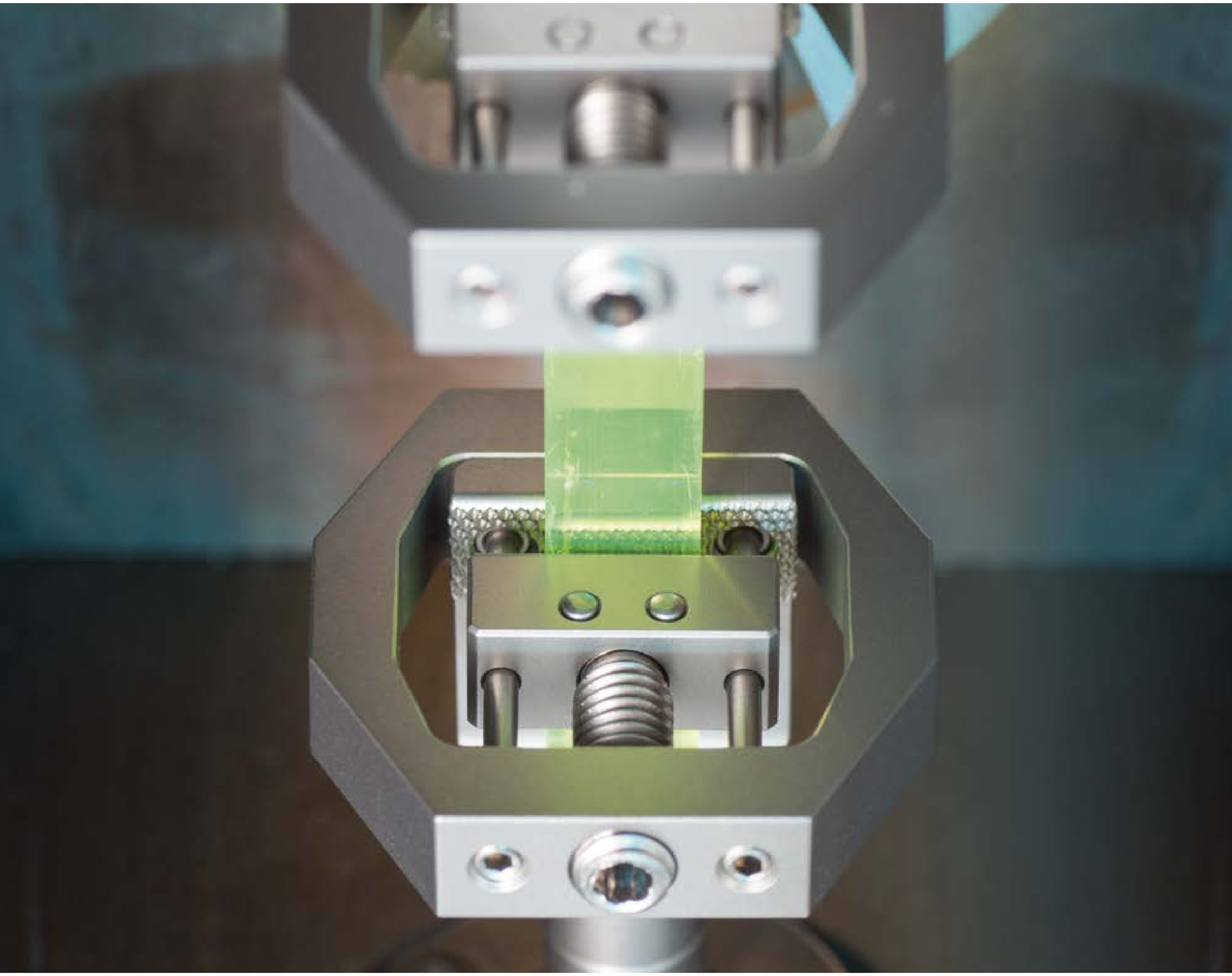
NETZSCH

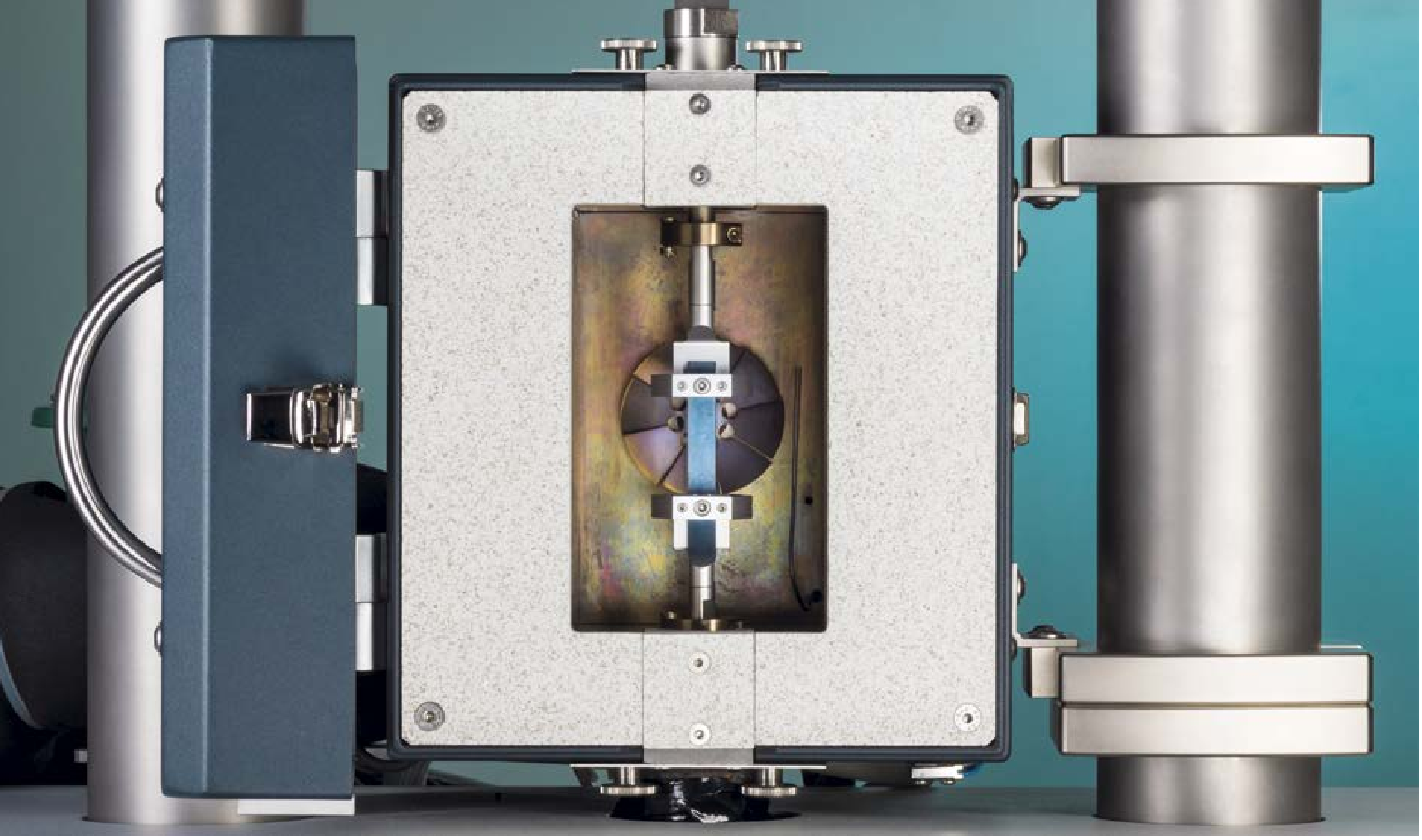
Proven Excellence.



High-Force DMA GABO EPLEXOR® Series up to ± 500 N

Dynamic Mechanical Testing Systems

Analyzing & Testing



Smart Material Testing

UP TO HIGH FORCES

More than 40 years of experience in R&D for premium-quality dynamic mechanical analysis

Successful introduction of materials and products onto the market is always preceded by a great deal of testing to determine suitability in day-to-day applications. Temperature, time, frequency, load level and other parameters change the visco-elastic properties of polymers and composites.

- How are your products influenced by different temperatures or moistures?
- How do the material properties depend on mechanical loading or different frequencies?
- What is the lifetime of the material under extreme stress conditions (cycling, hysteresis, etc.)?

NETZSCH instruments can answer these questions and more using our trend-setting technology in the field of material development and design. Our product line – designed by experts for experts – offers cost-effective and competitive solutions for nearly any experimental task.

The DMA GABO EPLEXOR® instrument series is in line with a variety of standards including DIN 53513, ISO 6721/1, ISO 6721/4, ISO 6721/5, ISO 6721/6, ISO 4664, ASTM D4065, and ASTM D4473.

Dynamic Mechanical Analysis

The Dynamic Mechanical Thermal Analyzer applies forced periodic loads to the sample and analyzes the phase shift between this primary excitation and the material's response. The response of an ideal elastic system (e.g., spring) on a sinusoidal load at a given frequency is of the same frequency and exactly in phase with the excitation. The situation changes in a real system: A phase shift ($\delta > 0°$) between the primary excitation and response of the same frequency occurs in the case of linear visco-elastic materials (e.g., polymers); see figure 1.

Elastic and non-elastic properties inherently describe the dynamic mechanical performance of the material. The storage modulus E', the real part of the complex modulus E*, represents the elastic component; the loss modulus E'', the dissipated part, is the imaginary part. Depicted in the complex plane, the loss and storage modulus are the projections of the complex modulus onto the real and imaginary axis (figure 2). The tangent of the angle between the real axis and the complex modulus (E*) represents the phase shift (tanδ) between the two.

DMA Results

- Dynamic modulus
- Damping factor (tanδ)
- Young's (static) modulus
- Frequency dependence
- Temperature dependence
- Glass transition
- Secondary transition
- Master curve
- Hysteresis representation
- Relaxation and retardation
- Creep testing
- Aging behavior
- Fatigue test
- Predictive testing
- Durability test
- Impact test
- Immersion test
- Tests under UV light
- Tests under controlled humid atmosphere
- Thermal expansion

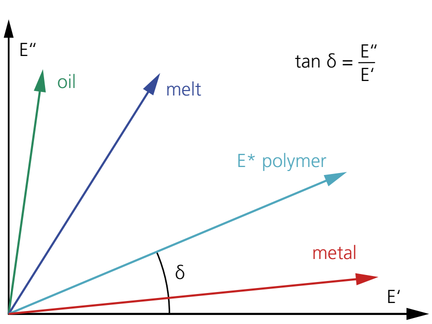


Figure 1: Visco-elastic properties in the complex plane; various material classes exhibit significant differences in phase shifts

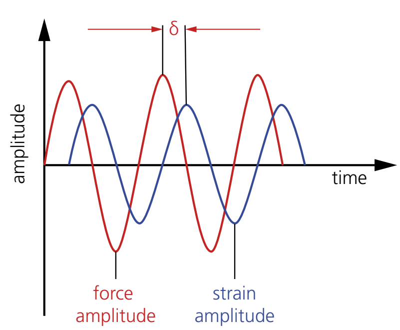


Figure 2: Measured parameters: damping (δ), force and strain amplitudes

DMA GABO EPLEXOR® Series

MODULAR DESIGN

The DMA GABO EPLEXOR® high-force systems allow for a variety of upgrades – addressing tomorrow's tasks today!

– ALL SET FOR THE FUTURE

Set for the Future

The DMA GABO EPLEXOR® series allows for easy upgrading of the system with a variety of force, sensors and strain extension as well as furnaces. For non-stop operation, a fully automatic sample changer is available. The different DMA GABO EPLEXOR® versions are operated without a hydraulic pump system – thus providing energy-efficient operation.

Results-Oriented Tailoring of Force Range

This one-of-a-kind DMA system offers the ability to install different force sensors to meet individual users' needs, with a maximum force range from ± 10 N to ± 2500 N. All instruments offer static forces up to 1500 N. The maximum dynamic force for the most powerful instrument is ± 500N. This allows for application of the best possible conditions in order to optimize results. With the high-force sensors, for example, the entire application range of rubber and elastomer materials can be investigated under compression or tension – even below the glass transition temperature. These force sensors can be changed out easily with a minimum of effort.

Two Independent Drives for Static and Dynamic Force

The DMA GABO EPLEXOR® system is the only DMA system on the market with two independent drives for static and dynamic force. The system works fully automatically and offers high precision in position measurement over a broad working distance.

Wide Deformation Range at High Resolution

Strain is accurately measured by two contactless optical sensors. This allows nanometer resolution throughout the entire range of up to 60 mm static displacement and up to ± 6 mm dynamic amplitude.

IMMERSION & HUMIDITY
UV ACCESSORY
VERSATILITY OF SAMPLE HOLDERS
FUTURE-PROOF
REAL-TIME OPERATION
EXTENSION OF FORCE RANGE
DIGITAL SHAPE GENERATOR
BROAD TEMPERATURE RANGE
INTERCHANGEABLE FORCE SENSORS
LINEAR AND NON-LINEAR MECHANICAL CHARACTERISTICS
OPTICAL SENSOR TECHNOLOGY
NANOMETER RESOLUTION
AUTOMATIC SAMPLE CHANGER
TWO INDEPENDENT DRIVES
MULTI-PURPOSE SAMPLE CHANGER
WIDE DEFORMATION RANGE
FATIGUE TESTS & TENSILE TESTS
UNDER HIGH SAFETY
HIGH MECHANICAL STIFFNESS

First-Rate Performance via Stiff Frame

Unique by Virtue of Real-Time Operation and Digital Signal Generator

The DMA system allows for real-time operation. The quasi-continuous frequency range with high data acquisition rate allows for operation between 0.001 Hz and 100 Hz. Frequency sweeps with high detection sensitivity are suitable for detecting even weak transitions and can be taken for master curve generation. The frequency range can be extended (0.0001 Hz; 200 Hz).

The optional digital signal processor for conventional and pulse DMA is a prerequisite for generating excitation signals of various shapes including pulses by harmonic synthesis. Predefined signal shapes (e.g., rectangular, saw tooth, Hanning, Hamming, Blackman, Blackman-Harris, or user-defined shapes) can be generated by optional software tools*.

* Please contact your local representative for more information

Perfect Loading Flexibility Thanks to Two Independent Drives

Static and dynamic force can be actuated independently. The static force is realized by a servo motor; the dynamic force is generated by an electrodynamic shaker system. Therefore, high static forces on the specimen can be generated by deforming the sample against the blade springs and not against the shaker system.

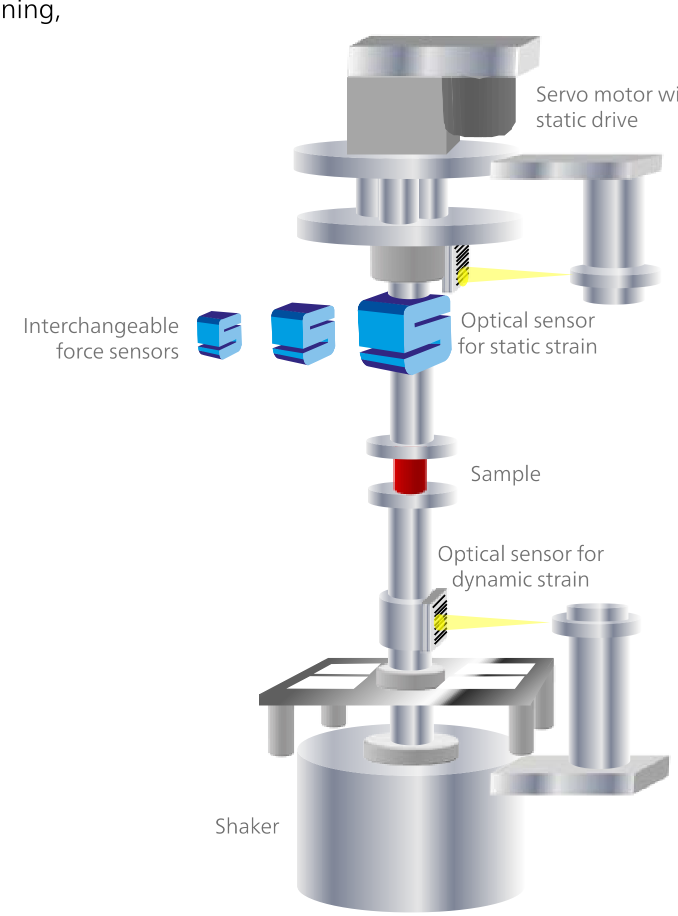


Diagram of the EPLEXOR®: Force sensors are interchangeable.

and Real-Time Operation

High Stiffness for Reliable Testing

The DMA GABO EPLEXOR® series up to ± 500 N uses a very stiff frame which allows for direct compression measure-ments on solid samples below glass transition from -160°C upward in strain-controlled measurements. The low compli-ance enables investigations on stiff samples such as metals, ceramics and composites.

High-Safety Fatigue and Tensile Tests

Fatigue or tensile tests at high force levels are often destructive experiments. The shock absorption property provided through the unique blade spring system is very advantageous in such cases.

Linear and Nonlinear Mechanical Characteristics Under Application Conditions

The DMA GABO EPLEXOR® is the only DMA system on the market revealing both the linear and the nonlinear mechanical character-istics of materials under appli-cation conditions. Nonlinear material properties can easily be evaluated with Fourier transfor-mation and the method of hysteresis analysis (optional). All dynamic results (E', E'', tanδ) are supplied for linear and nonlinear sample excitation.

Broad Temperature Range for Extended Applications

You can choose between three different furnaces in the temper-ature range from -160°C to 1500°C.

UV Accessory

The DMA GABO EPLEXOR® testing machines can be equipped with a UV irradiation system. The UV intensity is frequency dependent (≈10 W/cm^2, source); the light guide has a transmission of approx. 80%. The UV unit is designed to operate in the temperature range between 0°C and 300°C.

OPEN THE DOOR FOR YOUR APPLICATION TASKS

A Variety of Sample Holders for Handling the Tasks of Today and Tomorrow

Any investigations, characterizations and quality control tests conducted on a material should be in line with its application. The results obtained via measurements which closely parallel real applications allow for more accurate appraisals of a material's true performance.

A variety of sample holders in standard geometries (e.g., bending, tension) are available, as well as in dedicated user-defined geometries. Immersion systems are also offered.

THE PERFECT SAMPLE HOLDER FOR ANY APPLICATION


Compression


Film tension


Fiber cord tension


3-point bending


Asymmetric bending

- Compression – large and small specimens
- Tensile-bars and strips with self-tightening mechanism
- Tensile-fiber and fiber cords
- Tensile-films
- 3-point bending
- 3-point bending up to 1500°C
- Asymmetrical 3-point bending – up to 1500°C
- 4-point bending
- Immersion holders – can be used with various sample holder systems
- Double shear
- Dual cantilever
- Combined DMA and DEA

4-point bending

Tension-immersion

Double shear

Dual cantilever

Dielectric dynamic-mechanical combination

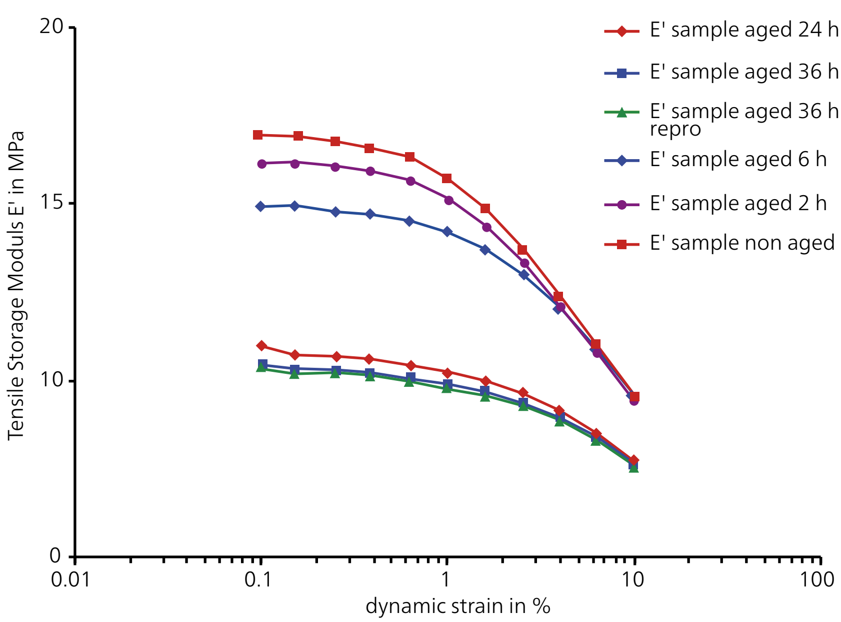
More Investigative Power through

IMMERSION & HUMIDITY – SIMULATION OF ENVIRONMENTAL INFLUENCES

Immersion for Testing Swelling Behavior and Other Effects

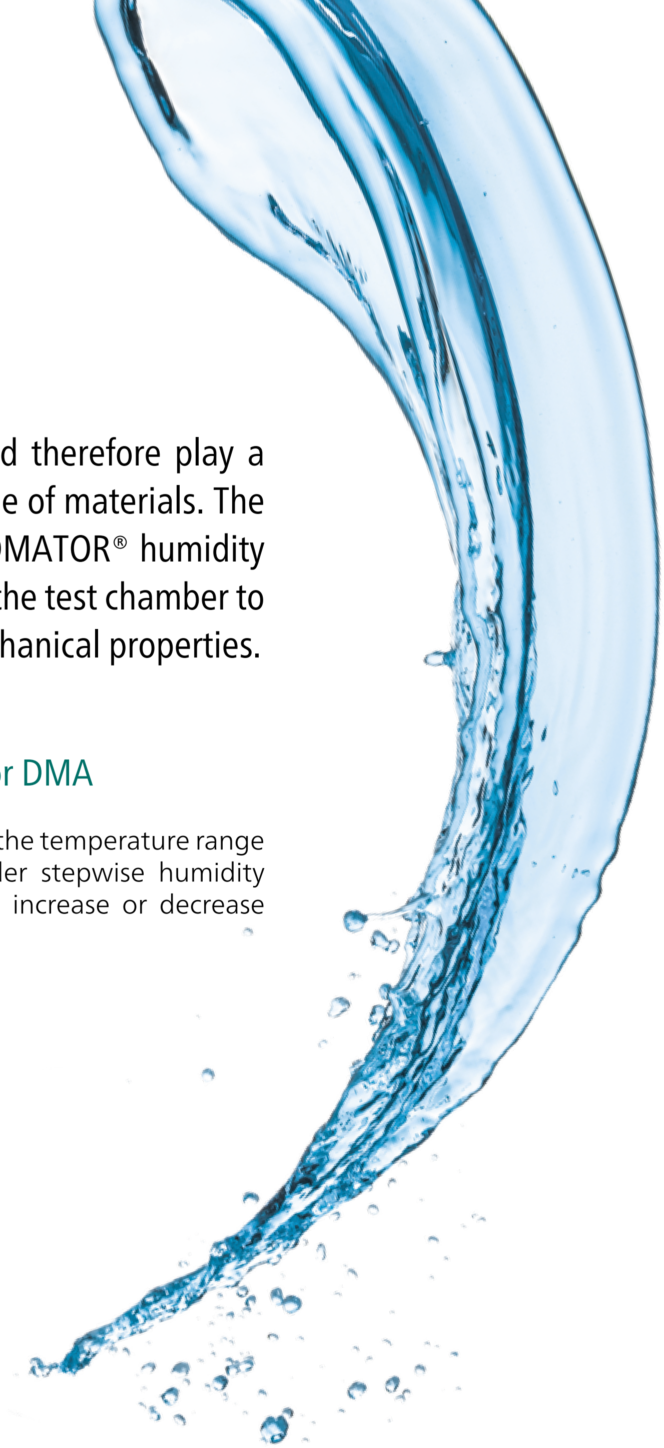
The immersion bath allows for measurements in a liquid such as water or oil in combination with sample holders such as those for 3-point bending tests (picture on the right) or tension tests (picture on the left), in cases where evaporation and decomposition temperature of the solvent or liquid are not an issue.

The plot below shows results of room temperature measurements on rubber carried out at a prestrain of 20% and a frequency of 10 Hz. Amplitude scans were applied after each aging step. It can be clearly seen that E' significantly decreases with immersion time.



Sample holder for tensile tests (left) and bending tests (right) in an immersion bath

Add-Ons



Environmental conditions may cause water uptake and therefore play a decisive role in manufacturing processes and the storage of materials. The DMA GABO EPLEXOR® in combination with the HYGROMATOR® humidity generator is able to create a humid environment inside the test chamber to reveal the influences of environmental humidity on mechanical properties.

HYGROMATOR® – The World's First Climate Chamber for DMA

The HYGROMATOR® can adjust humidity from 5% rH to 95% rH in the temperature range between 5°C and 95°C. Measurements can be performed under stepwise humidity variation. Alternatively, linear humidity ramps can be set up to increase or decrease humidity. Stabilized conditions are guaranteed for up to 24 h.

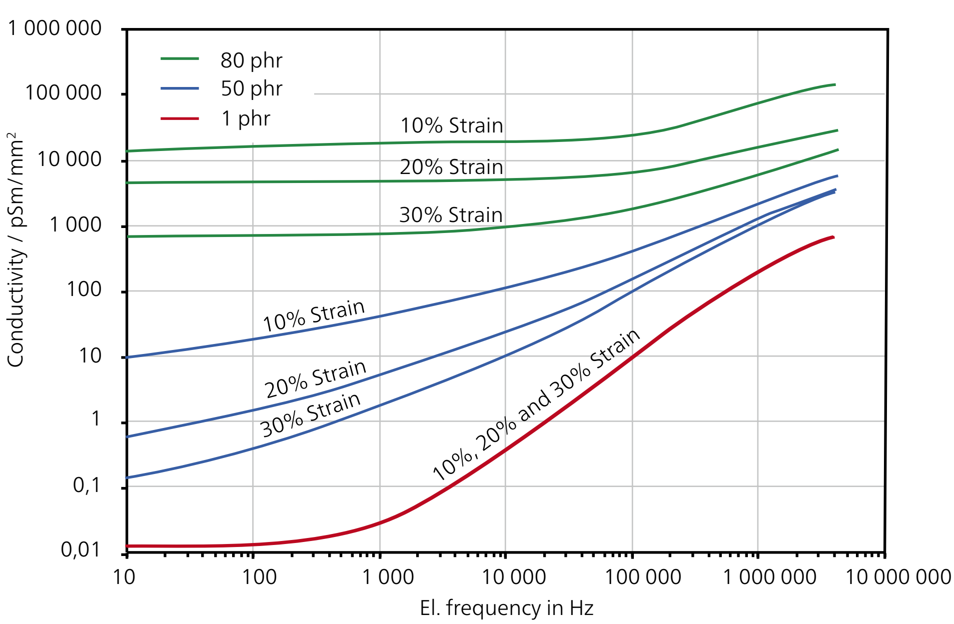
Humidity generator connected to the standard furnace. The HYGROMATOR® can be easily installed and dismounted. Any existing DMA GABO EPLEXOR® system can be retro-fitted.

DIPLEXOR® – SIMULTANEOUS DMA AND DEA

For the simultaneous determination of dielectric and mechanical properties, special sample holders and a dielectric controller are available for the DMA GABO EPLEXOR® systems. Dielectric analysis (DEA) explores the structure of a material by applying a sinusoidal voltage to two electrodes at a defined frequency.

In combined DMA-DEA measurements, the frequency ranges from 10^{-2} Hz up to 10^{7} Hz. The electrodes hold a solid dielectric specimen between planar capacitor plates. The tests are carried out in compression mode. An alternating current results "through" the specimen which is phase shifted across the capacitor. The complex dielectric function $\varepsilon^* = \varepsilon' - i\,\varepsilon''$ (ε^* = dielectric behavior) is calculated. The DIPLEXOR®* system is configured for combined DMA-DEA tests.

* DIPLEXOR® only registered in Europe



NBR samples with different levels of carbon black N550 content: 80 phr, 50 phr and 1 phr in compression mode at 25°C.

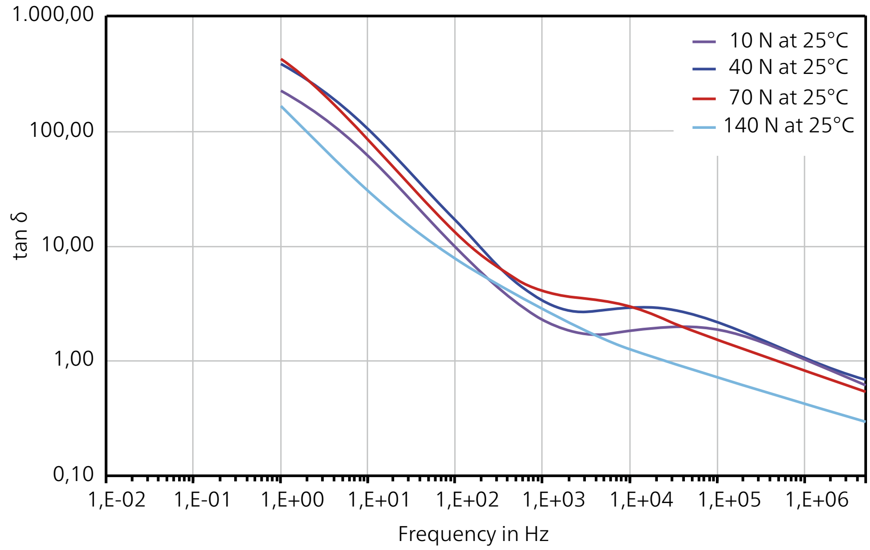
Influence of Carbon Black Content and Strain Amplitude on Conductivity

This plot shows DMA-DEA measurements on three HNBR samples with different levels of carbon black N550 content. Each sample was compressed by 10%, 20% and 30%. The conductivity increases with increasing carbon black filler content. However, it can also be observed that the conductivity decreases with increasing static deformation. In the case of a negligible carbon black content level (1 phr**), any filler-induced influences on the conductivity are lacking as there is no filler present. The situation changes at 50 phr carbon black. This concentration is closer to the percolation limit, as in the case of 80 phr carbon black. At 50 phr, the strain dependence of the conductivity is higher than at 80 phr carbon black.

**phr = parts per hundred rubber

Influence of Static Load at High Frequencies on EPDM

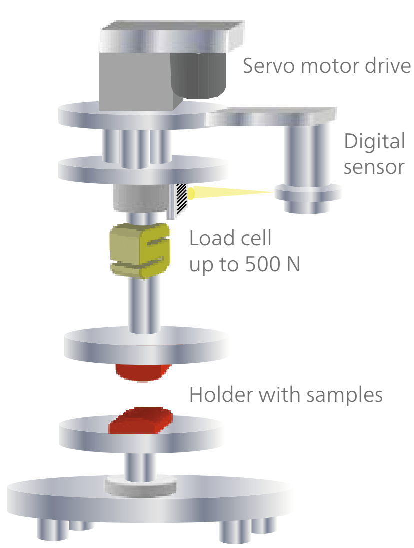
This plot shows force-induced shift in DMA-DEA measurements on EPDM with increasing static load from 10 N to 140 N at 25°C. At a static load of 10 N, a peak can be observed at a frequency of ≈70000 Hz. This peak moves to lower frequencies with increasing force applied and disappears at 140 N in the rising damping signal at lower frequencies.



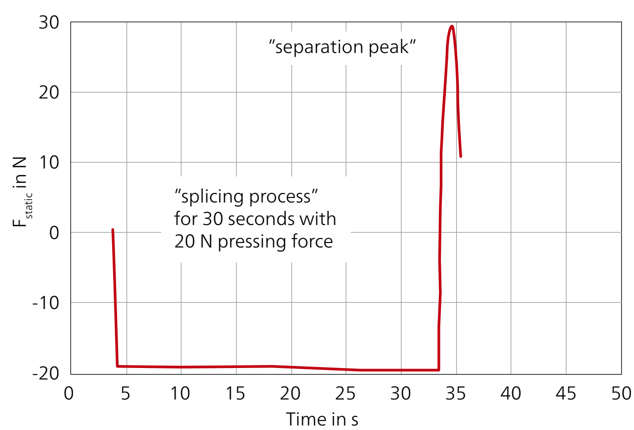
For DMA-DEA tests in compression mode, sample dimensions can be 2 mm in height with diameters of 10 mm to 25 mm.

TACKINESS EXTENSION

The tackiness extension for the DMA GABO EPLEXOR® and GABOMETER® uses a patented procedure for the reliable measurement of the peel force of two adhesive components.



Measuring principle of the tackiness extension



Contact adhesive of two unvulcanized rubber areas; normal force 20 N, duration 20 s

Application Range

Tackiness of "green tires", adhesives and paint layers.

Special Features

Adhesions are applied with a force of up to 500 N; adhesion forces are recorded with a resolution of 10 mN and up to 50 measuring points per second.

MEASUREMENTS IN PASSING

Any DMA GABO EPLEXOR® model can have the Automatic Sample Changer (ASC) or Multi-Purpose Automatic Sampler (MPAS) added on to create a fully automatic material testing system. These systems provide measurement results of the same levels of reproducibility and precision as would be the case with conventional sample change.

Our fully automatic testing systems allow for precise measurements and help you save money. Any DMA GABO EPLEXOR® system can be equipped with an Automatic Sample Changer (ASC) or Multi-Purpose Automatic Sample Changer (MPAS), featuring a material tester for up to 160 samples to be investigated from a single magazine.

Automatic Sample Changer Systems

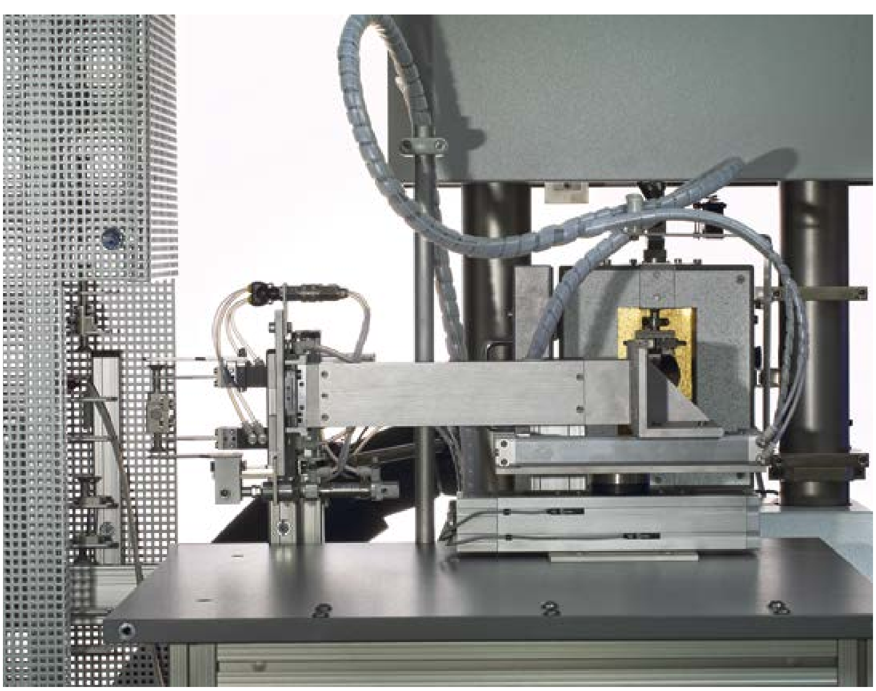
Always at Your Disposal!

Automatic Sample Changer

You can select your required samples in tensile, compression, shear, bending or cantilever geometry. The Automatic Sample Changer (ASC) sample supply system removes the samples from the magazine and places them into the temperature chamber at analysis position. All tests are run fully automatically. However, the user must choose the test geometry, install the corresponding gripper and start the system in the automatic mode.

Multi-Purpose Sample Changer

The Multi-Purpose Sample Changer (MPAS) – the most state-of-the-art sample supply system on the market – allows for tension, compression, shear, bending and single cantilever measurements in any order and without any mechanical intervention by the operator. Sample geometry and position in the magazine are at your disposition.



ASC gripper changing out the double shear sample holder

Ingenious Sample Change

The sample changer systems are capable of changing out either the entire sample holder (MPAS, all geometries) or just the sample (ASC).

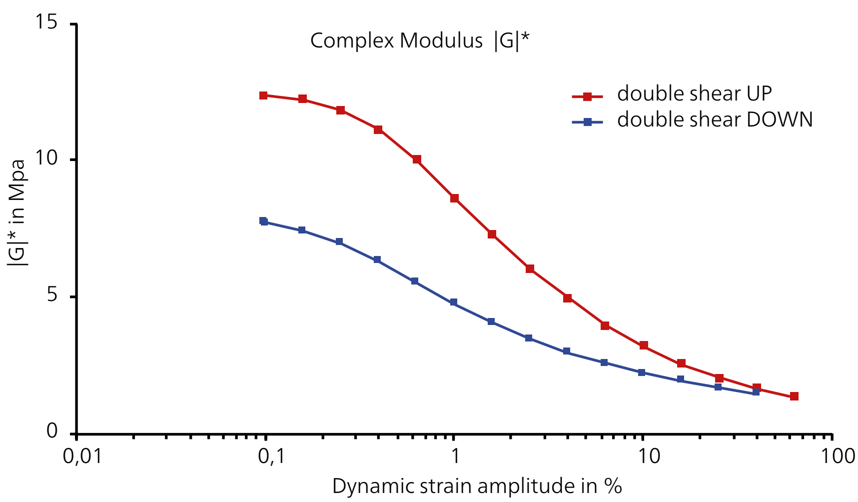
Specimens which are not fixated inside the sample holder, such as compression or bending samples, are handled individually.

However, in the case of firmly mounted specimens, the entire sample holder is replaced (see image at left).

APPLICATIONS

Payne Effect – Common Test for Rubber Materials

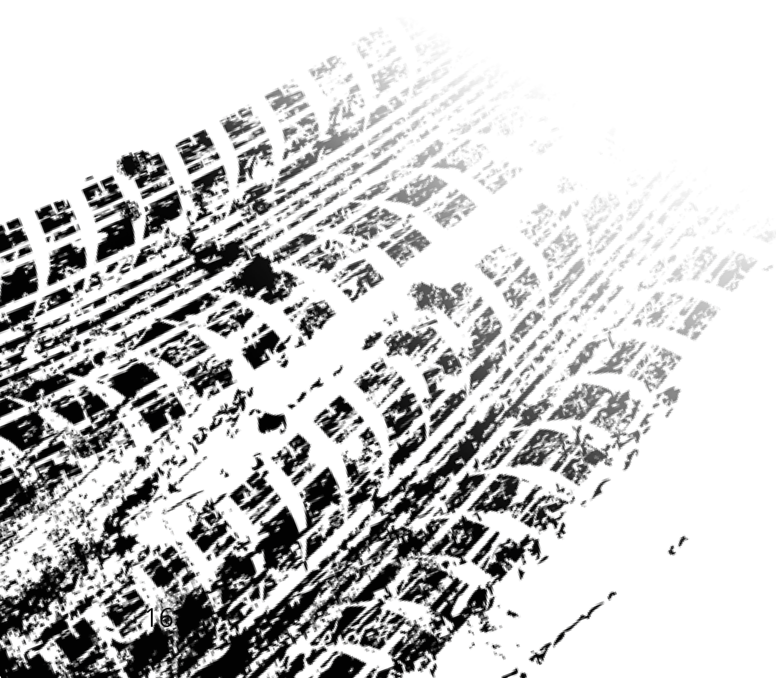
Both the Mullins and the Payne effect describe changes in elastomer properties as a function of strain. Increasing nonlinearity is observed with increasing strain amplitudes.



Filled elastomer in double shear mode

Filler-Filler Interactions

The Payne effect only occurs in filled elastomers and develops in the filler network. It causes a decrease in the storage modulus and is a function of such filler-filler interactions as the breakage of physical bonds between filler particles. Once the strain is released, this becomes a reversing effect after some time.
This plot shows the results of strain sweeps on a rubber material in double shear mode. The modulus decreases with increasing deformation due to the weakening filler-filler interactions.



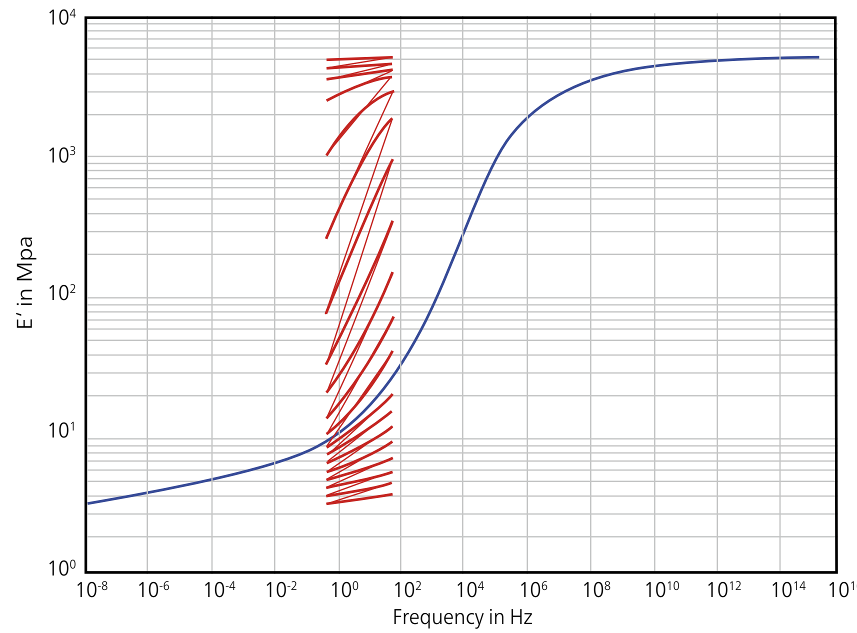
Mechanical properties at high deformation under realistic conditions

Multi-Frequency Sweeps for Master Curve Calculation

Master curve calculation extrapolates a material's properties to frequencies beyond the measurable range (0.001 to 200 Hz). This allows for improved investigation of the dynamic mechanical properties under realistic conditions.

Time-Temperature Superposition

Rubber applications often involve dynamic stress over a broad frequency range. Investigations of the frequency dependence of dynamic mechanical properties are therefore often used to provide data for the development of proper rubber compounds. This plot shows a multi-frequency test result of a rubber loaded in tensile mode. Using Time-Temperature Superposition (TTS; red dots), a master curve can be calculated (blue curve; per the Williams-Landel-Ferry equation).

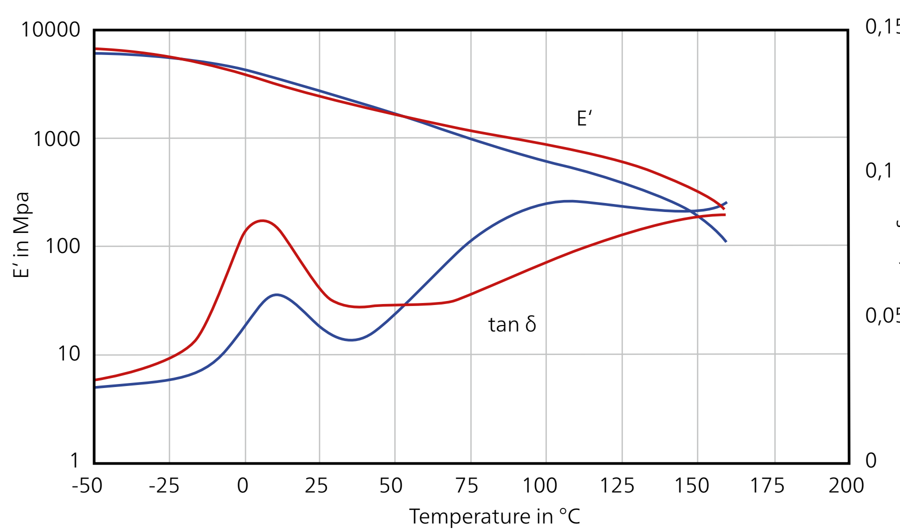


This measurement on a rubber material was carried out between -80°C and 80°C. At each 5 K interval, the temperature was kept constant and a frequency scan was performed from 0.5 Hz up to 50 Hz. Here, the frequency was extrapolated above GHz range.

Temperature Sweeps

Thermal Treatment of PP

Temperature sweeps are useful to analyze the visco-elastic behavior of a polymer before and after thermal treatment. This plot shows the storage modulus, E', and the visco-elastic damping, tanδ, as functions of the temperature of polypropylene. The damping behavior changes significantly due to the thermal exposure in the 1st sweep. The glass transition (peaks in tanδ curves) shifts slightly to lower temperatures and exhibits a higher damping peak. The tanδ shoulder between 50°C and 125°C disappears in the 2nd run.

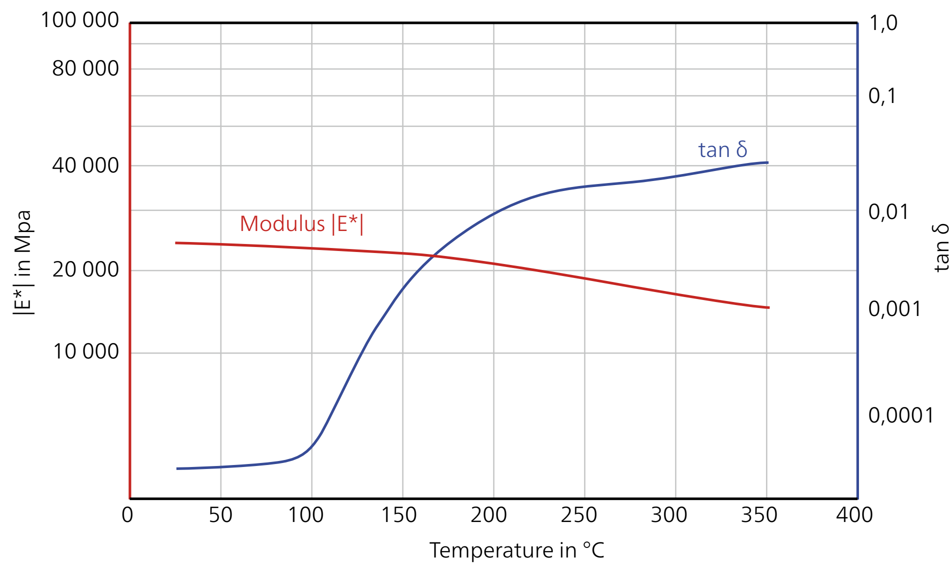


Here, temperature sweeps were performed in tensile mode. The 1st sweep (blue curves) is compared with the 2nd sweep (red curves). Static strain load amounted to 1%; dynamic strain load to 0.1%. The frequency was 10 Hz.

Lowest tanδ Values for Stiff Materials

Low Damping Behavior of Magnesium

This plot exhibits the temperature dependence of the complex modulus |E*| (red curve) and the damping behavior (tanδ; blue curve) of a magnesium sample. At room temperature, tanδ is extremely low (approximately 1.5-10^{-4}). Such low damping values, corresponding to a minimal phase shift between force and sample deformation, can only be realized with high-performance sensors which provide a high resolution to determine the phase shift.



Damping behavior of magnesium

Maintenance and Calibration

Do you have any questions concerning your applications? NETZSCH provides you with full support. All-inclusive maintenance and calibration are part of our after-sales service, as your perfect satisfaction with our top-class systems is of great importance to us.

Should you require more detailed information, please don't hesitate to contact us by phone, e-mail or fax.

Contract Testing

NETZSCH, of course, also provides contract testing services. Testing programs can be prepared upon request and tailored to customer needs.

Please contact us for further information.

We are looking forward to your questions!

Technical Specifications

DMA GABO EPLEXOR® Series up to ± 500 N				
	25 N	100 N	150 N	500 N
Dynamic force range	± 25 N (50 N)*	± 100 N (200 N)*	± 150 N (300 N)*	± 500 N (1000 N)*
Static force range	1500 N	1500 N	1500 N	1500 N
Dynamic strain	± 1.5 mm (3 mm)*	± 1.5 mm (3 mm)*	± 1.5 mm (3 mm)* Optional: ± 3 mm (6 mm)*	± 1.5 mm (3 mm)* Optional: ± 6 mm (12 mm)*
Static displacement	Up to 60 mm	Up to 60 mm	Up to 60 mm	Up to 60 mm
Frequency range	0.001 Hz to 100 Hz Optional ranges: 0.0001 to 200 Hz	0.001 Hz to 100 Hz Optional ranges: 0.0001 to 200 Hz	0.001 Hz to 100 Hz Optional ranges: 0.0001 to 200 Hz	0.001 Hz to 100 Hz Optional ranges: 0.0001 to 200 Hz
Temperature	RT to 500°C Optional**: -160°C to 500°C, RT to 1000°C/1500°C	RT to 500°C Optional**: -160°C to 500°C, RT to 1000°C/1500°C	RT to 500°C Optional**: -160°C to 500°C, RT to 1000°C/1500°C	RT to 500°C Optional**: -160°C to 500°C, RT to 1000°C/1500°C
HYGROMATOR® Optional	Humidity range: 5% rH to 95% rH; Temperature range: 5°C to 95°C	Humidity range: 5% rH to 95% rH; Temperature range: 5°C to 95°C	Humidity range: 5% rH to 95% rH; Temperature range: 5°C to 95°C	Humidity range: 5% rH to 95% rH; Temperature range: 5°C to 95°C
UV accessory	Optional	Optional	Optional	Optional

* Peak force (peak-to-peak)
** The high temperature options, 1000°C or 1500°C, can also be retrofitted to installed EPLEXOR® systems