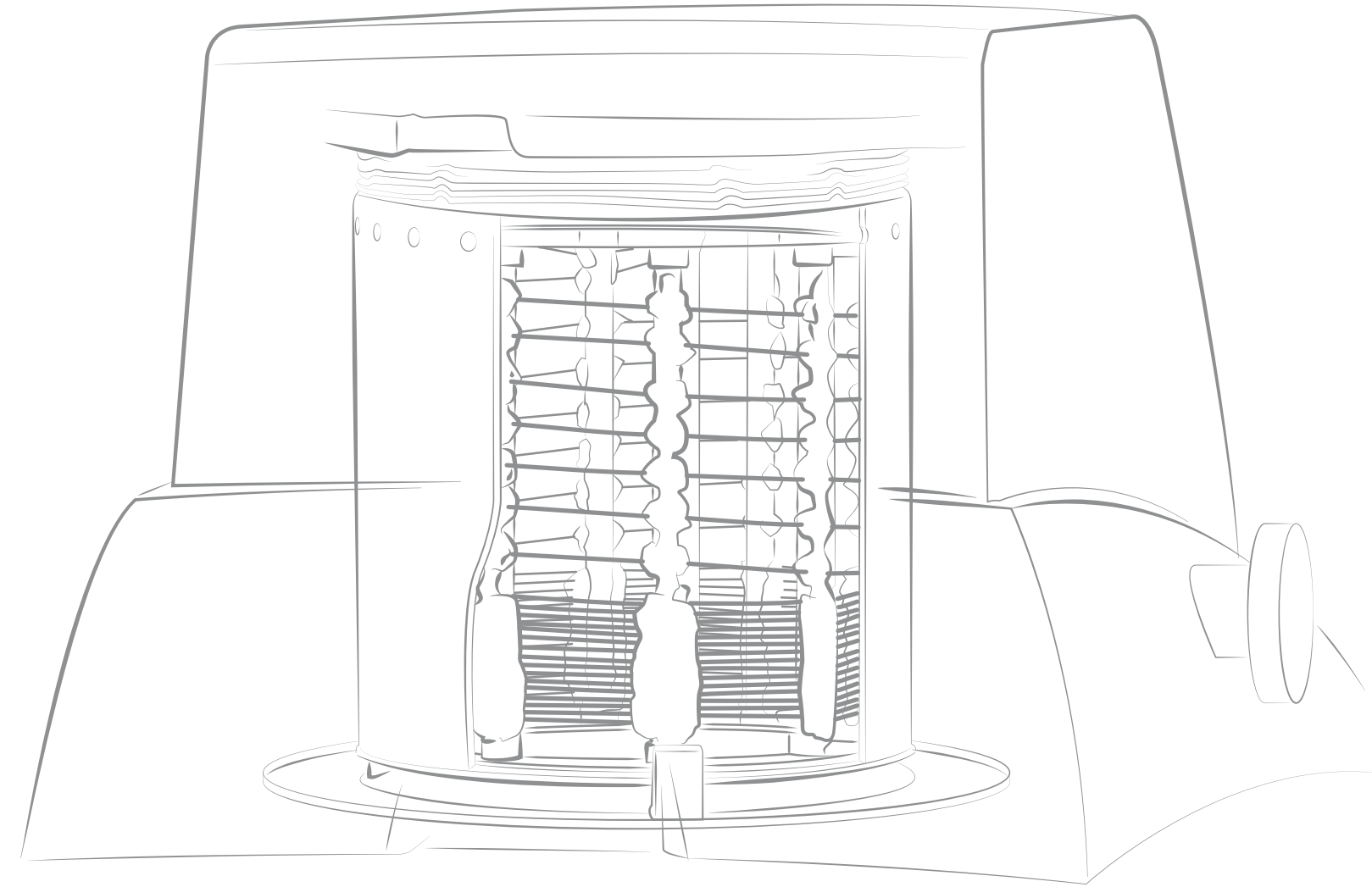


*5 nm Oscillation Displacements*

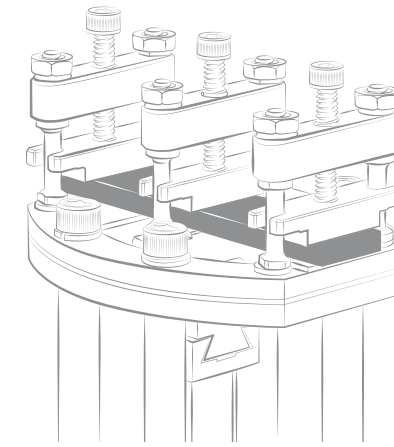


...and **SMALLEST DISPLACEMENTS**

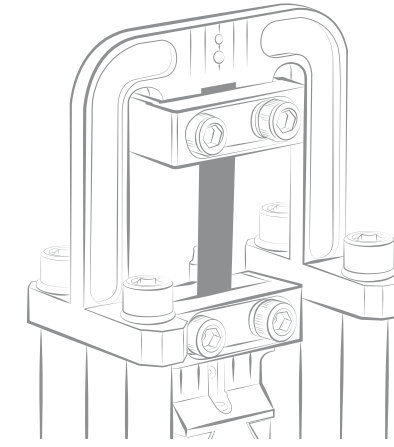
with Reliable, Efficient Environmental Systems



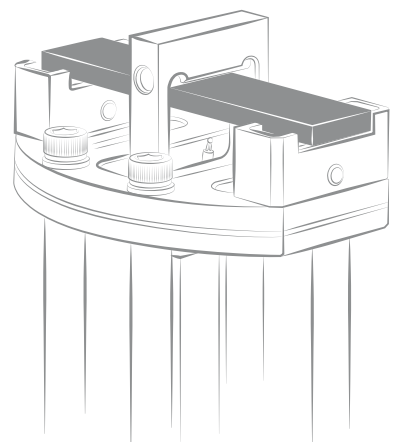
...and clamps optimized for  
**ACCURACY** and **EASE-OF-USE**



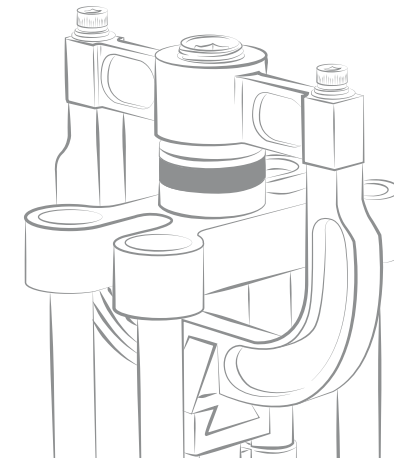
Cantilever



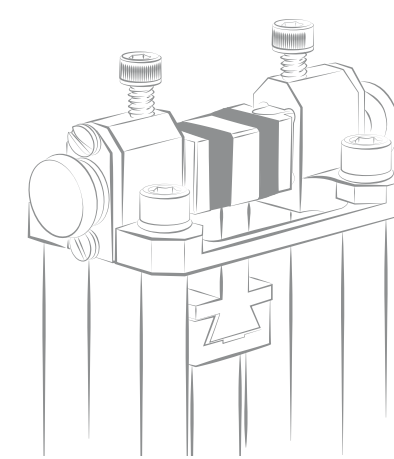
Tension



3-Point Bend



Compression



Shear

TA Instruments invites you to experience the ultimate in Dynamic Mechanical Analyzers, the Discovery DMA 850. Building on superior technologies of the world's best-selling DMA, improvements in every aspect of DMA performance deliver the most accurate and reproducible measurement of mechanical properties over a wide temperature range. It's never been easier to get great DMA data!

#### Features and Benefits:

- Non-contact, low mass motor delivers continuous forces from 0.1 mN to 18 N to measure everything from soft to stiff materials
- Frictionless, low-compliance air bearing design ensures superior force sensitivity and accuracy
- Unique optical encoder technology provides 0.1 nm resolution over a 25 mm continuous range of travel for ultimate testing versatility
- New DirectStrain™ and Intelligent Autoranging controls allow you to measure the widest range of sample stiffness and frequencies for the best data, the first time, every time
- Choice of two dedicated environmental systems for precise, responsive control under the most relevant test conditions
- Exclusive Air Chiller Systems provide effective controlled cooling to -100°C without the cost or hassle of liquid nitrogen
- Purpose-built, high-stiffness, low mass clamps are easy to use and ensure data repeatability
- New innovative "app-style" touch screen puts instrument functionality simply One-Touch-Away™, enhancing usability and making it easier than ever to get great data
- Powerful TRIOS software provides simple setup and execution through separate test interfaces designed for novice or expert users
- Commitment to quality backed by the industry's **ONLY** five-year furnace warranty for peace of mind



### Responsive Direct Drive Motor

The DMA 850's non-contact motor applies both dynamic and static deformation over the full 25 mm range of motion, providing exceptional control in all modes and clamp positions.

The motor is constructed of high-performance lightweight composites that maximize axial and torsional stiffness while minimizing system inertia. Sophisticated control electronics enable the **fastest motor control over the widest continuous range of force, from 0.1 mN to 18 N**. This enables the system to capture a broad spectrum of material properties with the highest level of sensitivity and accuracy. These precision controls also provide vast improvements in transient response, including a step-displacement response of 50 ms, as well as a 100x improvement in stress-control accuracy.

Unlike competitive motor designs that provide either high force or high resolution, or require separate inferior motors for linear travel, the DMA 850 achieves a continuous range of linear travel and high-resolution force measurement.

### Stiff, Frictionless Air Bearing Support

The non-contact drive motor transmits force directly to a rectangular air bearing slide. The slide is guided by eight porous carbon air bearings. Pressurized gas forms a frictionless surface that permits the slide to "float." The slide connects directly to the drive shaft and sample clamp for an unsurpassed 25 mm of frictionless displacement. The rectangular shape of the drive shaft completely eliminates off-axis motion.

Only TA Instruments employs sophisticated air bearing technology for DMA measurements. Systems without this design feature suffer from poorly controlled deformation in unsupported designs, or diminished sensitivity where spring guidance is employed.

### Wide Range, High Resolution Optical Encoder

Based on diffraction patterns of light through gratings, optical encoders provide exceptional resolution over very wide ranges compared to LVDT's used in competitive devices. Due to the excellent 0.1 nanometer resolution of the optical encoder, very small amplitudes can be measured precisely. Enhanced optical encoder sensitivity, combined with refined motor controls, results in **displacements up to 100x smaller than previous drive technology, including control of displacements as small as 5 nm**.

The non-contact motor, frictionless air bearing support, and wide range optical encoder provide unparalleled flexibility for small and large samples, materials that creep, expand, or contract during an experiment, and application of static or transient deformations.



**An accurate mechanical measurement is built on a foundation that completely transfers all motor deformation to the sample, while also eliminating any influence from external factors such as system resonance, thermal drift or frame deformation.**

### Optimized Mechanics

The critical drive components of the DMA 850 are mounted within a high-stiffness aluminum casting that is rigidly mounted to an FEA-optimized instrument frame. Competitive systems based on moveable, hanging, or soft-mounted frames are constrained in their effective frequency-range by the combination of sample stiffness and system resonance. The rigid design of the DMA 850 overcomes this limitation, providing accurate modulus and  $\tan \delta$  values across the broadest range of measurement frequencies and sample stiffness.

### Faster Calibration

New system mechanics mean that routine calibrations are faster and easier than ever. Quick, robust calibration routines guide the user for better measurement accuracy in **80% less time** than previous DMA technology. Spend less time maintaining your instrument, and more time getting valuable material insights.

### Temperature-Controlled Transducer

The transducer is temperature-controlled to eliminate drift associated with temperature changes from the sample or laboratory environment. The result is the most stable platform for mechanical characterization of materials even under extreme conditions. The DMA 850 is the only commercial DMA instrument to feature a temperature-controlled force and displacement transducer, providing unparalleled measurement stability and accuracy.



FEA - Optimized Instrument Foundation

**OPTIMIZED CASTING** and  
**FRAME MECHANICS** provide  
**UNPARALLELED MEASUREMENT ACCURACY**

The DMA 850 offers you a choice of two dedicated environmental systems: the Standard Furnace and the DMA-RH Accessory for humidity and temperature control. Installation is simple, making it convenient to switch between systems as required. All environmental systems and accessories are designed specifically for high performance DMA measurements and seamless integration and are manufactured by TA Instruments.

#### Standard Furnace

The Standard Furnace for the DMA 850 is a wide-range bifilar wound furnace that provides uniform temperature control from -160°C to 600 °C. This field-proven design provides for efficient and precise temperature control over the entire temperature range in heating, cooling, and isothermal operation. For subambient temperature control, the furnace is used in combination with one of four available cooling accessories to meet your testing requirements.

A high-sensitivity thermocouple is in close proximity to the sample to provide a representative measurement of sample temperature, regardless of the mode of deformation being employed.

All TA Instruments  
furnaces are covered  
by the industry's **only**

**5** YEAR WARRANTY

## Industry-leading ENVIRONMENTAL CONTROL SYSTEMS





### DMA-RH Accessory

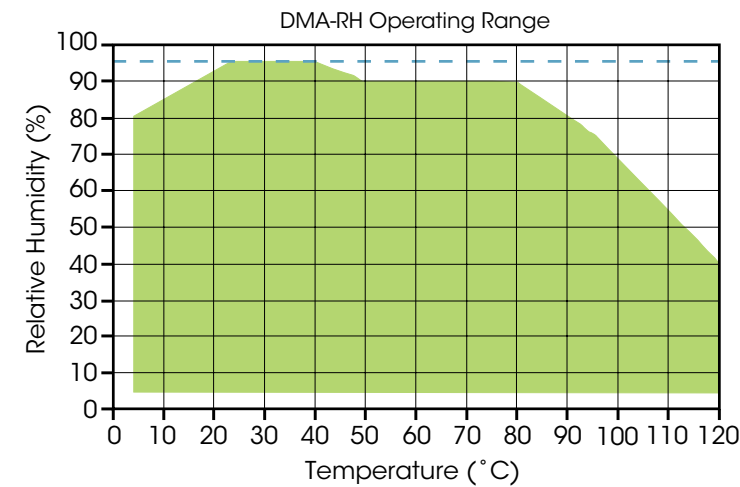
This precision environmental system provides accurate control of sample temperature and relative humidity for DMA experiments. A custom-designed humidity and temperature chamber optimized for mechanical measurements provides stable, reliable control of temperature and humidity over a wide range of operating conditions. The system successfully prevents condensation, a common occurrence in controlled-humidity environments which makes accurate control of relative humidity impossible. Stable, responsive peltier elements precisely control sample temperature while calibrated digital mass flow controllers deliver pre-heated gas of the prescribed ratio to achieve the target humidity.

The DMA-RH accessory offers the widest range of temperature and relative humidity.

Temperature Range	5 to 120°C
Temperature Accuracy	±0.5°C
Heating/Cooling Rate	Maximum ±1°C/min
Humidity Range	5 to 95% See operating range chart.
Humidity Accuracy	5-90% RH: ±3% RH >90% RH: ±5% RH
Humidity Ramp Rate (both increasing and decreasing)	2% RH/min (fixed)

The DMA-RH Accessory is a fully integrated unit and includes the following hardware components:

- 1 The sample chamber mounts directly to the DMA. Peltier elements in the chamber precisely control the temperature to ±0.1°C. The sample chamber accommodates standard DMA clamps (tension, cantilever, and 3-point bending).
- 2 A heated vapor-transfer line is maintained at a temperature above the dew point temperature of the humidified gas in order to avoid condensation and provide accurate results.
- 3 The DMA-RH Accessory contains the humidifier and electronics which continuously monitor and control temperature and humidity of the sample chamber.

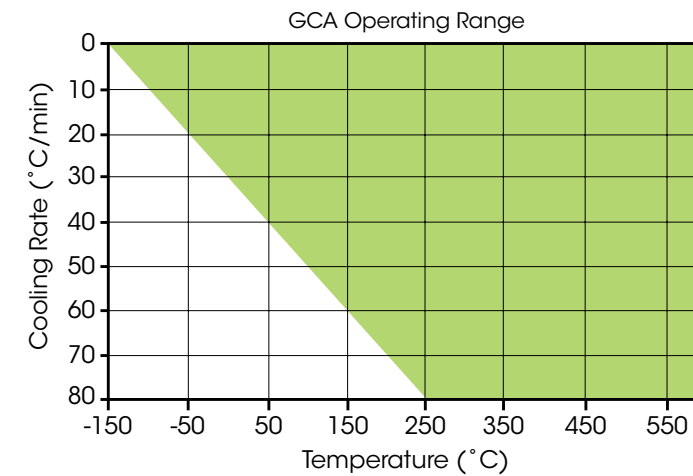




### Gas Cooling Accessory (GCA)

The GCA extends the operating range of the DMA 850 to  $-150^{\circ}\text{C}$ . It uses cold nitrogen gas generated from controlled evaporation of liquid nitrogen. Automated filling of the tank can be programmed to occur after the scan is complete.

The GCA will provide ballistic or controlled cooling rates over the entire operating range of the DMA 850 ( $-150$  to  $600^{\circ}\text{C}$ ). In general, the maximum cooling rate is a function of the installed clamp and the thermal characteristics of the sample. The figure below shows the typical range\* of controlled cooling rates available as a function of temperature.



\*Actual performance may vary slightly depending on laboratory conditions and the clamping system installed.

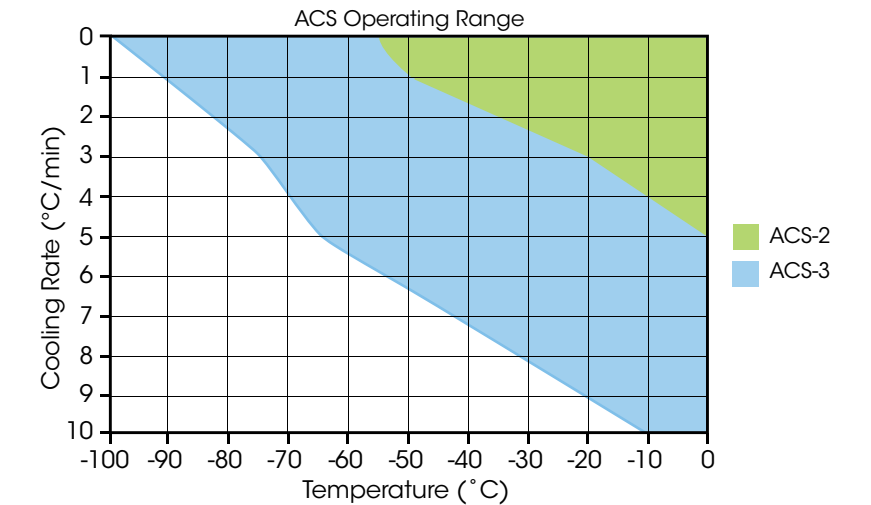
### Nitrogen Purge Cooler (NPC)

The NPC is an economical cooling option that provides crash-cooling and controlled-heating at temperatures as low as  $-160^{\circ}\text{C}$ . The innovative design purges nitrogen gas (2 to 8 bar at 30 L/min) through a heat exchanger immersed in a 2.5 L dewar filled with liquid nitrogen and into the furnace. The compact design minimizes space requirements and the crash-cooling capability make it an ideal choice for increasing throughput of low temperature experiments.



### Air Chiller Systems (ACS)

The new ACS models offer unique gas flow cooling systems that provide the capability for subambient testing without the use of liquid nitrogen. Available in two models, the ACS-2 and ACS-3, the chillers feature a multi-stage cascading compressor design that employs compressed air (7 bar, 200 l/min) as the cooling medium. The ACS-2 and ACS-3 models permit operation of the DMA 850 with Standard Furnace at temperatures as low as  $-50^{\circ}\text{C}$  and  $-100^{\circ}\text{C}$  respectively\*. The chiller systems can eliminate liquid nitrogen usage and associated hazards from any laboratory and offers an incredible return on investment.





The DMA 850 features clamps in a complete set of deformation types, so a broad range of samples can be accurately analyzed and closely resemble real world process or application conditions. Each clamp is individually optimized for accuracy and ease-of-use.

#### Clamp features and benefits:

- High stiffness, low mass designs provide maximum modulus accuracy
- Low thermal mass reduces temperature equilibration time and optimizes transition temperature accuracy and precision
- Individual clamp stiffness calibrations ensure modulus accuracy and repeatability, especially between operators
- Simple dovetail connection is easy to install and self-aligns, increasing precision and reducing installation time
- Limited number of individual components reduces complexity, misalignment, and measurement error
- Innovative designs for difficult measurements like powder and materials immersed in a fluid
- NEW, improved designs for tension, compression, and shear clamps significantly improve ease-of-use by further simplifying alignment and making sample loading more reproducible

**Only TA offers clamps that are ready to use out of the box without complex assembly procedures inherent to competitive designs.**



#### Dual/Single Cantilever

Cantilever (clamped) bending is a good general-purpose mode for evaluating thermoplastics and highly damped materials (e.g., elastomers). Available in sample lengths of 8 mm, 20 mm, and 35 mm, the cantilever clamps can be used in single or dual configurations. Dual cantilever is especially ideal for measuring the cure of supported thermosets.



#### Tension

Tensile clamps are designed for uniaxial deformation of films and fibers. In oscillation experiments, the instrument uses constant and variable methods to apply a static load that prevents buckling and unnecessary creep. A newly designed film tension clamp simplifies the clamping mechanism to improve ease-of-use, clamping uniformity, and effectively prevents sample slippage. Visual guides aid in aligning film samples and integrated supports simplify fiber testing. The continuous travel of the DMA 850 makes sample loading in tension especially convenient.



### 3-Point Bend

3-point bending, or free bending, is often considered a "pure" mode of deformation because clamping effects are eliminated. Sample spans of 5 mm, 10 mm, 15 mm, 20 mm, and 50 mm are available to accommodate a wide range of sample stiffness and specimen sizes. A unique low-friction, roller bearing supported design available on the 20 mm and 50 mm clamps improves modulus accuracy and reproducibility by accommodating and accounting for twist or curvature in the test specimen.



### Shear Sandwich

Two equal-size pieces of the same material are sheared between a fixed and moving plate for the measurement of shear modulus,  $G$ . This mode is ideal for soft materials such as gels, pressure sensitive adhesives, and high viscosity resins.



### Compression

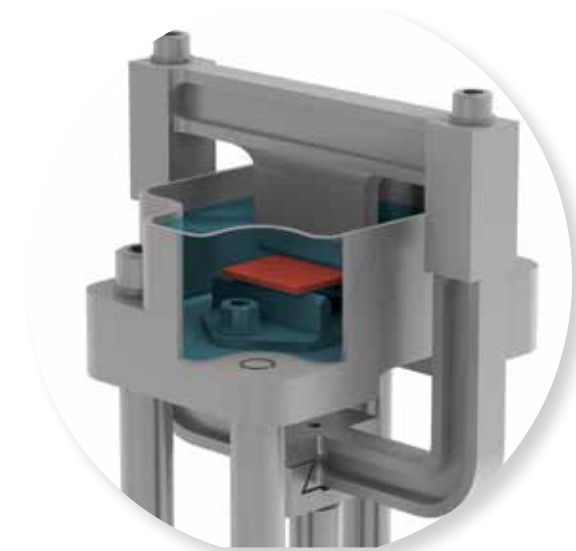
Parallel plate compression measurements are most suitable for low to moderate modulus materials such as foams and elastomers. It can also be used to measure expansion or contraction, tack testing for adhesives, compression set of rubber o-rings, and much more. A new self-aligning mechanism ensures the parallelism of upper and lower plates, enhancing strain and force uniformity while simplifying user interaction and improving modulus accuracy and precision.

The standard compression kit includes parallel plates of 15 mm and 40 mm diameter, ideally designed for bulk measurements of moderate to low stiffness samples. The penetration kit is designed for higher stiffness materials and local measurements through the use of smaller probes: hemispherical, 1 mm penetration, or 6 mm plate.

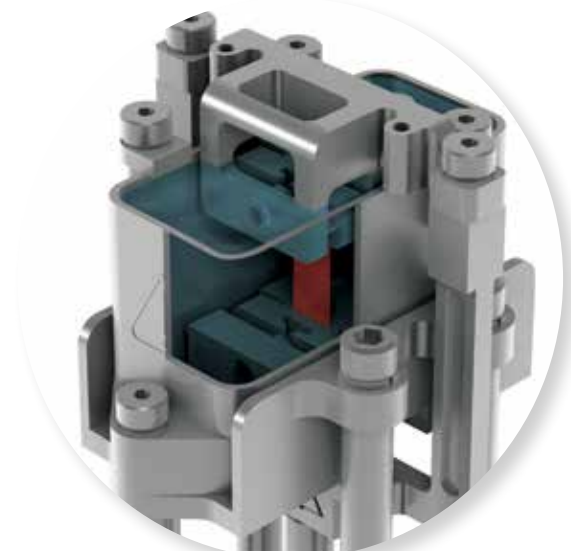


### Powder Clamp

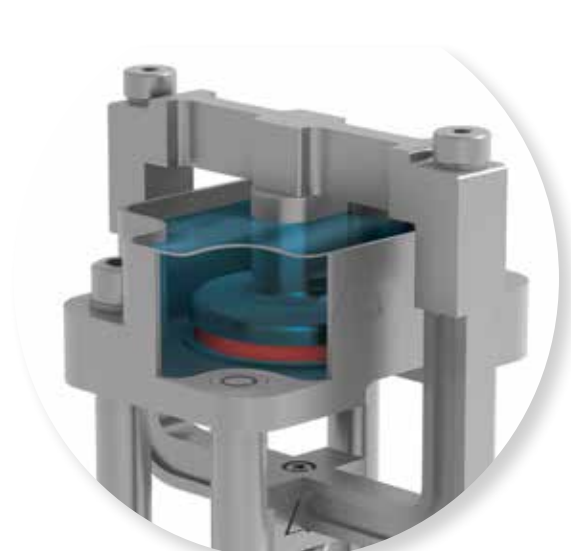
The transition temperatures of loose powders can be difficult to measure by mechanical techniques. The powder accessory for the DMA 850 is used with the dual cantilever clamp to observe transition temperatures of loose powdered materials by DMA, combining the enhanced sensitivity of mechanical analysis with the simple sample preparation of powder characterization techniques.



3-Point Bend



Film



Compression

**Submersion Clamps**

Submersion clamps for the DMA 850 are designed specifically to provide the ideal test conditions for measuring mechanical properties in a fluid environment up to 150°C.

- Accurate sample temperature is obtained by a thermocouple placed within the fluid reservoir and close to the sample
- Inert stainless steel construction and a seal-free design ensure compatibility with a wide range of fluids
- Temperature control provided by the Standard Furnace without additional circulators or environmental systems

**Deformation Modes and Sample Size**

<b>Dual/Single Cantilever</b>	8/4* mm (L), Up to 15 mm (W) and 5 mm (T) 20/10* mm (L), Up to 15 mm (W) and 5 mm (T) 35/17.5* mm (L), Up to 15 mm (W) and 5 mm (T)
<b>3-Point Bend</b>	5, 10, or 15 mm (L), Up to 15 mm (W) and 7 mm (T) 20 mm (L), Up to 15 mm (W) and 7 mm (T) 50 mm (L), Up to 15 mm (W) and 7 mm (T)
<b>Tension</b> Film/Fiber Fiber	5 to 30 mm (L), Up to 8 mm (W) and 2 mm (T) 5 to 30 mm (L), 5 denier (0.57 tex) to 0.8 mm diameter
<b>Shear</b>	10 mm square, Up to 4 mm (T)
<b>Compression</b>	15 and 40 mm diameter, Up to 10 mm (T)
<b>Submersion</b> Tension Compression 3-Point Bend	Fixed at 15 mm (L), Up to 8 mm (W) and 2 mm (T) 25 mm diameter, Up to 10 mm (T) 5, 10, or 15 mm (L), Up to 15 mm (W) and 7 mm (T)

\* Lengths are for dual/single cantilever



### Revolutionary DMA performance at your fingertips

The DMA 850 boasts a brand-new One-Touch-Away™ app-style touchscreen that greatly enhances usability by placing key instrument features at your fingertips.

- Ergonomic design for easy viewing and operation
- Packed with functionality to simplify operation and enhance user experience

### The app-style touch screen includes:

- Start/stop experiments
- Set temperature
- Set clamp position
- Toggle motor modes
- Measure sample
- Real-time signals
- Test and instrument status at a glance

The app-style touchscreen, powerful new TRIOS software, and quick robust calibration routines work seamlessly to dramatically improve laboratory workflows and productivity.



TA Instruments' state-of-the-art software package uses cutting-edge technology for instrument control, data collection, and data analysis for thermal analysis and rheology. The intuitive user interface allows you to simply and effectively program experiments, and move easily between processing experiments and viewing and analyzing data.



### TRIOS Features:

- Control multiple instruments with a single PC and software package
- Overlay and compare results across techniques including DSC, TGA, DMA, SDT, TMA and rheometers
- Unlimited licenses and free lifetime software upgrades
- One-click repeated analysis for increased productivity

### Quick & Easy Calibration

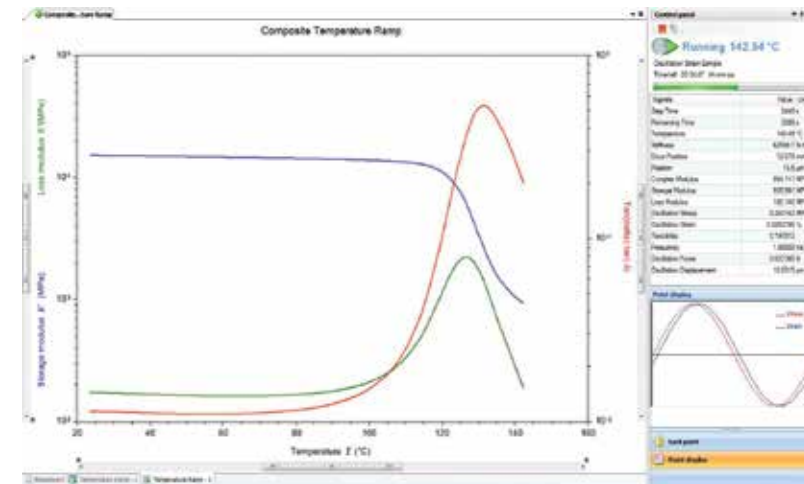
TRIOS software makes calibrating the clamps and the DMA 850 effortless, even for users with no previous DMA experience! Photorealistic images and clear instructions reduce operator training time by guiding them through simple procedures. A summary report provides calibration status at a glance and ensures data integrity.



- Automated custom report generation including: experimental details, data plots and tables, analysis results
- Convenient data export to plain-text, CSV, XML, Excel®, Word®, PowerPoint®, and image formats
- Optional TRIOS Guardian with electronic signatures for audit trail and data integrity

### Complete Data Record

The advanced data collection system automatically saves all relevant signals, active calibrations, and system settings. Waveforms for each data point may be displayed as Lissajous plots and provide a visual representation of the stress-strain relationship. This comprehensive set of information is invaluable for method development, procedure deployment and data validation.



# The Most VERSATILE CONTROL and ANALYSIS SOFTWARE!

### Complete Data Analysis Capabilities

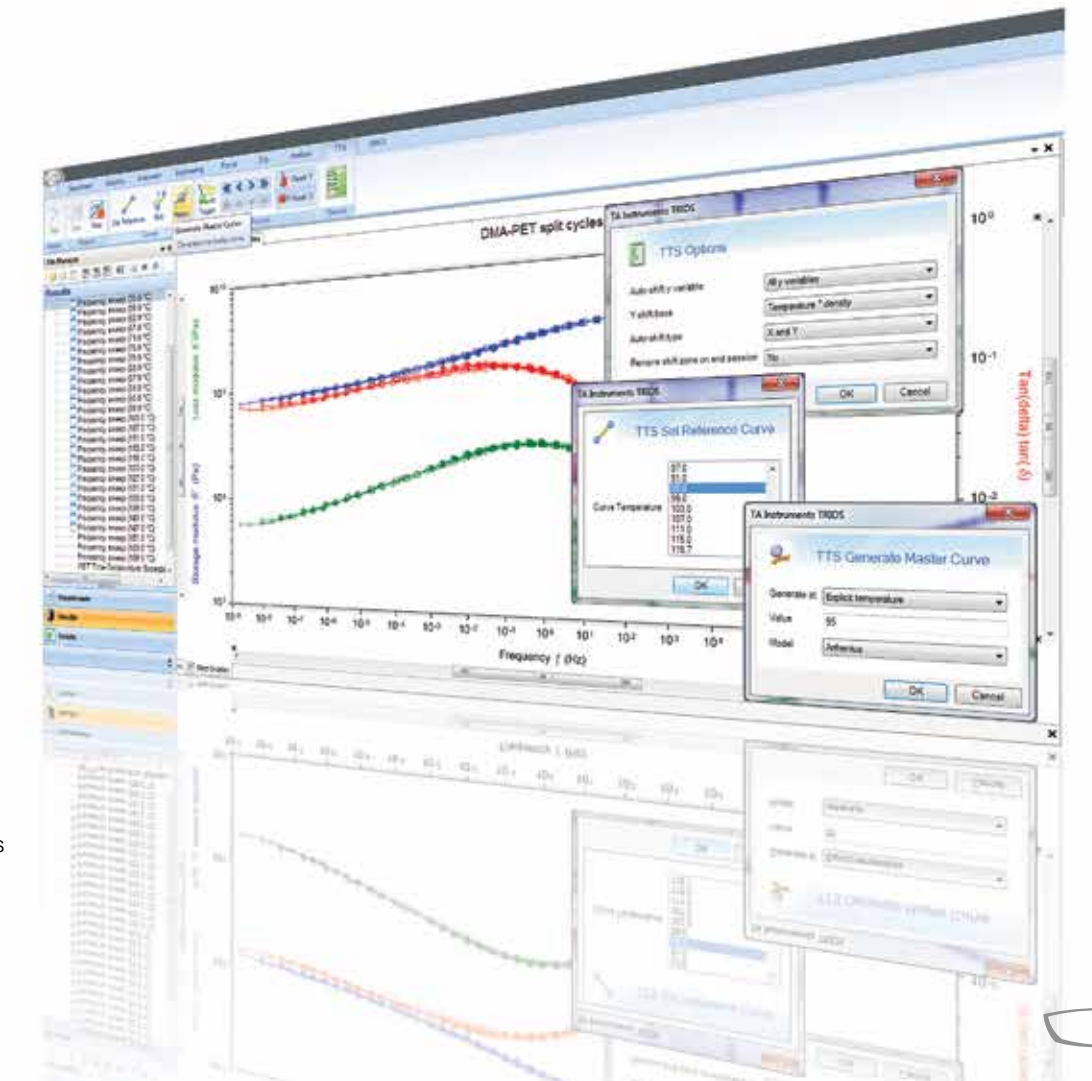
A comprehensive set of relevant tools are available for real-time data analysis, even during experiments. Gain actionable insights into your material behavior through a powerful and versatile set of features seamlessly integrated into TRIOS.

### All Standard DMA Analyses:

- Onset and endset analysis
- Signal maximum and minimum
- Signal change
- Modulus crossover
- Curve values at specific X or Y points
- 1st and 2nd derivatives
- Area under the curve
- Peak height
- Peak integration, and running integral
- Mathematical fitting: straight line, polynomial, or exponential

### Advanced Analysis Capabilities:

- Time-Temperature Superposition (TTS) analysis with automatic curve shifting and simple Mastercurve generation
- Activation Energy calculation
- WLF coefficient calculation
- Cole-Cole and Van Gorp-Palmen plots
- Built-in models for: relaxation spectra, interconversion of moduli, and creep ringing analysis
- Advanced custom analysis with user-defined variables and models



## Experimental Design

The DMA 850 is controlled by powerful TRIOS instrument control and data analysis software featuring a revolutionary new multi-level test programming interface. The *DMA Express* interface empowers novice users by making DMA programming simple and accessible, while the *DMA Unlimited* interface removes testing limitations allowing advanced users unprecedented flexibility in experimental design. With TRIOS Software, DMA experiments have never been so simple and powerful.

## DMA Express

The new *DMA Express* interface is designed specifically for new users and those with simple, well-defined experimental requirements. It presents test setup details in easy-to-choose, self-contained forms. The user is presented with all necessary testing parameters in a self-contained window, populated with sensible default starting parameters. For routine use and common test types, *DMA Express* shortens training time, reduces the possibility for mistakes in experimental design, and inspires confidence.

Test Mode	Available Tests
Oscillation	Frequency Sweep, Strain Sweep, Stress Sweep, Temperature Sweep, Temperature Ramp, Time Sweep, Temperature Sweep (Multi-frequency)/ TTS, Temperature Ramp (Multi-frequency), Fatigue Test
Stress Control	Creep, Creep-Recovery, Creep TTS, IsoStress
Strain Control	Stress Relaxation, Stress Relaxation TTS, IsoStrain
Rate Control	Strain Ramp, Stress Ramp

Oscillation
Temperature Ramp

Amplitude   $\mu\text{m}$

Frequency  Hz

Use current temperature

Ramp from   $^{\circ}\text{C}$  to   $^{\circ}\text{C}$

Ramp rate   $^{\circ}\text{C}/\text{min}$

Soak times

at Start temperature  min

at End temperature  min

Estimated time to complete 00:38:20 hh:mm:ss

Test Settings
Post Test Conditions

## DMA Unlimited

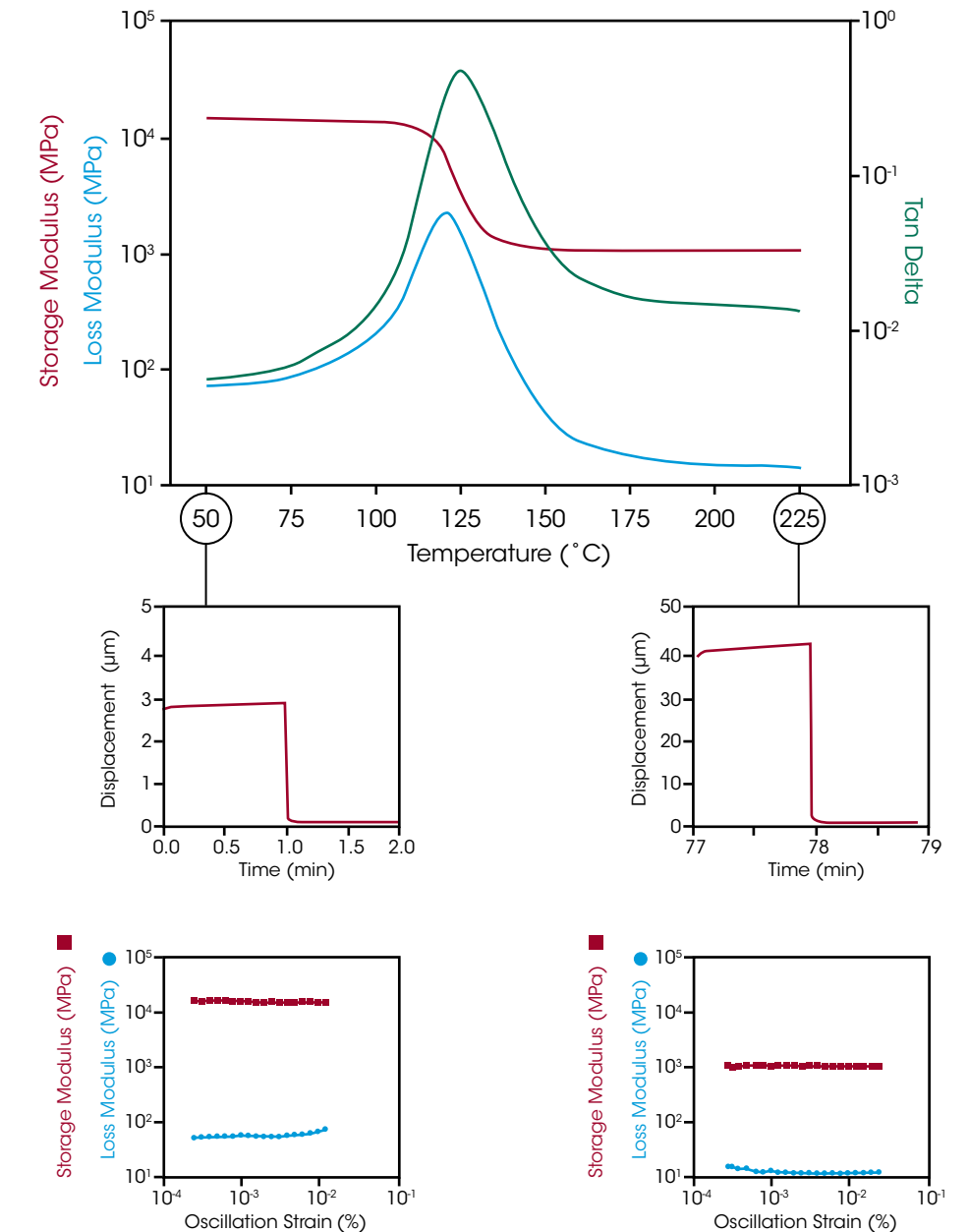
The *DMA Unlimited* interface delivers the DMA 850's powerful new capability to sequence **any and all** deformation modes and thermal profiles in a single test. Go beyond conventional DMA testing and program experiments that mimic complex real-world conditions through an unlimited combination of 23 available steps. Choose from the core *DMA Express* test modes plus advanced sample conditioning, deformation, conditional step termination, and repeat segment capabilities. The only limit is your imagination!

### Additional Experiment Controls:

- Equilibrate or Jump to a set temperature, set Soak time at target temperature
- Set or Increment Relative Humidity levels, set Soak time at target RH
- Set or Increment a Force/Stress
- Set or Increment a Displacement/Strain
- Loop and repeat previous steps
- Data storage On/Off, set data sampling intervals
- Control Motor State, set external events, refill GCA

### Unlimited Test Sequencing

The DMA 850's advanced system architecture opens up unprecedented mechanical testing possibilities that are not bounded by limitations inherent to conventional DMA instruments. For the first time, design test procedures that contain any combination of available test types including oscillation, transient, strain and stress control, mechanical and thermal conditioning, and more. With this new capability, the DMA 850 can perform a complete material characterization protocol under diverse test conditions in a single experiment, or apply mechanical conditioning immediately followed by characterization. This new capability unlocks complete material characterization under virtually any set of test conditions.



Creep recovery and strain sweeps before and after a temperature ramp.  
All data collected from a single experiment.

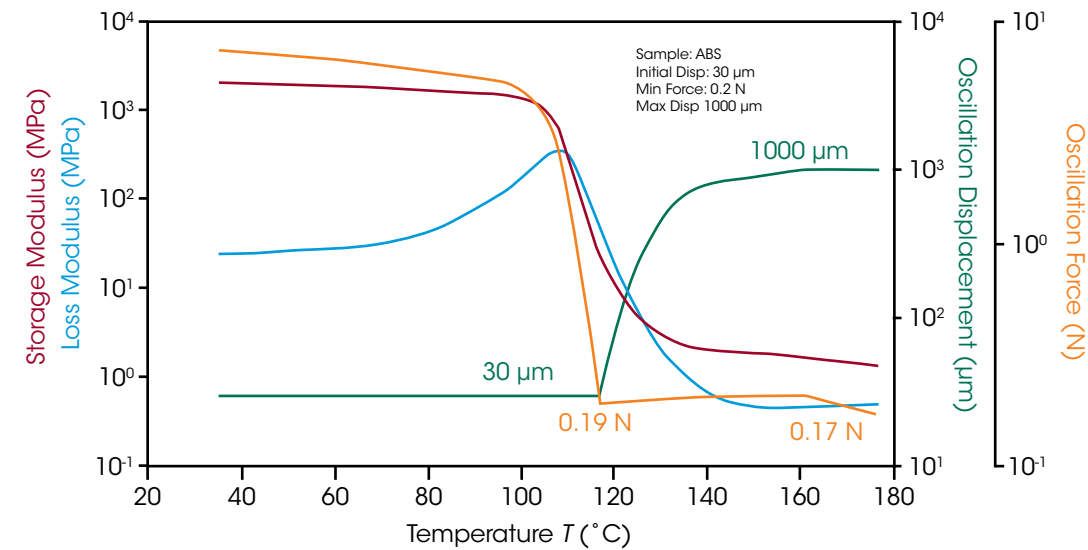


# ADVANCED CONTROLS

take your...

## NEW Intelligent Auto-Ranging

Because the modulus of a material can change by several orders of magnitude in a narrow range of time or temperature, the selection of programming parameters can make or break an experiment. If the deformation chosen is too large there could be excessive sample creep. If it is too small, force sensitivity suffers. The all-new intelligent Auto-Ranging feature takes the guesswork out of selection of starting conditions and ensures force and displacement are automatically maintained within reasonable user-defined limits. Program the experiment and walk away with the peace of mind that you will **get great data the first time, every time.**



# MATERIAL CHARACTERIZATION FARTHER

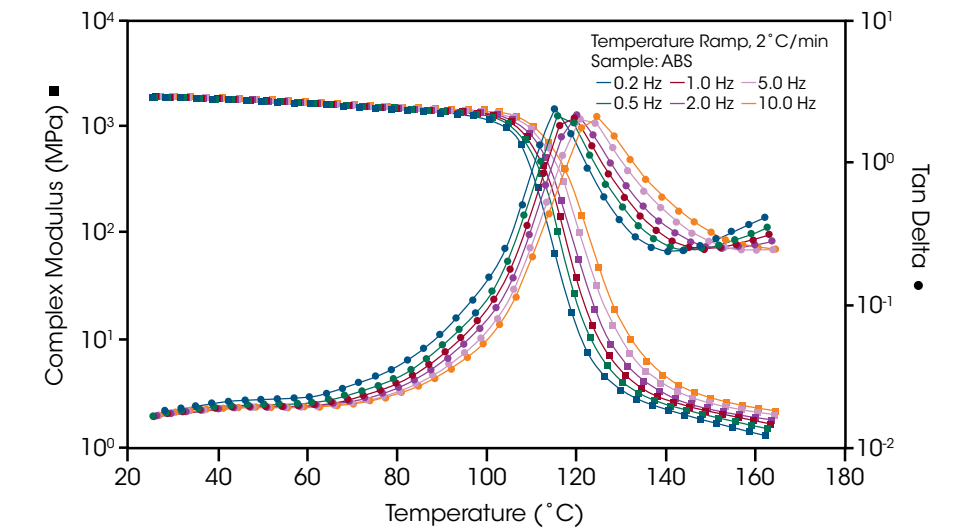
## NEW DirectStrain

Faster electronics, all new digital signal processor (DSP) controls, and an enhanced drive system allow for an all-new type of strain control in the DMA 850. DirectStrain is real-time strain control for faster and more accurate measurements of challenging samples and test conditions, such as rapidly changing materials or soft specimens at high frequencies. DirectStrain guarantees consistent data collection even during transitions on quickly changing samples and a **50x improvement in strain accuracy** over conventional DMA technology.

In this example, the use of DirectStrain allowed for modulus at  $\tan \delta$  at **six frequencies** to be measured in a single experiment at a ramp rate (2°C/min) that is typical of single-frequency temperature ramps.

### Benefits of DirectStrain include:

- Real-time strain control for fast and accurate measurements
- 50x improvement in strain accuracy
- 35% improvement in measurement speeds
- No overshoots or undershoots that are typical of iterative control methods
- Improved accuracy for soft specimens at high frequencies
- Uniform data collection even at fast ramp rates



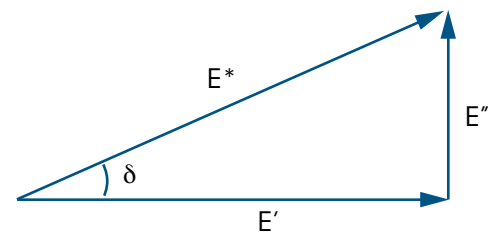
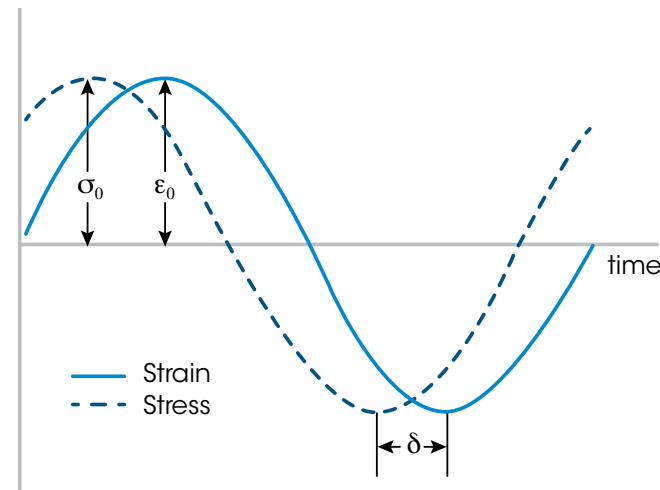
### Dynamic Mechanical Analysis

Dynamic Mechanical Analysis (DMA) is used to evaluate the mechanical properties of materials, often as a function of environmental factors such as temperature, time, or humidity. The most commonly measured mechanical property for simple elastic materials is the stiffness, or Young's Modulus,  $E$ . However, more complex materials like polymers and composites cannot be well-described by this value alone. These materials exhibit elastic as well as viscous, or damping, behavior, and so are described as viscoelastic.

The most commonly useful test protocol for measuring viscoelastic properties is small-amplitude oscillation. In this group of methods, a sample is deformed according to a sinusoidal deformation profile at a fixed frequency and amplitude (strain) while the force with which the sample resists deformation (stress) is measured\*. The information collected in this experiment is used by the control software to produce a host of important material properties that describe the overall resistance to deformation (complex modulus), as well as the individual elastic (storage modulus) and viscous (loss modulus) components of that resistance. Oscillatory experiments are often used in conjunction with temperature profiles to characterize thermal events such as the glass transition, melting, crystallization, curing, and aging.

The viscoelastic properties of a material are often a function of the observation time, or test frequency,  $f$ , reflecting the tendency of many materials to relax if given sufficient time to do so. For this reason, it is often important to collect accurate data over a range of test frequencies to adequately describe a material's behavior.

At small test amplitudes, the viscoelastic properties are independent of strain. This region of deformation, known as the linear viscoelastic regime, most directly reflects molecular structure and is predictive of overall product performance. For some materials, this linear viscoelastic regime can be quite small, especially in the case of filled or crosslinked networks. For this reason, the control of very small deformations is critical to obtaining meaningful, reproducible, actionable results.

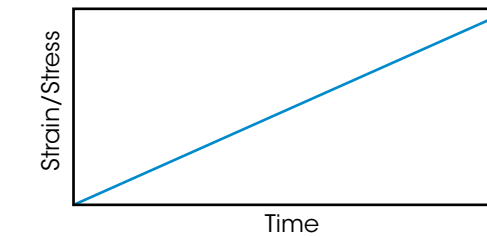


$\epsilon_0$	Strain amplitude
$\sigma_0$	Stress amplitude
$\delta$	Phase angle
$E^* = \sigma_0 / \epsilon_0$	Complex Modulus <i>Total resistance to deformation</i>
$E' = E^* \cos \delta$	Storage Modulus <i>Elastic, solid-like resistance</i>
$E'' = E^* \sin \delta$	Loss Modulus <i>Viscous resistance, damping</i>
$\tan \delta = E'' / E'$	Damping factor <i>Relative amount of damping vs elastic resistance</i>

\* The Discovery DMA 850 can control equally well in strain or stress control and the measured material properties are identical.

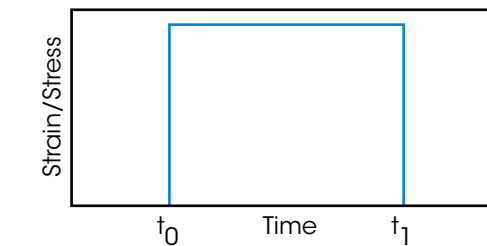
### Additional Test Modes

In addition to oscillation experiments, the DMA 850 can be used to program a full range of additional deformations that provide complimentary material characterization information or permit mechanical conditioning of materials. The new capabilities of the DMA 850 allow these deformation types as well as oscillation protocols to be programmed in a single experiment with any combination of test mode or control type.



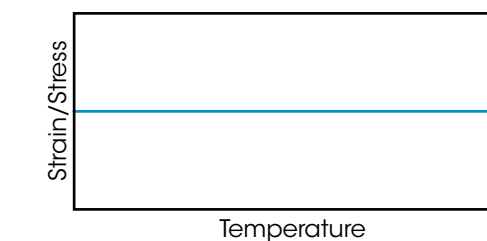
### Stress-Strain Curves

This classical experiment may operate in controlled force or strain, generating transient curves of stress and strain. These are often used to measure modulus and mechanical failure. They may also be used to impart a known strain or stress history on a material prior to dynamic characterization.



### Creep and Stress Relaxation

Transient experiments involve the instantaneous application of a stress (creep) or strain (stress relaxation). This stimulus is maintained while the sample deformation or stress is monitored. Transient experiments compliment oscillation protocols as a means of measuring viscoelasticity and are especially suitable for longer time relaxations. These protocols often simulate relevant application conditions and can be particularly helpful in replicating deformations that may be outside the linear viscoelastic regime. These transient steps are often followed by a relaxation step that reveals the degree to which the observed deformation was reversible or irreversible.



### Isostress and Isostrain

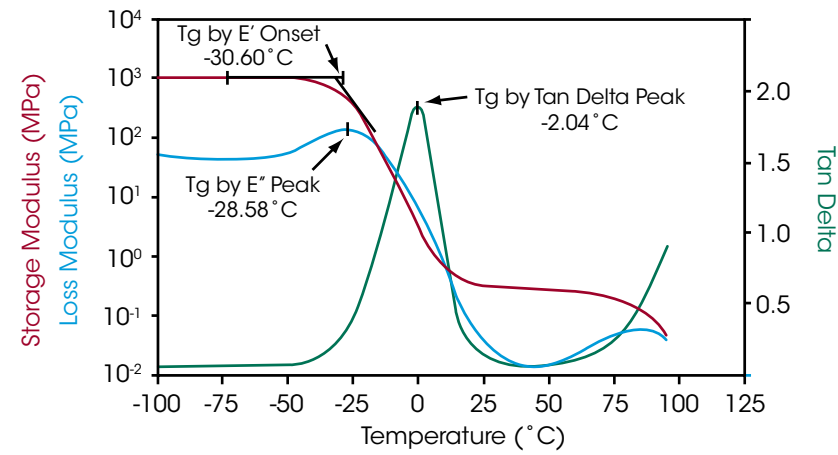
Isostress and isostrain experiments maintain a constant deformation on a specimen while the sample is heated or cooled. These experiments are used to measure the shrinkage or relaxation processes that occur through thermally-initiated transitions.

### Typical properties and behaviors measured by the DMA 850 include:

- Modulus of Elasticity ( $E$ )
- Modulus of Rigidity ( $G$ )
- Complex Moduli ( $E^*, G^*$ )
- Storage and Loss Moduli ( $E', E'', G', G''$ )
- Damping Properties ( $\tan \delta$ )
- Glass transition
- Secondary Transitions
- Melting and crystallization
- Softening
- Relaxation behavior
- Frequency Effects
- Creep and Recovery
- Stress Relaxation
- Time-Temperature Superposition (TTS)
- Viscous flow
- Dynamic Fatigue
- Impact Strength
- Toughness
- Resiliency
- Stress-strain Curves
- Shrink Force
- Composites
- Composition of blends
- Phase Separation (Polymer Blends, Copolymers, ...)
- Material defects
- Effects due to fillers
- Orientation Effects
- Effects of Additives
- Aging (physical or chemical)
- Gelation
- Crosslinking Reactions
- Crosslink Density
- Mullins Effect

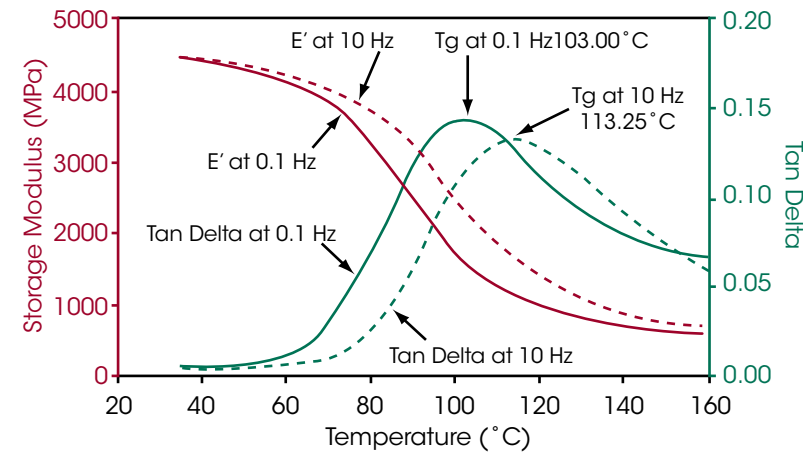
### Measurement of Tg of Polymeric Materials

A common measurement on polymers is the glass transition temperature, Tg. It can be measured with various techniques, but DMA is by far the most sensitive. The figure to the right shows a scan of a pressure-sensitive adhesive run in the tension clamps at a frequency of 1 Hz. Tg can be measured by the E' onset point, by the E' peak, or the peak of Tan δ. In addition to the Tg, the absolute value of the various viscoelastic parameters is also useful.



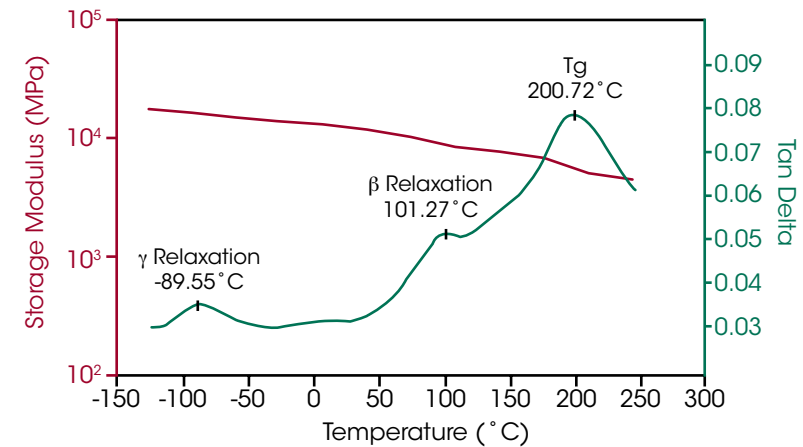
### Frequency Effect on Modulus and Glass Transition of Polyethylene Terephthalate (PET)

Because the Tg has a kinetic component, it is strongly influenced by the frequency (rate) of deformation. As the frequency of the test increases, the molecular relaxations can only occur at higher temperatures and, as a consequence, the Tg increases at higher frequency as illustrated to the right. In addition, the shape and intensity of the Tan δ peak as well as the slope of the storage modulus in the transition region will be affected. Based on end-use conditions, it is important to understand the temperature and frequency dependence of transitions.



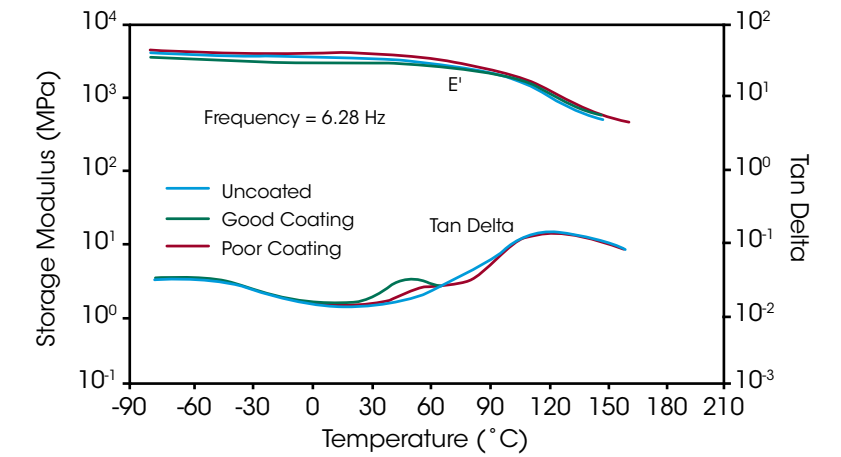
### The Measurement of Secondary Transitions in Vinyl Ester

DMA is one of the few techniques sensitive to β and γ secondary transitions. Secondary transitions arise from side group motion with some cooperative vibrations from the main chain as well as internal rotation within a side group. The transitions are below the Tg and typically subambient. They are very important as they affect impact resistance and other end-use properties. This data was generated using 3-point bending and also illustrates the ability to run stiff composites.



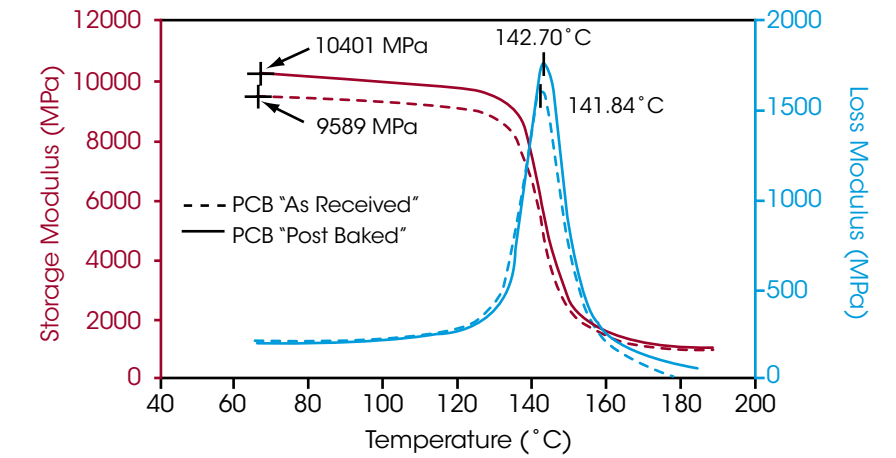
### Measuring Effect of Adhesive Coatings on Films

This figure shows a comparison among three PET samples in tension on the DMA; one with a uniform adhesive layer that performs well, one with a non-uniform layer that performs poorly, and one that is uncoated. A transition peak due to the adhesive is seen in tan δ around 40°C in the "good" sample, whereas the "poor" sample shows a much smaller peak. Knowing the characteristics of good and poor samples enables quality control of the coating process and the finished product.



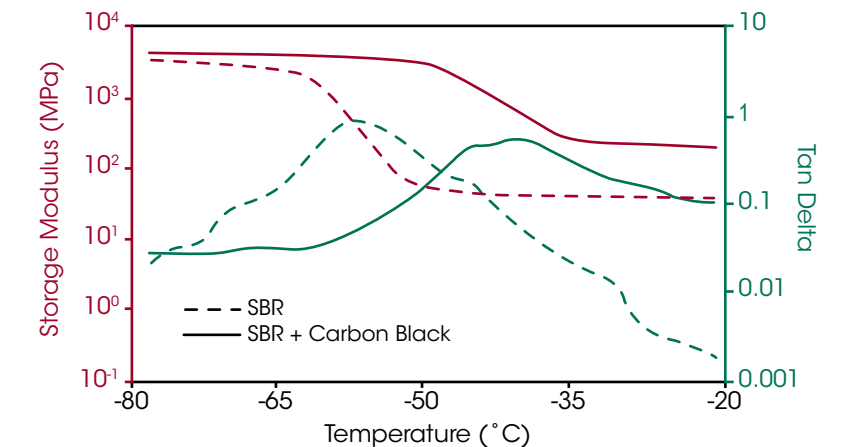
### Characterizing Printed Circuit Boards

Printed Circuit Boards (PCB) are typically comprised of fiberglass braid impregnated with a thermosetting resin. Characterizing the Tg of PCBs is often difficult due to the very low amount of resin used. This figure shows a typical PCB run in single cantilever bending. The Tg is clearly discernible and the difference between the sample "as received" and "post baked" clearly shows the effect that further crosslinking has on both the Tg and the absolute value of modulus.



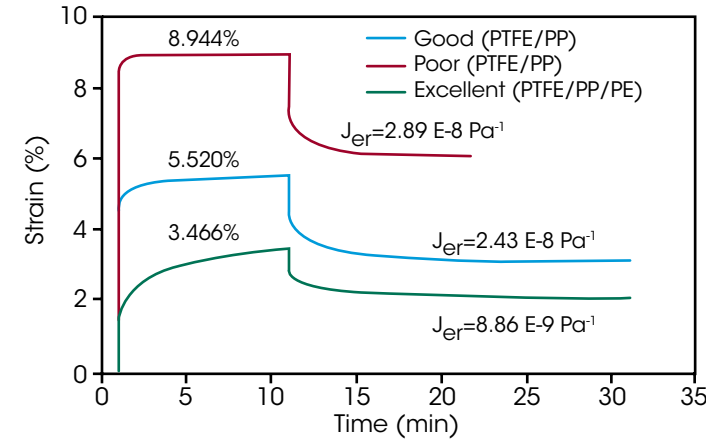
### Effect of Carbon Black in Elastomers

Another very common application is the effect of fillers and additives on viscoelastic properties. The figure to the left illustrates the effect on storage modulus (E') and tan δ when adding carbon black to an SBR rubber. This test, performed in dual cantilever on the DMA, shows that adding carbon black increases the absolute value of the storage modulus and significantly increases the Tg temperature. Understanding how fillers and additives affect material properties is crucial in many industrial applications.



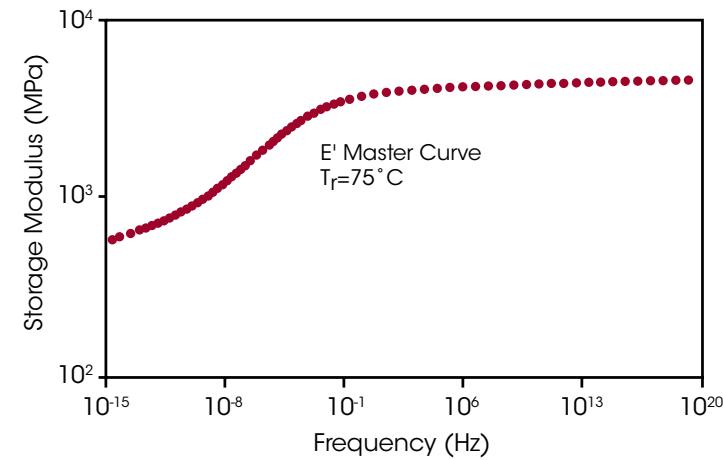
### Characterizing Packaging Films Using Creep

In a thermoforming process, a film is pulled down into a heated mold to form a desired shape. The ability to produce a stable product can be predicted by using a creep-recovery experiment. This figure illustrates data on a packaging film using the tension mode. In the recovery phase, the equilibrium recoverable compliance, ( $J_{er}$ ) can be calculated. If the sample compliance is too high, as observed by a high  $J_{er}$ , then the elasticity may be too low at the forming temperature to maintain the desired shape.



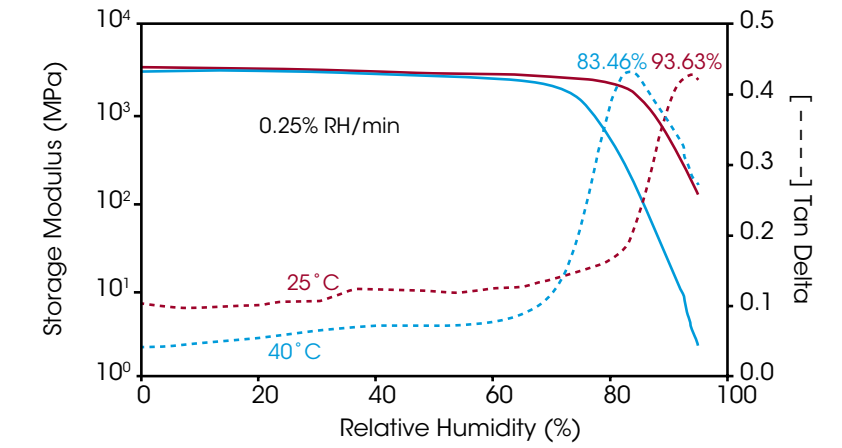
### Predicting Material Performance Using Time/Temperature Superpositioning (TTS)

The TTS technique, well-grounded in theory, is used to predict material performance at frequencies or time scales outside the range of the instrument. Data is usually generated by scanning multiple frequencies during a series of isothermal step-hold experiments over a temperature range. A reference temperature is selected and the data shifted. A shift factor plot is generated and fit to either a Williams-Landel-Ferry (WLF) or Arrhenius model. Finally, a master curve at a specific temperature is generated as illustrated to the right for a PET film sample. Using this technique, properties at very high frequencies (short time scales) or very low frequencies (long time scales) can be assessed.



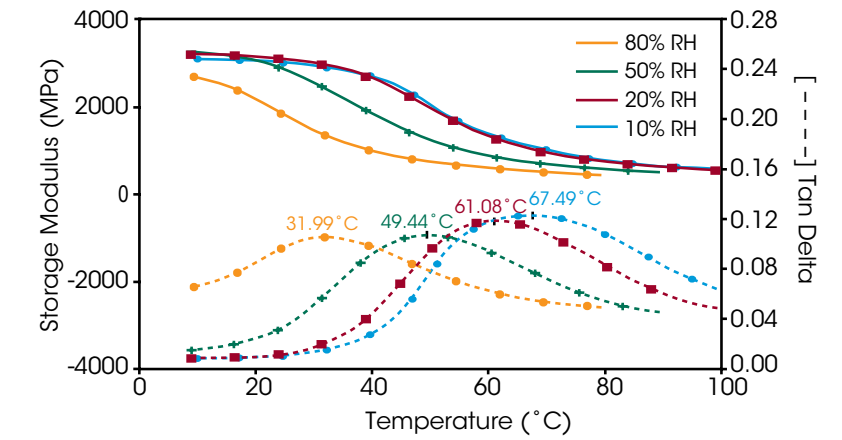
### Analysis of a Pharmaceutical Gelatin Capsule

Gelatin capsules are widely used in the pharmaceutical and dietary supplement market. When stored in an ambient, low-humidity environment, gelatin is remarkably stable. However, when combined with water, gelatin forms a semi-solid colloid gel which can profoundly affect its mechanical properties. The data in this example illustrate the effect of increasing relative humidity on a gelatin sample cut from the side wall of a two-piece capsule at 25°C and 40°C. As the relative humidity is increased, the material undergoes a multi-step transition resulting in a significant decrease in modulus near 80% RH. The transition is resolved in both the storage modulus and  $\tan \delta$  signals.



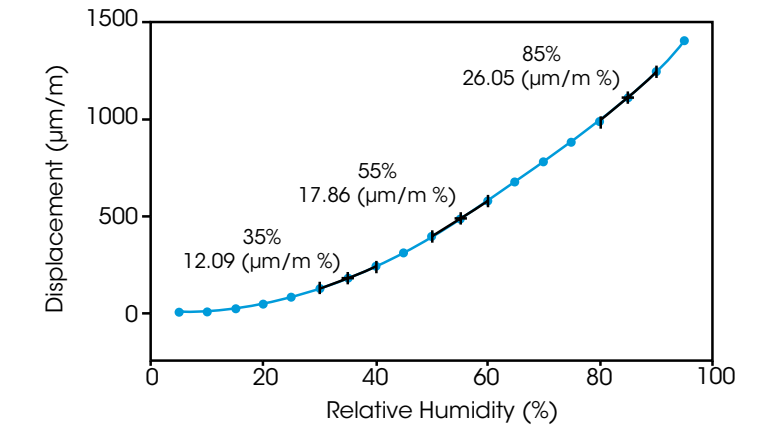
### Effect of Relative Humidity on the Glass Transition of Nylon 6

Nylon 6 is strongly plasticized by water; as such the mechanical properties will be dependent on the surrounding relative humidity. The data in this figure demonstrate the effect of relative humidity on the glass transition of Nylon 6 as measured using the DMA-RH accessory. The sample was analyzed in single cantilever mode at a frequency of 1 Hz at a variety of constant RH conditions. Note how the mechanical properties and glass transition are significantly influenced by the imposed relative humidity.



### Measurement of the Coefficient of Hygroscopic Expansion (CHE)

Hygroscopy is defined as the ability of a substance to attract water molecules from the surrounding environment through either absorption or adsorption. The effect of moisture sorption on the mechanical characteristics of a material can be quantified by the Coefficient of Hygroscopic Expansion (CHE), the constant which relates the dimensional change of a material to a change in the surrounding relative humidity. The data in this figure show the effect of imposed relative humidity on the Nylon 6 sample as measured with the DMA-RH Accessory. As the relative humidity is increased the sample expands. The resulting slope of the line is equivalent to the CHE for the material.



Specifications	
Max Force	18 N
Min Force	0.0001 N
Force Resolution	0.00001 N
Frequency Range	0.001 to 200 Hz
Dynamic Deformation Range	± 0.005 to 10,000 µm
Strain Resolution	0.1 nm
Modulus Range	10 <sup>3</sup> to 3×10 <sup>12</sup> Pa
Modulus Precision	± 1%
tan δ Sensitivity	0.0001
tan δ Resolution	0.00001
Temperature range	Standard Furnace: -160 to 600°C RH Accessory: 5 to 120°C

Environmental System	Temperature Range	Heating/Cooling Rates	Purge Gas
Standard Furnace	-160 °C to 600 °C	20 °C/min Heating 10 °C/min Cooling	Air, nitrogen, argon, helium
DMA-RH Accessory	5 °C to 120 °C	± 1 °C/min	Controlled humidity 5% to 95% RH

Features	
Standard	Optional
TRIOS software including <b>DMAExpress</b> and <b>DMAUnlimited</b>	Standard Furnace
35 mm Single/Dual Cantilever Clamp	DMA-RH Accessory
Strain control including NEW DirectStrain	Tension Clamps
Stress control	3-Point Bend Clamps
Color App-Style Touch Screen	Compression Clamps
Unlimited test sequencing	Powder Clamp
TTS analysis	Shear Sandwich Clamp
Oscillation: Strain sweep, Frequency sweep, Temperature Ramp (Single, Multi-frequency), Temperature Step (Single, Multi-frequency/TTS), Time sweep, Fatigue	Submersion Clamps
Strain control: Stress relaxation, Stress relaxation TTS, IsoStrain	GCA
Stress control: Creep, Creep-Recovery, Creep TTS, IsoStress	NPC
Rate control: Strain ramp and Stress ramp to generate stress-strain curves	ACS-2 or ACS-3
Sample conditioning: temperature, applied force or displacement	TRIOS Guardian software for 21 CFR11 compliance



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