

NETZSCH

Proven Excellence.



Thermal and Rheological Characterization of Polymers

Thermoplastics, Thermosets, Elastomers

Analyzing & Testing

Polymers – Materials that Shape Our World and Our Future

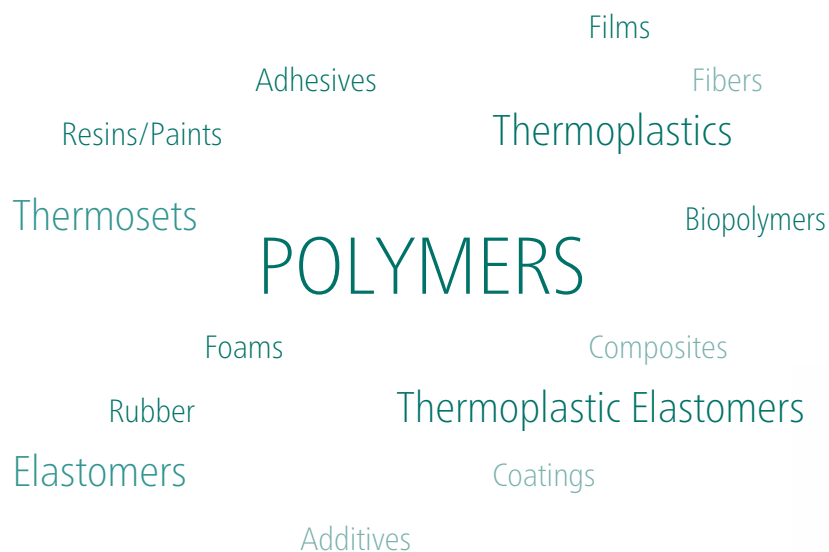
Polymer materials have revolutionized modern life – and they continue to do so. From packaging and electronics to mobility and medical technology, polymers are indispensable due to their versatility, functionality, and cost-efficiency. Today, however, the focus is not only on performance, but also on sustainability. The ability to recycle polymers, develop bio-based alternatives, and accurately characterize material properties is becoming essential for responsible innovation.

The plastics industry is undergoing a major transformation. Recyclates, bioplastics, and high-performance compounds are increasingly used in demanding applications – but with that comes the need for reliable testing and quality assurance. Understanding how a material behaves during processing, how it performs in use, and how it reacts under fire or environmental stress is more critical than ever.

Digitalization is unlocking new possibilities. With the rise of generative AI and machine learning, material data from thermal analysis, rheology, and fire testing can now be used to accelerate the development of new polymers, predict their performance, and optimize formulations before physical testing. These data-driven tools are transforming polymer design, enabling faster innovation cycles and smarter decisions across the value chain.

The widespread use of polymers is no accident. Their success is rooted in a unique combination of functional, economic, and environmental advantages.

With modern analytical tools and precise testing methods, we can not only improve existing materials but also unlock the full potential of the next generation of sustainable, AI-guided polymer innovations.



During their production, processing, and application, polymers are subjected to temperature- and time-dependent structural changes that influence their flow behavior, stability, and overall performance. To fully understand and control these effects, thermal analysis, rheology, and fire testing have become essential tools in both industrial and research environments.

These analytical techniques provide deep insights into the thermal, mechanical, and fire-related properties of polymers and polymer-based products. They allow users to evaluate not only basic material characteristics, but also the influence of processing conditions, the presence of additives or fillers, and compliance with regulatory standards (ISO, EN, ASTM, DIN, etc.). More and more applications are now supported by internationally recognized testing protocols.

Thermal Analysis and Rheology

Thermal analysis helps determine phase transitions, thermal stability, and composition, while rheology reveals how materials deform and flow under various shear and temperature conditions – critical for predicting processability and end-use performance.

Fire Testing

Fire testing, in turn, evaluates flammability, smoke generation, and heat release, enabling manufacturers to ensure safety and meet application-specific fire regulations.

These methods are widely used for quality control and assurance, incoming goods inspection, and materials selection. In research and development, they serve as indispensable tools for understanding material behavior and designing innovative, sustainable, and high-performance polymers.

With our broad portfolio of instruments, decades of applications expertise, and global support network, NETZSCH Analyzing & Testing is your trusted partner in material characterization – from routine testing to cutting-edge innovation.

This brochure provides an overview of our key methods and selected application examples, ranging from thermoplastics and elastomers to thermosets, fiber composites, and recyclates.

The variety of thermoanalytical test methods opens a broad application range for polymer testing, e.g.:

Curing behavior	DSC, Rheology, DEA
Cure monitoring	DEA
Specific heat capacity	DSC
Thermal transitions	DSC, DIL, TMA, LFA, Rheology
Melting, crystallization and reaction enthalpies	DSC
Glass transition temperatures	DSC, TMA, DMA, DEA, LFA, Rheology
Degree of crystallinity	DSC
Thermal stability	TGA, STA
Oxidation Induction Time/ Oxidation Onset Temperature (OIT, OOT)	DSC
Viscoelastic behavior	DMA, TMA, Rheology
Young's modulus	DMA, TMA
Kinetics of reactions	DSC, TGA, DIL, TMA, DEA, Rheology
Compositional analysis	DSC, TGA, EGA
Thermal expansion coefficient	DIL, TMA, DMA
Filler content	TGA, STA
Thermal conductivity/diffusivity and many more	LFA, HFM, GHFM



Differential Scanning Calorimetry (DSC)

Differential Scanning Calorimetry (DSC) is the most frequently employed thermal analysis method. It can be used to analyze nearly any energetic effect occurring in a solid or liquid during thermal treatment. DSC analysis in accordance with ISO 11357 provides the following valuable information for the development and quality control of polymers:

Product Identification and Characterization

- Melting/crystallization temperatures
- Melting/crystallization enthalpies
- Cross-linking temperatures
- Cross-linking enthalpies
- Degree of crystallinity
- Glass transition temperatures
- Specific heat capacity

Advanced Materials Analysis

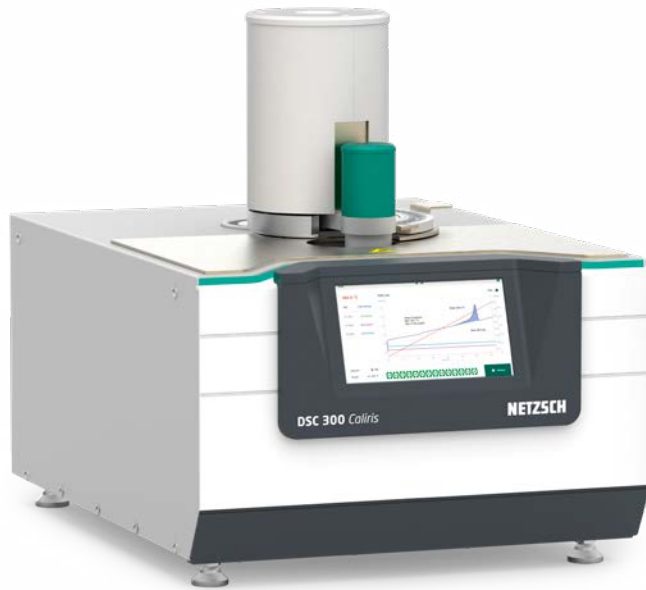
- Decomposition effects
- Oxidative stability (OIT, OOT)
- Reaction behavior and kinetics
- Predictions
- Degree of curing
- Purity determination for additives
- Curing by UV irradiation
- Stability under pressure
- *Peak Separation*
- *Identify*
- *Proteus® Now Quantify*

Product/Process Information

- Incoming goods inspection
- Thermomechanical history
- Failure analysis
- Competitor product analysis
- Process optimization



DSC 300 Caliris® Select/Supreme with touch display and ASC for up to 192 samples



DSC 300 Caliris® Classic

DSC Systems Made for Polymer Applications

The DSC 300 Caliris® Classic is a robust, economical entry-level instrument with excellent performance for quality control and teaching. This system has an optional automatic sample changer with 20 samples and a touch display.

The DSC 300 Caliris® Select allows the sensor module to be interchanged with an identical module, while the DSC 300 Caliris® Supreme allows the module to be freely interchanged with any available module. A large automatic

sample changer and a coupling option are available for DSC 300 Caliris® Select/Supreme. The P-Module was specially developed for the analysis of polymers.

Thermally activated reactions can be studied by conventional DSC, but cationic polyadditions and radical polymerizations can also be started by UV irradiation with sufficiently high energy. For this purpose, NETZSCH offers the DSC 300 Caliris® series with UV accessory.

High-Pressure DSC

Numerous physical processes and chemical reactions are influenced by the surrounding gas pressure. In practice, it is therefore often necessary to define a higher pressure under which to conduct DSC measurements. With the high-pressure DSC 204 HP Phoenix®, thermal effects in a sample can be analyzed in the pressure range from vacuum to 15 MPa (150 bar) and at temperatures from -150°C to 600°C, depending on the type of gas.

The system is also ideal for OIT (Oxidation Induction Time) measurements, which can be performed at lower temperatures under increased oxygen pressure – minimizing the risk of thermal degradation and enabling accurate assessment of oxidative stability, relevant e.g., for geotextiles.



DSC 204 HP Phoenix®

Thermogravimetric Analysis (TGA)

Thermogravimetry (TG), or Thermogravimetric Analysis (TGA), is a well proven thermal analysis method for measuring mass changes as a function of temperature or time. TGA is used in the research & development of various substances and engineering materials – both solids and liquids – in order to obtain knowledge about their thermal stability and composition.

In recent decades, TGA has been used increasingly in quality control and assurance for raw materials and incoming goods, as well as in the failure analysis of finished parts, especially in the polymer-processing industry.

Various international standards describe the general principles of thermogravimetry for polymers (ISO 11358) or other specific applications, such as the TGA method for the compositional analysis of rubber (ASTM D6370 and ISO9924).

Our vertical, top-loading design not only provides for easy operation and sample loading, but also allows gases to flow naturally in an upward direction. Evolved gas analyzers such as mass spectrometers, FT-IR (Fourier Transform Infrared) spectrometers and/or GC-MS (gas chromatograph-mass spectrometers) can be coupled directly to the gas outlet on the top of the furnace.

The Automatic Sample Changer (ASC) can also be used to conduct routine measurements around the clock.

TGA provides complementary and supplementary characterization information to DSC.



TG 309 Libra® Select/Supreme



TG 309 Libra® Classic

Simultaneous Thermal Analysis (STA)



STA 319 Jupiter®

Simultaneous Thermal Analysis (STA) generally refers to the simultaneous application of thermogravimetry (TG) and DSC to one and the same sample in a single instrument. Main advantages are the identical test conditions for the TGA and DSC signals (same atmosphere, gas flow rate, vapor pressure of the sample, heating rate, thermal contact to the sample crucible and sensor, radiation effect, etc.). In addition, sample throughput is improved as more information is simultaneously gathered from each test run.

The DSC, TGA and STA systems meet the majority of the respective instrument and application standards, including: ISO 11357, ISO 11358, ASTM E967, ASTM E968, ASTM E793, ASTM D3895, DIN 51004, DIN 51006, DIN 51007.

TGA Measurement Information

- Mass changes
- Temperature stability
- Estimation of product lifetime
- Oxidation/reduction behavior
- Filler content
- Moisture and volatiles content
- Decomposition
- Compositional analysis of inorganic and polymer content
- Data for kinetic evaluation using Kinetics Lite and Kinetics Neo

DSC Measurement Information

- Specific heat capacity
- Melting/crystallization behavior
- Degree of crystallinity
- Glass transition temperatures
- Compositional analysis of polymer blends
- Cross-linking reactions
- Oxidative stability
- Purity determination
- Data for kinetic evaluation using Kinetics Lite, Kinetics Neo and Termica Neo



Thermal Analysis Coupled to Evolved Gas Analysis (EGA)

Top-level polymer research and characterization can be achieved by coupling the thermoanalytical methods of TGA, DSC, STA, TMA and DIL to a mass spectrometer (MS), gas chromatograph/mass spectrometer (GC-MS) or Fourier Transform Infrared (FT-IR) spectrometer. These hyphenated techniques may also include simultaneous coupling of the MS and FT-IR or GC-MS and FT-IR to the thermal analyzer. In addition, the unique adapter allows for coupling even when used in combination with an Automatic Sample Changer (ASC).



TGA-FT-IR coupling via an external FT-IR gas cell

Coupling Possibilities

- TGA-, DSC-, or STA-MS via capillary coupling
- STA-MS via *SKIMMER* coupling
- TGA-, or STA-GC-MS
- TGA-, DSC-, or STA-FT-IR
- TMA-MS
- DIL-MS

Evolved gases are directed straight to the gas analyzer via a heated capillary or transfer line. In addition to decomposition, such systems can also be used for investigating composition, evaporation and solid-gas reactions.

Measurement Information by Means of Evolved Gas Analysis Coupled to Thermal Analysis

Compositional analysis

- Polymers
- Plasticizers
- Solvents
- Additives
- Propellents

Decomposition

- Dehydration
- Stability
- Residual solvent
- Pyrolysis

Evaporation

- Vapor pressure
- Sublimation

Solid-gas reactions

- Combustion
- Oxidation
- Adsorption/desorption



Mass spectrometer

Gas chromatograph

STA 509 Jupiter®

Thermomechanical Analysis (TMA)/ Dilatometry (DIL)

Thermomechanical analysis (TMA) and dilatometry (DIL) are two of the most important characterization techniques in the field of thermal analysis. DIL determines the length change of samples under a negligible load (DIN 51045). The closely related TMA method also determines the dimensional changes of solids, liquids or pasty materials as a function of temperature and/or time under a defined static load (ISO 11359, DIN 51 005, ASTM E831, ASTM D696, ASTM D3386).

With the TMA 512 *Hyperion*®, measurements can be carried out in expansion, penetration, tension and bending mode. Investigations can be realized on plastics and elastomers, paints and dyes, composite materials, adhesives, films and fibers. The NETZSCH dilatometers (DIL 502 *Expedis*®) and TMA 512 *Hyperion*® are based on the instrument and application standards for polymers and composites.

TMA/DIL Measurement Information

- Thermal expansion
- Coefficient of linear thermal expansion
- Volumetric expansion
- Density change
- Delamination
- Glass transition temperatures
- Softening points
- Penetration behavior
- Phase transitions
- Creep/relaxation behavior
- Stress/strain curve
- Anisotropic behavior
- Young's modulus
- Data for kinetic evaluation using Kinetics Neo



Variety of TMA sample holders



TMA 512 *Hyperion*®



DIL 502 *Expedis*®

Dynamic Mechanical Analysis (DMA)

Dynamic Mechanical Analysis (DMA) allows for the quantitative determination of the mechanical properties of a sample under an oscillating force and as a function of temperature, time, frequency and strain (DIN 53513, DIN EN ISO 6721, DIN 53440, DIN-IEC 1006, ASTM D4065, ASTM D4092, ASTM D4473, ASTM D5023, ASTM D5024, ASTM D5026, ASTM D5418). The results portray the linear viscoelastic properties, typically depicting them as a graphical plot of E' (storage modulus), E'' (loss modulus), and $\tan \delta$ (loss factor) versus temperature.

The DMA *Eplexor*® series identifies transition regions, such as glass transitions in plastics and resins, and may be used for quality control or product development in the temperature range from -170°C to 1500°C.

Dynamic Mechanical Testing Supports Research and Quality Control of Polymers

R&D

The DMA method is a very sensitive tool for generating data that can help define the mechanical properties of polymers and composites in order to support product development in industries such as automotives.

Quality Control

α and β transitions can be used to compare production with standards and competitors' products.

Our DMA experts support you by finding the right approach for specific applications and areas of interest.

DMA Measurement Information

- Design data concerning stiffness and damping properties (modulus values and damping factor under a variety of conditions)
- Data on the composition and structure of polymer blends (miscibility)
- Glass transition of highly cross-linked, amorphous or semi-crystalline polymers and composites
- Curing/post-curing
- Aging
- Creep and relaxation
- Stress and strain sweeps
- Multi-frequency tests
- Prediction of the material behavior using Time-Temperature-Superposition (TTS) experiments
- Immersion tests
- Durability test
- Fatigue test
- Hysteresis



High-force DMA 503 *Eplexor*®



DMA 523 *Eplexor*®



DMA 303 *Eplexor*®

Dielectric Analysis (DEA)

A variety of questions may arise during the curing process of reactive resins.

- At which temperature, or after how much time, does the resin begin to cure?
- How high is the reactivity?
- When is curing completed?
- Is the curing profile identical for every position in the mold?
- How can the curing cycle be optimized in order to save energy and costs?
- Is there any potential for post-curing?

For investigation of the curing behavior of thermosetting resin systems, composite materials, adhesives, paints and coatings, dielectric analysis (DEA) in accordance with ASTM E2038 or E2039 has stood the test of time.

Measurement Principle

DEA allows for the measurement of changes in the dielectric properties during curing. The liquid or pasty resin must be placed in direct contact with two electrodes comprising the dielectric sensor. A sinusoidal voltage (excitation) is applied and the resulting current (response) is measured, along

with the phase shift between voltage and current. These values are then used to determine the ion mobility (ion conductivity) and the alignment of dipoles. In turn, the dielectric properties of permittivity ϵ' and loss factor ϵ'' are calculated from these effects. Of primary interest with regard to curing is the ion viscosity. This is the reciprocal value of the ion conductivity, which is proportional to the loss factor.

Use of the DEA technique is not limited to the lab environment; it can also be applied to monitor in-situ curing in the mold under processing conditions. For production monitoring and process control, a specific ion viscosity value can be programmed to trigger demolding when the part being produced is sufficiently cured. This reduces cycle times and increases throughput.

Portable Version

With up to seven channels, this DEA is the flexible version for your day-to-day work. It can be easily transported between different measurement locations.

Rack Version for Integration into an Industrial Process

The 19" Rack version is designed for an electrical cabinet. It supports 8 simultaneous measuring channels which can be extended up to 16 modules.

DEA Measurement Information

- Ion viscosity
- Reactivity
- Cure monitoring
- Degree of cure
- Glass transition temperature
- Permittivity
- Process control and optimization
- Diffusion properties
- Aging and decomposition effects



DEA 288 Ionic

Capillary Rheometry

Capillary rheometry is a well-established technique for measuring the shear and extensional flow properties of polymer melts and highly filled compounds under processing-relevant conditions. The Rosand twin-bore capillary rheometer enables precise control of shear rates and temperatures, allowing for the characterization of viscosity, wall slip, melt fracture, and die swell behavior.

Widely used in polymer R&D and quality control, capillary rheometry plays a key role in material development, formulation tuning, and troubleshooting in processes such as extrusion, injection molding, and additive manufacturing. It helps correlate laboratory measurements with processing behavior and end-use performance.

The Rosand rheometer series offers modular test configurations, high-force drives, and interchangeable dies, enabling a wide range of test conditions, including piston-driven shear flow, extensional viscosity via haul-off systems, and pVT measurements with optional accessories. Its robust design and intuitive software provide polymer users with accurate, repeatable data critical for understanding material behavior during high-speed processing.

Rosand Measurement Information

- Processability & Flow Behavior
- Shear Viscosity vs. Shear Rate (Melt Flow Curves)
- Shear Behavior → Thinning & Thickening
- Bagley & Rabinowitsch Corrections → Entrance Pressure & True Shear Rate
- Wall Slip (Mooney Method)
- Die Swell (Extrudate Swell)
- Melt Fracture (Extrusion Stability)
- Extensional Rheology & Elasticity
- Extensional Viscosity (Uniaxial & Planar via Entrance Pressure Drop)
- Flow Instabilities & Elastic Effects (Melt Fracture, Rupture, Shark Skin, Stick-Slip)
- Melt Strength (Haul Off)
- Thermal & Processing Stability
- Thermal Degradation of Polymer Melts
- Residence Time & Temperature Effects
- Volatile Content Impact on Flow
- pVT Analysis (Pressure-Volume-Temperature Measurement)
- Processing-Relevant Measurements
- pVT Diagram of Polymers (Density vs. Pressure & Temperature)
- Volumetric Expansion & Phase Transitions
- Shrinkage & Thermal Contraction Behavior
- Injection Molding Simulation (Shrinkage & Warpage Prediction)



Rosand RH10

Rosand RH2000

Rotational Rheometry

Rotational rheometry is an established method for characterizing the flow and deformation behavior of polymers under controlled temperature and shear conditions. The Kinexus rotational rheometer is used in the research and development of thermoplastics, thermosets, elastomers, and polymer blends to better understand their processability, viscoelastic properties, and performance across temperatures.

In recent decades, rotational rheometry has become a vital tool in quality control and assurance of polymer raw materials, batch consistency, and processing optimization – from compounding and extrusion to injection molding and curing. It also supports failure analysis of finished parts by revealing rheological fingerprints related to molecular weight, degradation, or contamination.

The Kinexus rheometer features a precision air-bearing system, automated tool recognition, and intelligent test sequencing, making it ideal for both routine QC and advanced R&D. It supports a wide range of rheological tests – including shear viscosity, oscillatory modulus, yield stress, and gelation behavior – offering deep insight into the behavior of polymers during storage, transport, and processing.



Kinexus Prime ultra+ equipped with the UV Curing System

Kinexus Measurement Information

- Shear Viscosity vs. Shear Rate (Melt Flow Curves)
- Zero-Shear Viscosity → Molecular Weight Estimation
- Viscoelastic Properties → Elastic / Viscous Modulus & Dynamic Viscosity
- Complex Modulus & Phase Angle → PDI / MWD (Modality)
- Relaxation Times → Processing Simulation
- Crossover Point → Gel Point, Molecular Weight Estimation, Crosslinking Kinetics & Density
- Shear Behavior → Thinning, Thickening, Thixotropy, Rheopexy
- Time/Temperature Dependence → Thixotropy, Creep, Degradation, TTS

The Kinexus rheometer can be equipped with a UV-curing system to study the real-time rheological behavior of photo-reactive polymers. This setup enables precise analysis of gelation, cure kinetics, and final mechanical properties under controlled UV exposure – ideal for applications such as adhesives, inks, and coatings.

Measurement of Thermal Conductivity and Thermal Diffusivity

Laser Flash Technique (LFA)

Thermal conductivity and thermal diffusivity are the most important thermophysical material parameters for describing the heat transport properties of a material or component.

For issues such as these, the Laser Flash technique (LFA) has become a fast and reliable tool; it is an absolute method for determining thermophysical properties, including the specific heat capacity. This data can then be used for:

- Prediction of the heat transfer and temperature profile for description of the processing behavior
- Thermal diffusivity and thermal conductivity as input data for numerical simulation

For polymer applications in the temperature range from -100°C to 500°C , the compact LFA 717 *HyperFlash*® is available. The integrated Automatic Sample Changer can test up to 16 samples in one run. The LFA 717 *HyperFlash*® is capable of testing thin and high-conductivity materials as well as 2- and 3-layer structures – a capability which allows for such analyses as the influence of coatings on heat transfer under real conditions.

The LFA 717 *HyperFlash*® operates in accordance with national and international standards (e.g., ASTM E1461, DIN EN 821).



LFA 717 *HyperFlash*®



Broad variety of LFA sample holders for liquids, powders, fibers, for studies of anisotropic behavior

Insulation Testing by Means of the Heat Flow Meter (HFM)

All NETZSCH HFM and GHP instruments are based on all respective application and industry standards:

- ASTM C177, ASTM C335-05Ae1, ASTM C1363-05, ASTM D5470-06, ASTM E1530-06, ASTM F433-02(2009), ASTM C1363-05
- DIN EN 12667/12939, DIN EN 13163
- ISO 8301, ISO 8302, ISO 8894-1 (EN 993-14), ISO 8894-2 (EN 993-15)
- JIS A 1412



HFM 706 *Lambda Small*

HFM 706 *Lambda Medium*

Heat Flow Meters

Heat Flow Meters are precise, fast and easy-to-operate instruments for measuring the thermal conductivity of insulations (e.g., polystyrene or polyurethane foams).

The HFM 706 *Lambda* allows the operator to apply a precise load on the specimen, enabling control over the thickness, and thus density of compressible

materials – requirements for obtaining reproducible thermal conductivity results.

The HFM 706 series consists of three instrument versions which cover the plate temperature range from -30°C to 90°C and specimen sizes of 203 mm, 305 mm and 611 mm (length and width).

Closing the Gap Between Classical Heat Flow Meters and Laser Flash Analyzers

The TCT 716 *Lambda* Guarded Heat Flow Meter

The TCT 716 *Lambda* allows investigations of homogeneous and inhomogeneous materials in the range of low to medium thermal conductivities. In combination with smaller specimens compared to conventional HFMs and larger specimens compared to LFAs, this instrument perfectly realizes the precise determination of thermal resistance and thermal conductivity.



TCT 716 *Lambda*

Fire Testing of Polymers

UL 94 and LOI 901 – Essential Screening Tools for Flame Behavior

Flame retardancy is a key safety factor for polymers in electronics, automotive, construction, and consumer goods. Two widely used methods to assess flammability are the UL 94 classification test and the Lowest Oxygen Index (LOI) test. Both are indispensable for material development, regulatory compliance, and quality control.

UL 94 – Flammability Classification of Plastics

UL 94 defines how plastics react to a small flame under controlled conditions. It is the most common screening test, assigning classifications such as V0, V1, V2 (vertical) and HB (horizontal). These are recognized worldwide to determine safe use in finished products.

The NETZSCH UL 94 test system features an electrically driven burner positioning system and intuitive touchscreen. It supports both test modes and complies with UL 94, DIN EN 60695-11, and ISO 9773.

This method is well suited for thermoplastics, elastomers, and reinforced compounds used in connectors, housings, trim parts, and small components. Fast, reliable classification accelerates formulation development and ensures compliance with safety specifications.



UL 94 Measurement Information

The following parameters are determined during testing:

- Linear burning rate
- Afterburning and afterglow time
- Formation of burning or glowing droplets
- Flame front position
- Total time of visible flame

LOI – Lowest Oxygen Index

The LOI test measures the minimum oxygen concentration required to sustain combustion in a nitrogen/oxygen mix. A higher LOI value indicates better flame resistance.

The NETZSCH LOI 901 system provides automated calibration, compact design, and touchscreen operation. It is ideal for laboratory screening and routine QA of thermoplastics, thermosets, rubbers, and fiber-reinforced composites.

LOI values are used to compare formulations, validate flame retardant additives, and ensure specification conformity for certification or approval.



LOI Measurement Information

During testing, the following information is obtained:

- Limiting oxygen concentration required to sustain burning
- Burning distance
- Burning time
- Combustion behavior under reduced oxygen levels

Advanced Fire Behavior Analysis

Cone Calorimetry with the TCC 918

For a full picture of polymer behavior under fire conditions, the Cone Calorimeter TCC 918 delivers comprehensive, real-scale data on fire growth, heat release, smoke, and toxicity. Recognized as the gold standard in fire testing, it quantifies how materials contribute to fire development.

The TCC 918 applies the oxygen consumption principle, where heat release is directly linked to oxygen use. This allows precise determination of the heat release rate (HRR) – the key parameter for predicting real-world fire behavior.

Samples are exposed to controlled radiant heat to simulate environments such as aircraft cabins, vehicles, buildings, or consumer devices. Alongside flammability and combustion data, the system records smoke and gas emissions (CO, CO₂), supporting fire modeling, regulatory approval, and material optimization in industries from aerospace to construction.

The TCC 918 meets ISO 5660-1, ASTM E1354, and related standards. With robust system design, accurate gas flow control, and integrated software, it ensures reproducible, reliable results for both R&D and compliance testing.

TCC Measurement Information

This advanced test method provides a broad range of data, including:

- Time to ignition (TOI)
- Time of combustion or extinction
- Heat release rate (HRR) and total heat release
- Mass-loss rate
- CO and CO₂ concentration
- Total smoke release (TSR) and smoke gas density
- Prediction of real-scale fire behavior
- Gas detection through coupling to FT-IR



Beyond Screening and Calorimetry

In addition to the UL 94, LOI, and Cone Calorimeter systems, NETZSCH offers a wide range of specialized fire testing devices designed to meet specific international standards for various industries, including construction, transportation, and electronics. These systems enable comprehensive characterization of flammability, heat release, smoke development, and fire propagation under both small-scale and real-use conditions.

Whether you are testing building materials for Euroclass classification, evaluating automotive interior parts, or certifying cable insulation, we provide reliable instrumentation tailored to your requirements.

Advanced Software

Kinetics Software

can analyze any process for which the reaction rate depends on temperature

Both the NETZSCH Kinetics Lite and Kinetics Neo software are used to analyze the kinetics of temperature-dependent chemical processes. The result of this analysis is a kinetic model that accurately describes the experimental data under different temperature conditions. Using the method/model allows for the prediction of a chemical system's behavior under user-defined temperature conditions. Alternatively, these models can be used for process optimization.



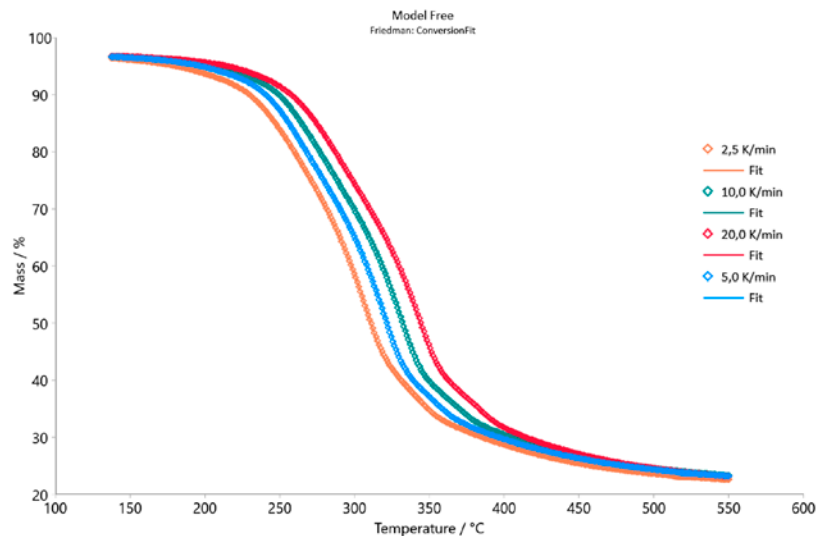
The Kinetics Lite software uses DSC or TGA data to analyze basic time- and temperature-dependent processes. It contains well-known isoconversional (model-free) kinetic methods, as well as the ability to automatically determine the reaction model and kinetic parameters for single-step reactions with Arrhenius temperature dependence. For each method, Kinetics Lite provides a simulated fit and an R^2 value to indicate its quality. The results of the kinetic analysis can be used for isothermal predictions at user-defined temperatures or for user-defined heating rates. <https://kineticslite.netzsch.com/>

Isoconversional methods allow to find the activation energy as the function of conversion:

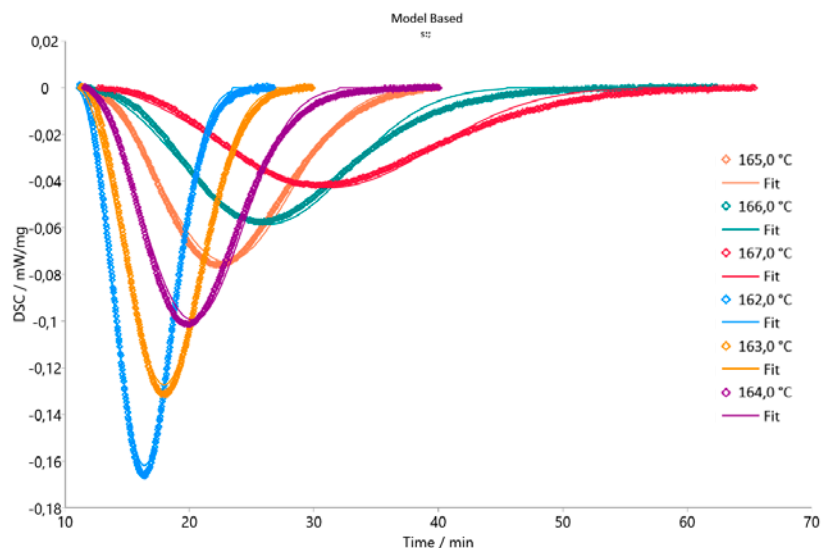
- ASTM E698, ASTM E2890, ASTM E1641
- Friedman
- Ozawa-Flynn-Wall
- Vyazovkin

The Kinetic model is automatically determined for single-step reactions:

- Reactions of n^{th} order
- Reactions with autocatalysis
- Nucleation of Avrami type



TGA data for pyrolysis with model-free Friedman analysis: simulation corresponds to an experiment with $R^2=0.9999$.

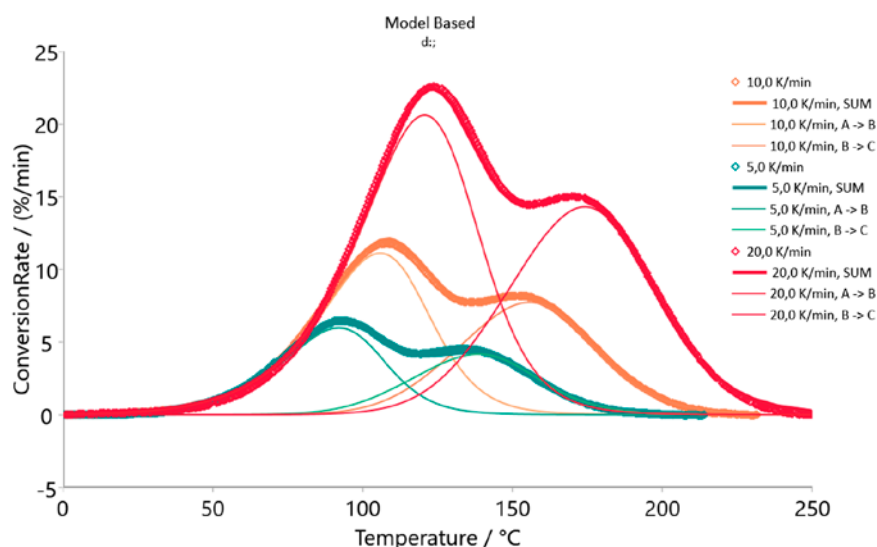


DSC data (exo down) for isothermal crystallization of polyamide 12 with model-based analysis of Avrami nucleation type: simulation corresponds to an experiment with $R^2=0.998$.

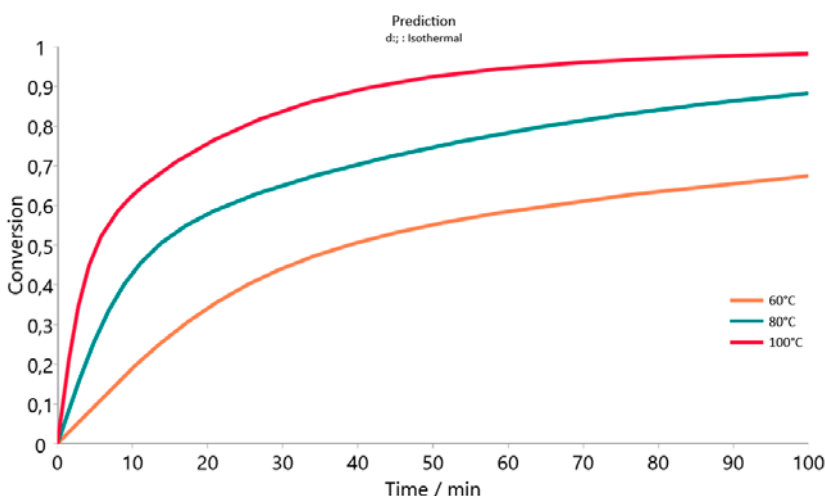
Kinetic analysis determines a set of kinetic parameters, such as the number of reaction steps, each step's contribution to the total process effect, the reaction type, the activation energy, and the reaction order for each step. This information can then be used to solve prediction problems for new temperature/time programs or to optimize behavior for a given system.

Kinetics Neo is a comprehensive software program for analyzing different types of kinetic data. Potential data sources include studies using TGA, DIL, DSC, FT-IR, MS and rheometry, as well as temperature analysis during adiabatic measurements. The software contains many model-free and model-based analysis methods for single- and multi-step models, as well as for independent, competing, or overlapping consecutive steps, each of which has its own reaction type. The software includes analysis for both Arrhenius and non-Arrhenius processes, and considers the glass transition temperature for cross-linking reactions with diffusion control, vitrification, and for crystallization kinetics during cooling.

Kinetics Neo allows to predict signal, and conversion rates, reaction rates of individual reaction steps, and formal concentrations of individual reactants at different temperatures. This includes not only heating or isothermal programs, but also multi-segment programs, arbitrary temperature curves, and predictions according to the climate at a selected weather station around the world.



Conversion rate based on DSC data for double-step curing of an epoxy resin with kinetics model of two consecutive steps (the first is autocatalytic and the second is n^{th} order reaction): simulation corresponds to an experiment with $R^2=0.9996$.



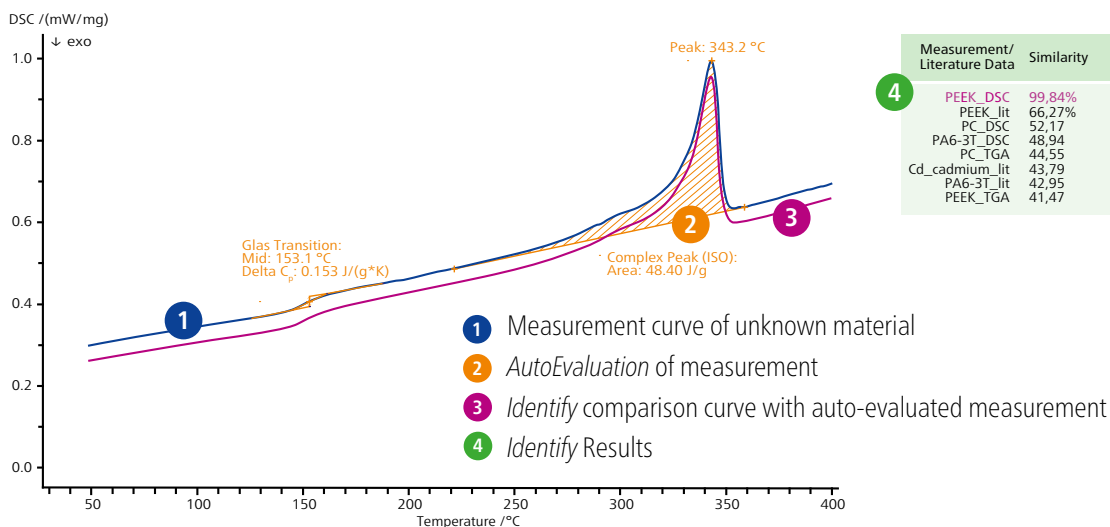
Prediction of the curing behavior at different isothermal temperatures

In this plot, the curing behavior is predicted based on the simulations shown above. The conversion rate is plotted against time for different isothermal temperatures. For example, at 100°C, the material investigated here was completely cured after 80 min (degree of curing of 100%)

Kinetics Neo optimizes the temperature profile for industrial applications whether the process rate is constant or dependent on the conversion time.

Proteus[®] Software

AutoEvaluation and Identify – Speed Up Results



AutoEvaluation

Results Immediately After the Measurement End

AutoEvaluation is the first self-acting evaluation routine for DSC curves on the market. Fully autonomously and without user intervention, it evaluates all effects such as glass transition temperatures, melting temperatures, and melting enthalpies of unknown substances. Oxidative Induction Time/Temperature (OIT/OOT) also gets evaluated for isothermal and dynamic tests, using the Tangent and Offset method in accordance with standards.

Experienced users can take the automatic evaluation result as a second opinion – and, of course, recalculate values if desired.

Report Generator

Each operator can easily create personal report templates – including logos, tables, description fields and plots. Several report examples are already included as templates within the *Proteus*[®] software.

Identify

Material Identification via Database Comparison

Identify is a unique software tool within the thermal analysis field for the identification and classification of measurements via database comparison. In addition to allowing one-on-one comparisons with individual curves and literature data, it can also check whether a particular curve belongs to a certain class. These classes can consist of curves of the same material type (material identification) or of reference curves for Pass/Fail testing (quality control).

The provided NETZSCH libraries contain about 1350 entries related to different application areas such as polymers, organics, pharmaceuticals, inorganics, metals/alloys or ceramics. The additionally available KIMW* database includes the DSC curves of another 1250 commercially available polymer products. Users can expand *Identify* as desired, adding unlimited amounts of their own data.

* KIMW = Kunststoff-Institut Lüdenscheld, Germany



Proteus[®] Now Quantify

USING PREDICTIVE AI TO DECODE RECYCLATE COMPOSITION

Save Time

After analyzing your sample on a NETZSCH DSC, simply upload the data to *Proteus[®] Now Quantify*. Within seconds, you'll receive accurate results – no manual evaluation or prior data science experience required.

Increase Confidence

Analyze your recyclates with confidence. Confirm composition, detect deviations early, and reduce quality risks – all with a transparent, AI-driven workflow.

Access Expert Knowledge

Even non-specialists can now achieve reproducible, high-quality evaluations. The integrated AI engine takes care of the complexity, delivering consistent results across a wide range of polymer types and blends.

Security for Recyclate Producers

Producers can verify material composition and improve quality control

Confidence for Recyclate Buyers

Buyers gain confidence in product consistency – supporting traceability and fair pricing



What's Behind the AI?

Proteus[®] Now Quantify combines classical machine learning (e.g., decision trees) with deep learning (neural networks) to accurately interpret even challenging material mixtures – including those with overlapping melting peaks. Every result includes an uncertainty score, similar to a standard deviation, providing a confidence measure for each prediction and helping identify unknown or borderline cases.

APPLICATIONS

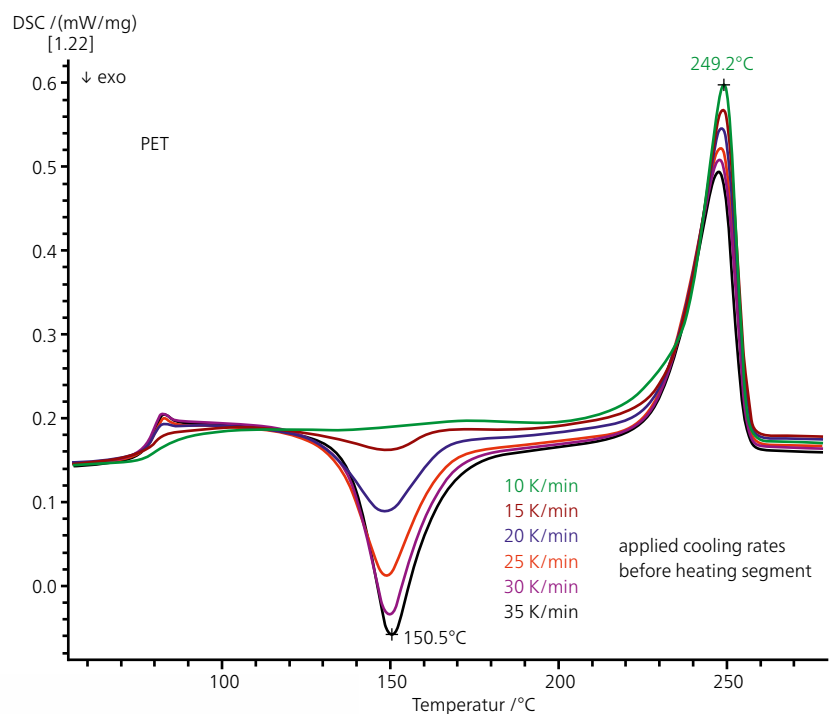
Thermoplastics

Differential Scanning Calorimetry

Crystallization Behavior of Semi-Crystalline PET

Polyethylene terephthalate (PET) is a semi-crystalline thermoplastic polymer with a relatively slow crystallization rate. High cooling rates lead to a high amorphous content, high glass transition steps (T_g) and post-crystallization during heating.

Low cooling rates allow more crystalline parts to crystallize during cooling, leading to a smaller glass transition step and no post-crystallization. The material then has an increased crystallinity and therefore loses its transparency.



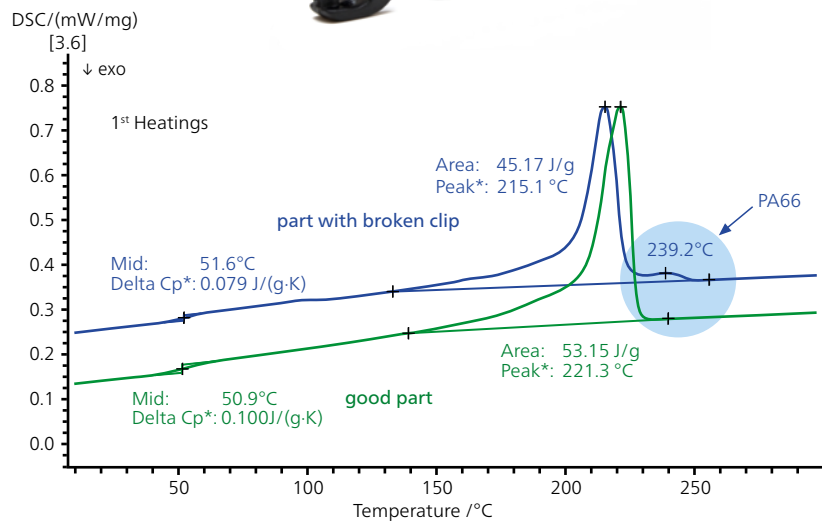
PET: glass transition, cold crystallization and melting measured at a heating rate of 10 K/min after different cooling rates – change in the crystallinity degree by means of DSC



Failure Analysis of a PA6 Clip

Failures might be due to a variety of causes, including selection of the wrong material for the application, manufacturing defects in the plastic raw material, production defects in the plastic part, or degradation of the plastic by exposure to aggressive chemicals, contaminants, UV radiation, etc. DSC is a convenient method for comparing good parts with poor ones.

In this example, the first heating runs on two PA6 clips already show that the poor clip (blue curve) has an additional melting peak at 239°C. This indicates the presence of PA66, which is often blended with PA6. The presence of a second component is confirmed in the 2nd heating.

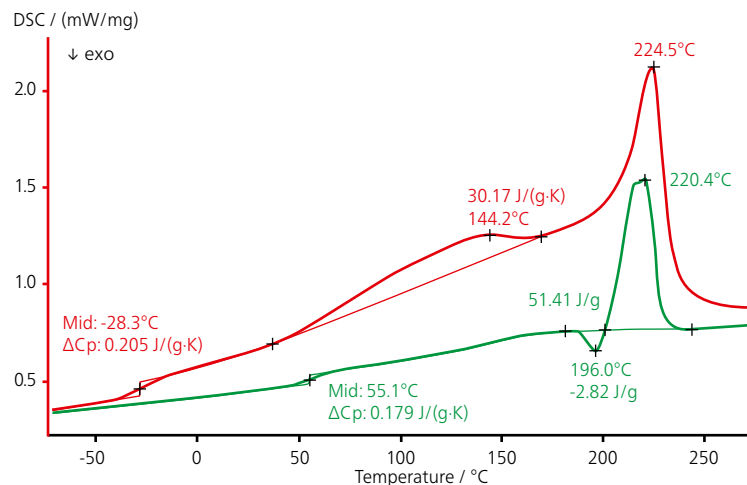


DSC comparison of the 1st heating runs of two clips made of PA6 reinforced with glass fiber; sample masses 12.98 mg and 13.13 mg; heating rate 10 K/min

Influence of Atmospheric Moisture

Polyamides absorb atmospheric moisture, which affects their mechanical properties.

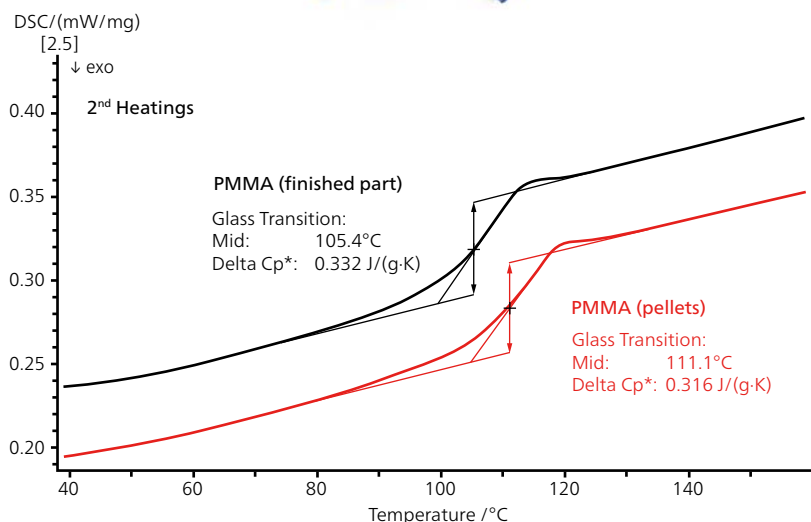
The endothermic step at -28°C of the 1st heating (red curve) indicates the glass transition of the moist PA6. The endothermic effect between 20°C and 180°C is due to the evaporation of water contained in the sample. In the 2nd heating, the sample is dry and the glass transition temperature is shifted to 55°C. Water acts as a plasticizer and lowers the glass transition temperature. The peaks at 225°C (1st heating) and 220°C (2nd heating) are related to melting. The 2nd heating additionally shows a cold crystallization at 196°C.



1st and 2nd heating of moist PA6 by means of DSC; sample mass 9.4 mg; heating rate 20 K/min



Influence of the Thermo-mechanical History on Amorphous PMMA



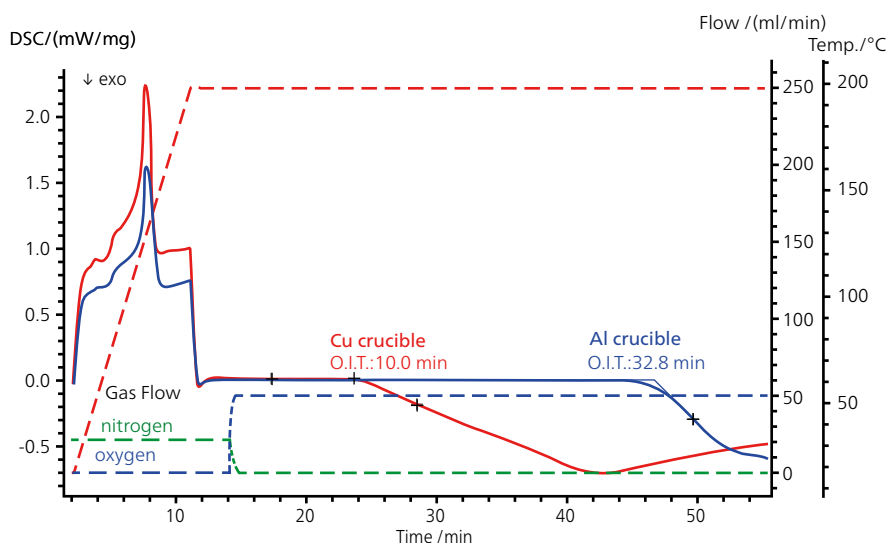
DSC measurement: shift of the glass transition to lower temperatures with increasing production steps; sample masses 11.54 mg and 12.5 mg; heating rate 10 K/min

The thermal and mechanical properties of polymer materials may vary greatly as a result of the thermal history associated with the sample. This DSC plot depicts the second heating runs of polymethyl methacrylate (PMMA) pellets and a finished PMMA part. It can clearly be seen that the glass transition temperature observed for the pellets (midpoint 111°C, red curve) is shifted to a lower temperature in the finished part (midpoint 105°C, black curve). Each additional unit of thermomechanical treatment of the polymer during thermoplastic processing may result in degradation of the molecular mass, in turn, leading to a reduction of the glass transition temperature.

Oxidative-Induction Time (OIT)

Factors that influence OIT include test temperature, sample preparation, sample geometry, sample mass, particle size, crucible material, etc. The Oxidative-Induction Time (OIT) can be determined in standard aluminum or in open copper crucibles in accordance with ASTM D3895.

This plot represents OIT measurements on high-density polyethylene (HDPE) carried out in a copper and in an Al crucible (red and blue curves, respectively). It can clearly be seen that, under isothermal conditions at 250°C under an oxygen atmosphere, oxidation of HDPE begins approximately 23 min earlier in the copper crucible than in the Al crucible. Copper works here as a catalyst for the oxidation.



Influence of the crucible material on the Oxidative-Induction Time (OIT) of HDPE by DSC; sample masses 12.21 mg and 12.11 mg

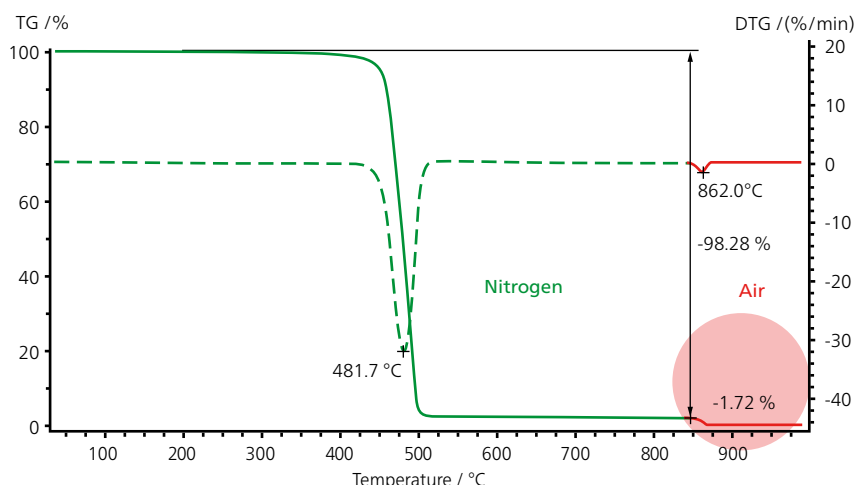
Thermogravimetric Analysis



Detection of Added Carbon Black

Static electricity may build up in polyethylene materials unless anti-static additives are used. PE macromolecules are also broken down by UV light and burns readily unless flame retardants are applied. Carbon black is one of the best and most economic stabilizers.

The level of added carbon black content in PE can be easily determined by means of a vacuum-tight TGA system. After the total decomposition of PE in a highly pure nitrogen atmosphere, combustion of even the smallest amounts of added carbon black can be observed in an oxidizing air atmosphere.

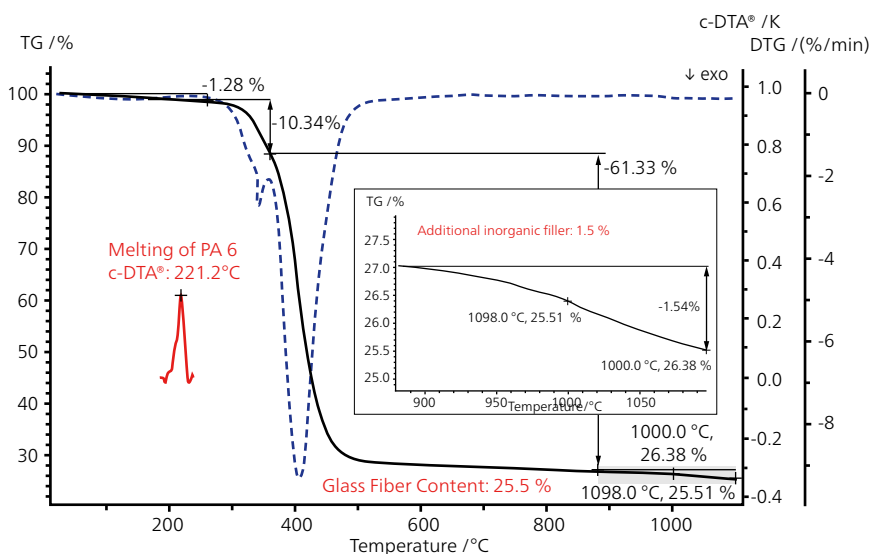


TGA measurement on polyethylene with added carbon black; sample mass 17.39 mg; Al_2O_3 crucible; heating rate 10 K/min

Determination of Different Filler

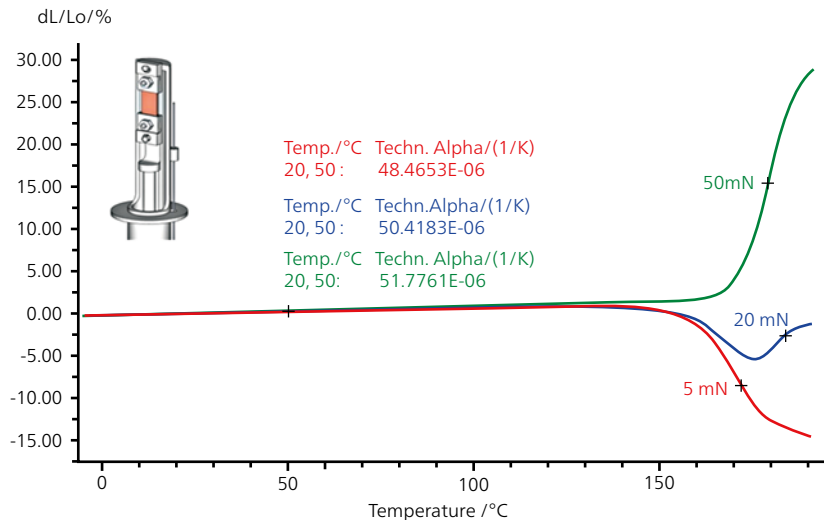
Fillers were previously used mostly to lower the price of finished products. Today, they are primarily used to improve the technical characteristics of polymer products.

In this example, the determination of the inorganic filler (here glass fiber) in a PA6 sample is carried out by means of TGA. The sample was filled with 25.5-% glass fiber. Decomposition of an additional inorganic filler can be observed between 900°C and 1100°C (see inset). Furthermore, by applying the c-DTA® feature of the TG 309 *Libra*® before polymer decomposition starts, an endothermic peak at 221.2°C can be detected. This effect represents the melting peak of PA6.



Determination of the melting temperature (identification) and filler content by TGA with c-DTA®; sample mass 12.45 mg; Al_2O_3 crucible; heating rate 10 K/min

Thermomechanical and Dynamic Mechanical Analysis



Orientation effects of a PC shrink film measured with the TMA ; sample thickness 40 μm ; length $\approx$ 5 mm; heating rate 5 K/min

Tension Test on a Shrink Film of PC

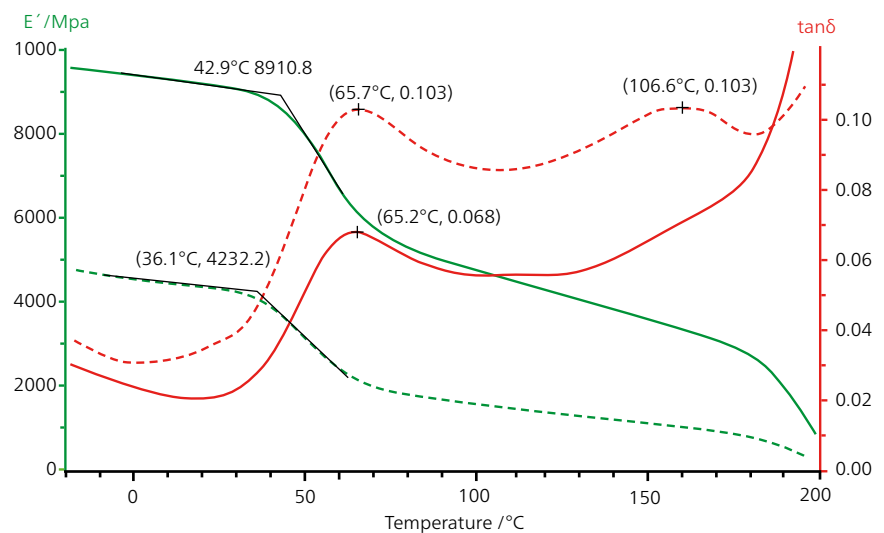
Orientation effects, stretch condition and shrinkage are measured under load for films with the TMA. In these examples, the expansion and contraction of a 40- μm -thick film of polycarbonate (PC) were tested under tensile load. The results vary significantly depending on the applied load. Under low amounts of force (5 mN), the film contracts at higher temperatures; however, it expands if a higher force (50 mN) is applied.

Anisotropic Behavior of a Glass Fiber-Reinforced (PBT) by Means of DMA

High mechanical stiffness due to glass fiber-reinforcement

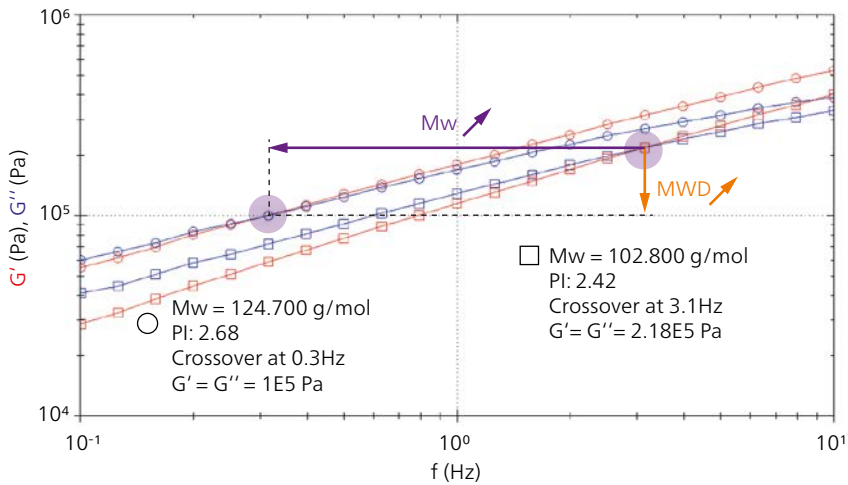
The DMA measurements of a finished part made of glass fiber-reinforced PBT were carried out on samples taken parallel or perpendicular to the cavity filling direction in order to investigate the anisotropic behavior.

The viscoelastic properties parallel to the fiber orientation (solid lines) indicate a significantly higher stiffness (E') and a lower damping ($\tan \delta$ level). In the perpendicularly-oriented fiber direction (dotted lines), on the other hand, damping is higher and stiffness is correspondingly lower.



Polybutylene Terephthalate: DMA measurements on PBT/30%GF parallel to the fiber direction (solid curves) and perpendicular to it (dotted curves); 3-point bending; heating rate 2 K/min; frequency 1 Hz

Rheology and Molecular Weight

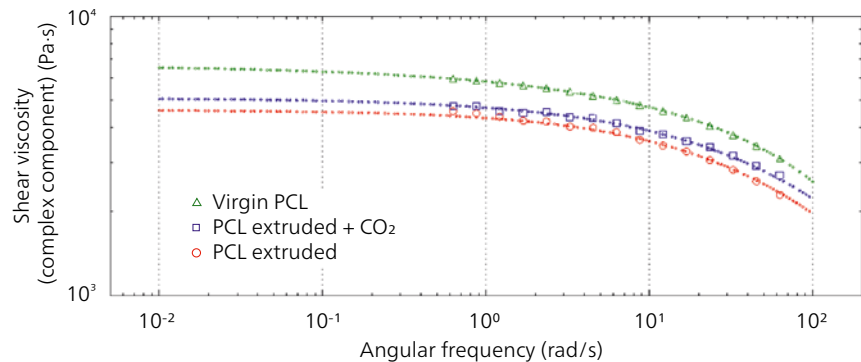


Oscillation: Frequency sweep of two polyamide samples with different molecular weights; elastic modulus (G' , red); viscous modulus (G'' , blue) vs. frequency (Hz)

The molecular weight of a polymer influences its processing and the mechanical properties of the final product and is therefore of great importance. The position of the G'/G'' crossover obtained during a frequency sweep is indicative of the molecular weight and the molecular weight distribution of a polymer. The measurements here show two frequency sweeps carried out on PA12 materials with glass fillers differing from each other only by molecular weight. An increase of the molecular weight by 20% leads to a decrease in the crossover frequency by one decade! Moreover, a small increase of the polydispersity index ($PI = M_w/M_n$) leads to a decrease of the shear modulus detected at the crossover.

Melt-Viscosity Measurements

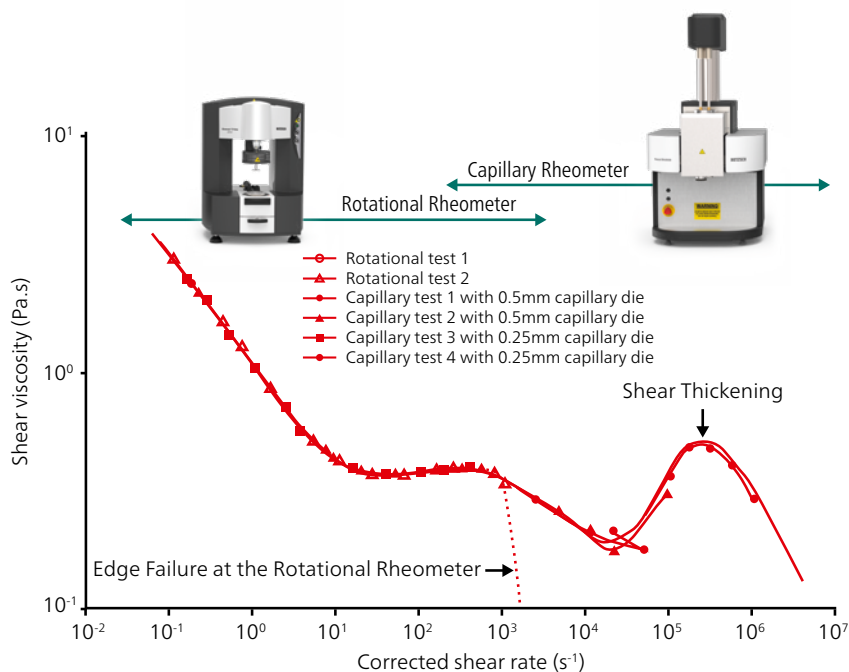
Melt-viscosity measurements are a valuable indirect method for estimating the molecular weight of polymers. In particular, the zero-shear viscosity plateau – obtained by fitting rheological data with models such as the Cross model – correlates strongly with molecular weight, especially in linear polymers like polycaprolactone (PCL). This relationship arises because higher molecular weight polymers exhibit greater chain entanglement, which increases resistance to flow under low shear conditions. Thus, by analysing the melt-viscosity behaviour, one can infer relative differences in molecular weight among samples without requiring direct techniques such as gel permeation chromatography. In this instance, processing



Melt-viscosity curves for three polycaprolactone (PCL) samples were measured using rotational rheometry and fitted with the Cross model via rSpace software to determine the zero-shear viscosity plateau.

conditions have an effect on molecular weight, and the amount of degradation caused – reflected as a reduction in both molecular weight and viscosity – can be observed through rheological analysis.

Unmatched Shear Rate Range with Decades of Experience



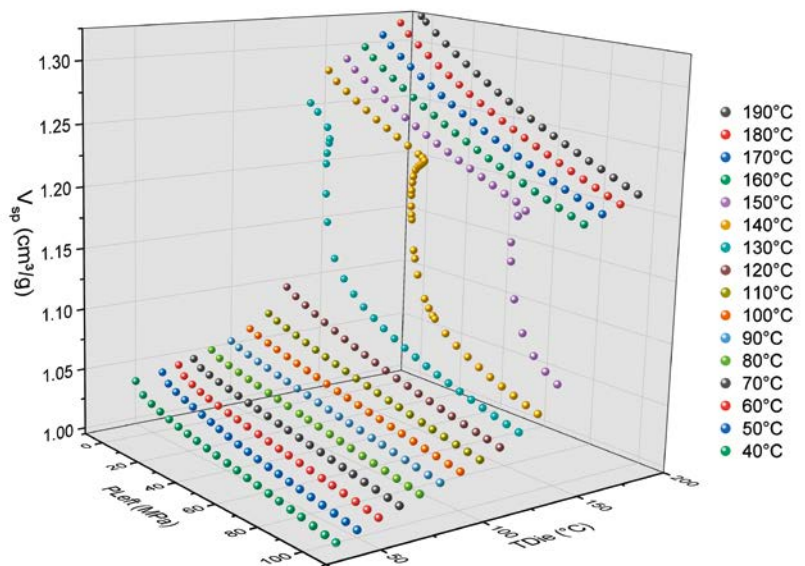
In a rotational rheometer, the maximum shear rate is reached if the sample is ejected from the measurement gap. Therefore, how can you obtain information regarding the flow behavior at higher shear rates, for processes such as spraying? The solution is a Rosand high pressure capillary rheometer, capable of achieving shear rates up to 10^8 s^{-1} .

Here, a spray coating substance was measured with both Kinexus and Rosand RH2000. At low shear rates, the material is shear-thinning. The faster the product is poured or mixed, it becomes less viscous. At the typical shear rates used for spraying ($\sim 10^6 \text{ s}^{-1}$), it shows a shear-thickening transition indicating this product is not suitable for spraying applications!

Simulation Data for Accelerated Development and Improved Part Quality

The use of simulation software to study the filling and cooling segments of the injection molding process is gaining importance. While flow curves are needed to predict mold filling, the cooling and accompanied shrinkage behavior can only be modelled with high quality Pressure-Volume-Temperature (pVT) data.

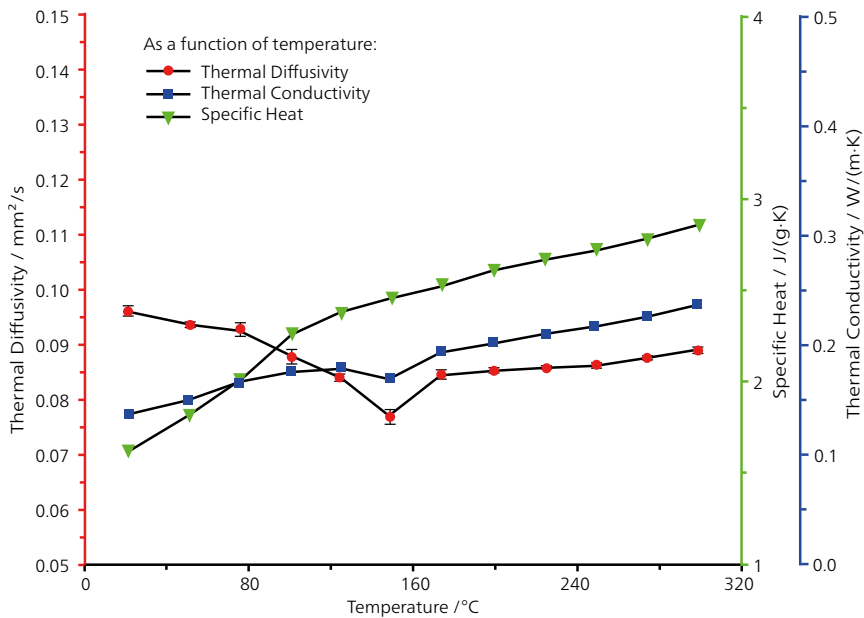
The graph to the right shows the pVT data of a HDPE measured with a Rosand RH10. This data enables prediction of the melt volume during filling. In addition, cooling under changing pressure conditions and mold sealing and ejection can also be determined. Isothermal compressibility of the material at different temperatures can also be deduced from such measurements.



Pressure-Volume-Temperature (pVT) data graph of a HDPE measured by isothermal compression, which yields both shrinkage and compressibility information as a function of pressure and temperature

Laser Flash Analysis

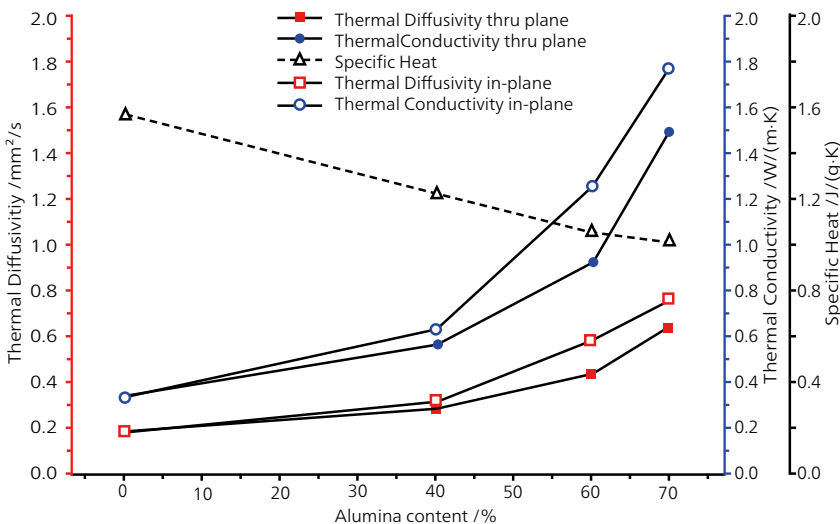
Determination of the Thermophysical Behavior Even in the Molten State



This measurement plot shows that the thermal diffusivity of a PP sample decreases significantly from 0.098 to 0.075 mm^2/s from room temperature to the onset of melting at 150°C (extrapolated onset of the melting peak from a DSC run). After melting, it reaches an almost constant value of 0.085 mm^2/s at 250°C. As expected, the specific heat capacity increases during heating: from 1.5 J/(g·K) at RT to 2.2 J/(g·K) at 90°C and, during softening and melting, from 2.3 J/(g·K) to 2.8 J/(g·K) at 250°C. Below and above melting, the resulting thermal conductivity shows an increase from 0.14 W/(m·K) to 0.2 W/(m·K) (250°C).

LFA measurement on PP between 20°C and 300°C;
sample thickness 1.05 mm, Ø 11.0 mm

Thermal Diffusivity and Thermal Conductivity of PA46 Filled with Al_2O_3 by Means of LFA

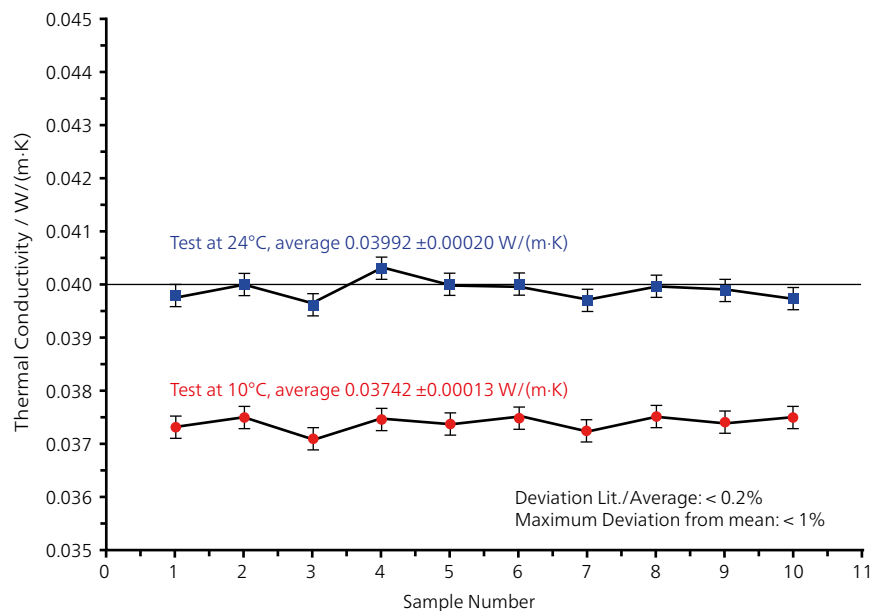


Thermophysical properties of filled PA46 depending on the alumina content at room temperature

The use of glass fiber and other reinforcements such as Al_2O_3 in highly crystalline PA types improve the mechanical properties (modulus, strength). These fillers also influence the thermophysical properties (TPP, thermal diffusivity/conductivity and specific heat capacity), which can be tested by means of LFA. Tests can be carried out in the thru-plane and the in-plane directions. For the in-plane tests, a special sample holder for laminates is available. In the case of nylons, only PA46 has a very low thermal conductivity. With an increasing filler content (here Al_2O_3), the specific heat capacity decreases while the thermal diffusivity and thermal conductivity increase.



Thermal Conductivity by Heat Flow Meter



Quality control of 10 EPS samples from the same batch between 10°C and 24°C; thickness 50 mm, HFM *Lambda* measurements, NIST 1450c calibration standard

Thermal Conductivity of Expanded Polystyrene Foam (EPS)

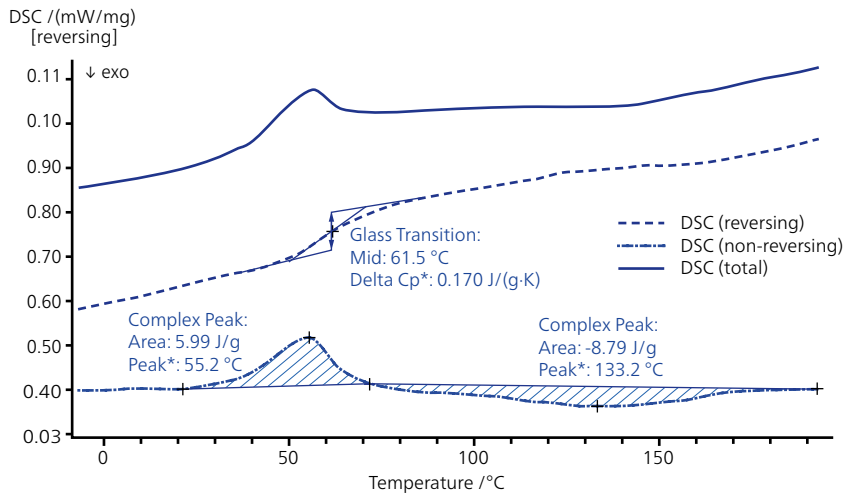
The tests shown here were of the typical quality control purpose types conducted on ten EPS samples from the same batch, to determine the thermal conductivity in accordance with DIN EN12667.

It can be seen that the thermal conductivity does not vary significantly from sample to sample. The values measured are around 0.04 W/(m·K), which is exactly the value specified for insulating materials in the datasheet.

The high test speed of the HFM allows for a large throughput to be tested. This becomes important if an insulating foam needs to be analyzed in accordance with DIN EN13163. In that procedure, the number of samples influences the $\lambda_{90/90}$ value which is determined from the test results.

Thermosets and Composites

Differential Scanning Calorimetry

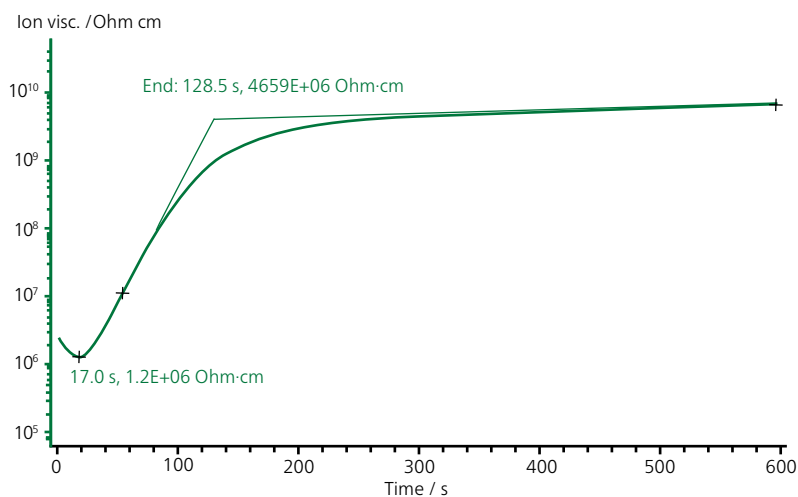


TM-DSC measurement of a polyurethane resin

Glass Transition and Curing of a PUR Resin

Temperature-Modulated Differential Scanning Calorimetry (TM-DSC) is a DSC technique in which the sample is subjected to a superposition of a linear and a periodic temperature program. With TM-DSC, it is possible to separate overlapping DSC signals by calculating the reversing and the non-reversing part. Glass transitions can therefore be well separated from other effects such as relaxation, curing, decomposition, evaporation or cold-crystallization processes.

The overlapping relaxation in the total DSC curve can be clearly separated from the endothermic glass transition (reversing) and exothermic curing (non-reversing) in a single run.



UV curing of a cationic epoxy resin at room temperature with the DEA at 1000 Hz

Fast UV Curing of an Epoxy Resin

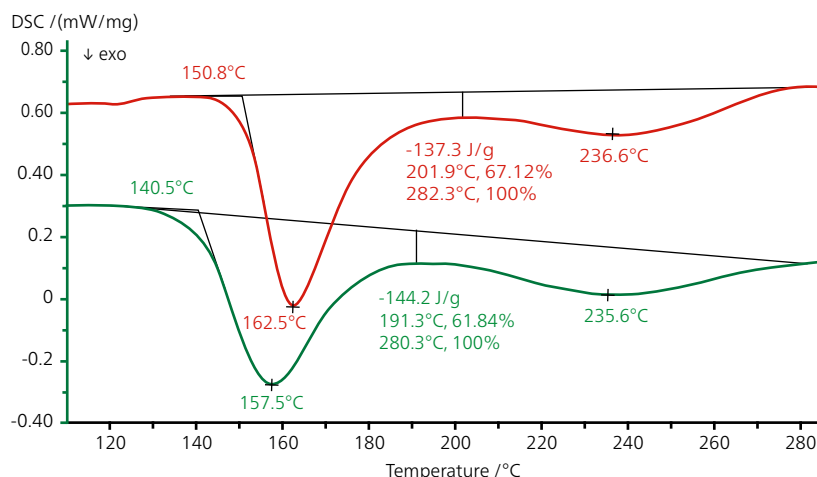
The fast curing of this epoxy adhesive can be observed with the DEA by using an IDEX sensor and applying a frequency of 1000 Hz. The UV light exposure (intensity 55 mW/cm² to 60 mW/cm²) was applied for 60 s on the sample layer, which was approx. 200 µm thick, at room temperature. After 17 s of light exposure, curing began. This was evidenced by the increase in ion viscosity. The adhesive was completely cured after approx. 350 s.

High-Pressure DSC

Polycondensation of Phenolic Resin

The curing reaction of phenolic resins is caused by polycondensation. The endothermal release of the polycondensation products overlaps the exothermal curing. In such cases, curing can only be investigated with standard DSC measurements using autoclaves, or with high-pressure DSC measurements.

This test example shows two phenolic resins measured with the DSC 204 HP *Phoenix*® under a practical pressure of 9 MPa (90 bar). The differences between these resins can be seen in the fact that curing begins at 141°C and 151°C (extrapolated onsets), respectively, as well as in the different results of the partial area evaluation.



DSC 204 HP: exothermal curing behavior of two phenolic resins under high pressure; sample mass: 10.5 mg; heating rate: 10 K/min; pressure: 9 MPa; atmosphere: inert

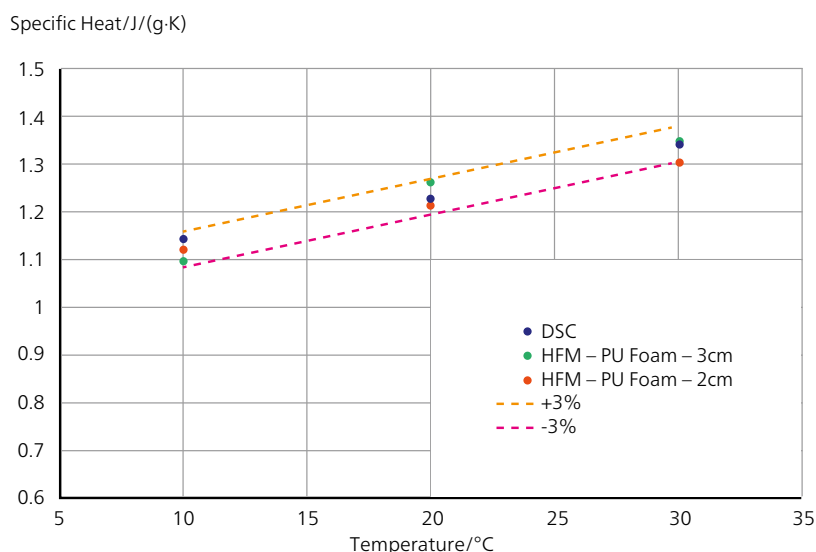
Heat Flow Meter

Specific Heat Capacity of a PU Foam

The plot compares the specific heat results for a PU foam between 10°C and 30°C (10 K steps) measured by DSC and HFM. The sample mass for the DSC test amounted to 10 mg; for the HFM tests, the sample masses were 38 g and 51 g, respectively.

The differences between the DSC and HFM results are less than 3%, which is within the stated uncertainty for the instruments and homogeneity of the material.

These tests show that the HFM is capable of determining the specific heat capacity of large-volume and inhomogeneous materials typical for applications in the building and insulation industries.



Comparison of the c_p test results on a PU foam obtained by DSC and HFM measurements. Sample thicknesses for the HFM tests were 2 cm and 3 cm, respectively.

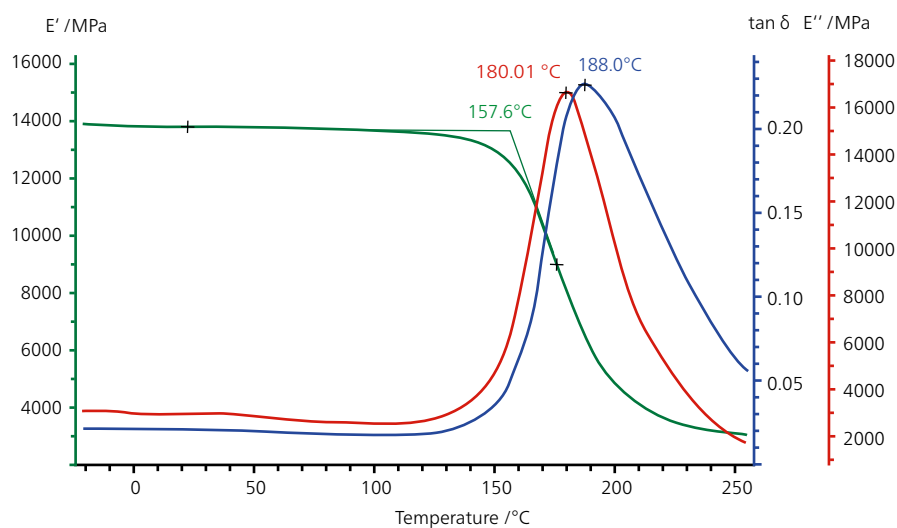


Dynamic Mechanical Analysis

Stiffness Determination

This example depicts the storage modulus E' (green), loss modulus E'' (red) and loss factor $\tan \delta$ (blue) of a carbon fiber-reinforced epoxy resin. The sample was measured in the bending mode at a frequency of 10 Hz and a heating rate of 3 K/min using the DMA. Prior to reaching 120°C, the material is even stiffer than titanium, at a value of 140,000 MPa.

At 158°C (extrapolated onset temperature of E'), the modulus drops due to the glass transition of the epoxy matrix. The corresponding peaks for E'' and $\tan \delta$ are at 180°C and 188°C, respectively.



DMA measurement on a high-modulus carbon fiber-reinforced epoxy resin

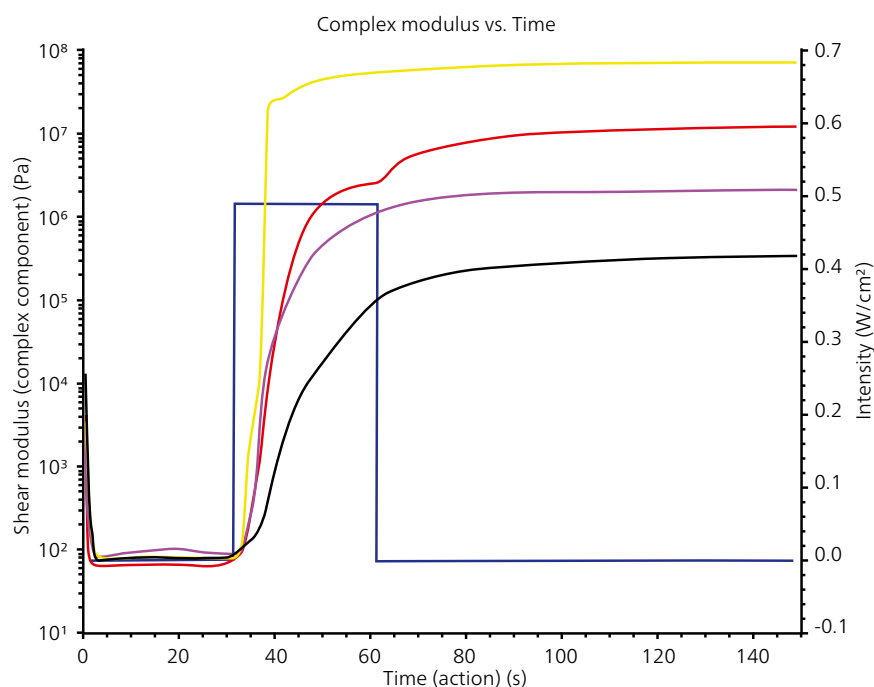
Rheology

UV-Curing Behavior of Pigmented Resins Analyzed by Rheology

The Kinexus rotational rheometer, equipped with a UV-curing accessory, was used to study the crosslinking behavior of pigmented UV-curable resins. Under constant UV exposure for 30 seconds, the system monitored the evolution of stiffness over time by tracking the material's shear modulus.

This test provides direct insight into crosslinking kinetics, which refers to the formation of covalent bonds that link polymer chains into three-dimensional networks. Significant differences in curing profiles were observed between formulations containing different pigments. Some samples reached a high modulus rapidly, indicating efficient network formation, while others exhibited slower crosslinking and lower final stiffness values due to the influence of pigment type and concentration on light penetration and cure efficiency.

Such rheological measurements are ideal for optimizing UV-curable formulations, especially in applications where precise control of curing speed and mechanical properties is critical.



The curing profiles of different pigmented UV-curable resins with time.

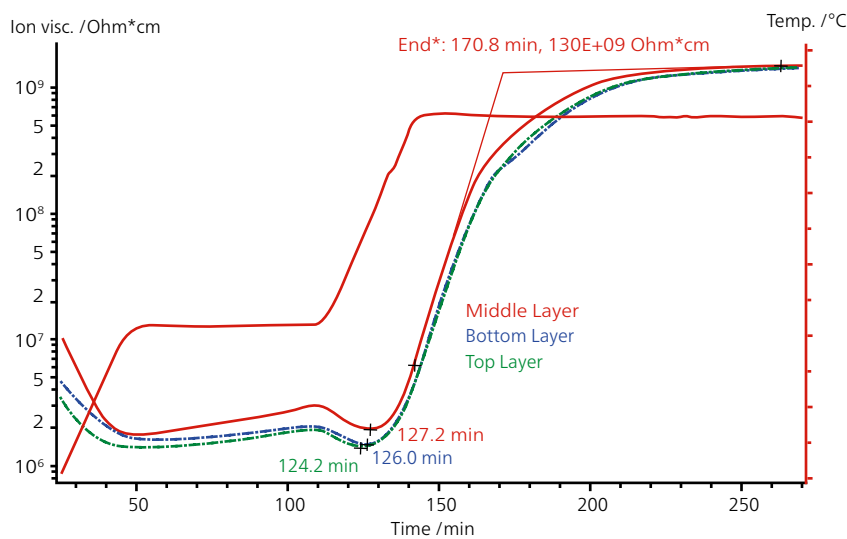
Dielectric Analysis

Cure Monitoring of a CF-Reinforced Epoxy Resin

After what amount of time or at what temperature does a curing reaction start? Is the thermosetting resin already fully cured? Such or similar questions are those that resin producers and thermoset processors would like to answer comprehensively.

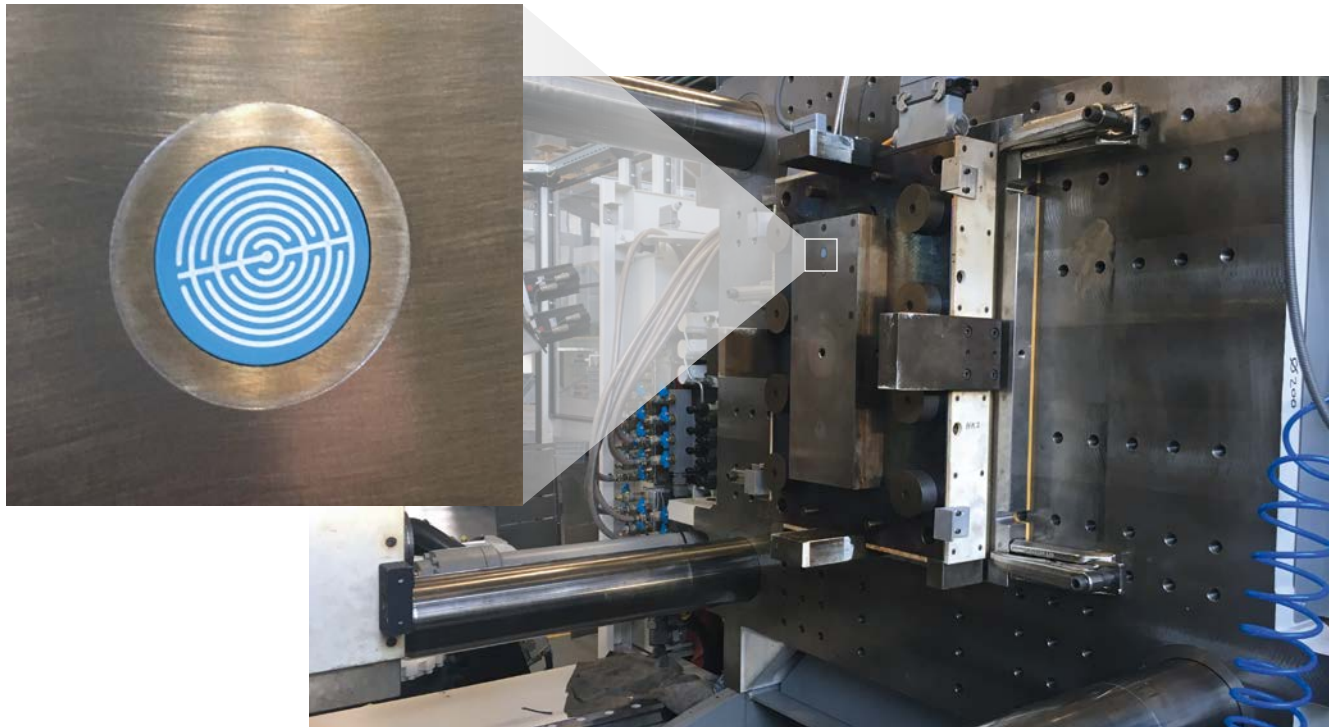
The plot depicts the curing of a carbon fiber-reinforced epoxy resin (DEA measurement) during Resin Transfer Molding (RTM) for aircraft applications. During a two-step temperature curing program, the

ion viscosity initially decreased due to the temperature increase. It then increased during the first isothermal segment, due to the start of curing. While heating to 180°C, the temperature increase counteracted with the curing so that the ion viscosity first decreased before curing began to dominate. Thereafter, the ion viscosity was recorded with a rising degree of cure. As soon as curing was completed, the ion viscosity reached a constant value (here evaluated as an extrapolated onset at $1.3 \times 10^9 \Omega\text{cm}$).



Dielectric analysis (DEA) with different IDEX sensor positions



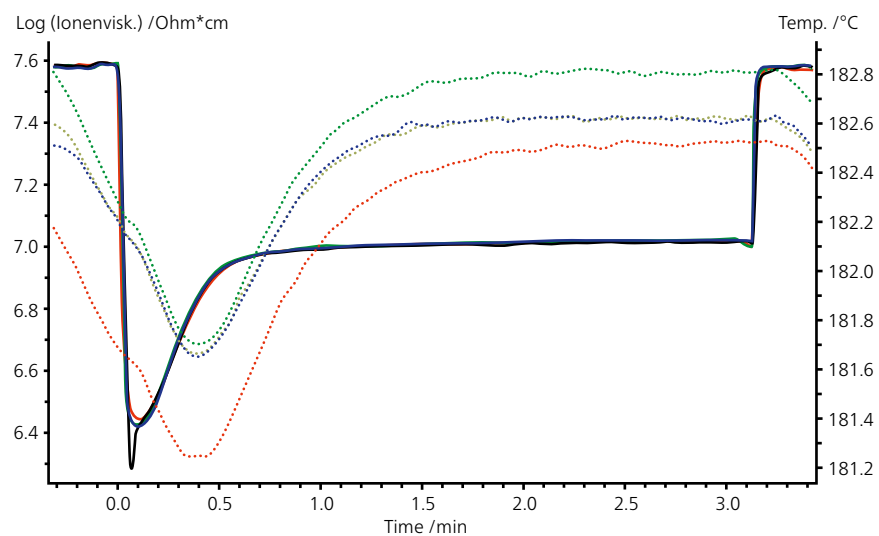


In-Process Cure Monitoring

The NETZSCH DEA 288 *Ionic* can be applied as a sensor for online cure monitoring during thermoset injection molding.

The upper pictures show the DEA sensor (blue area) integrated in a test mold applied in an injection molding machine.

The lower picture shows the ion viscosity signals for the four subsequent shots as a function of time. All shots show excellent agreement thus depicting perfect reproducibility of the process conditions used.



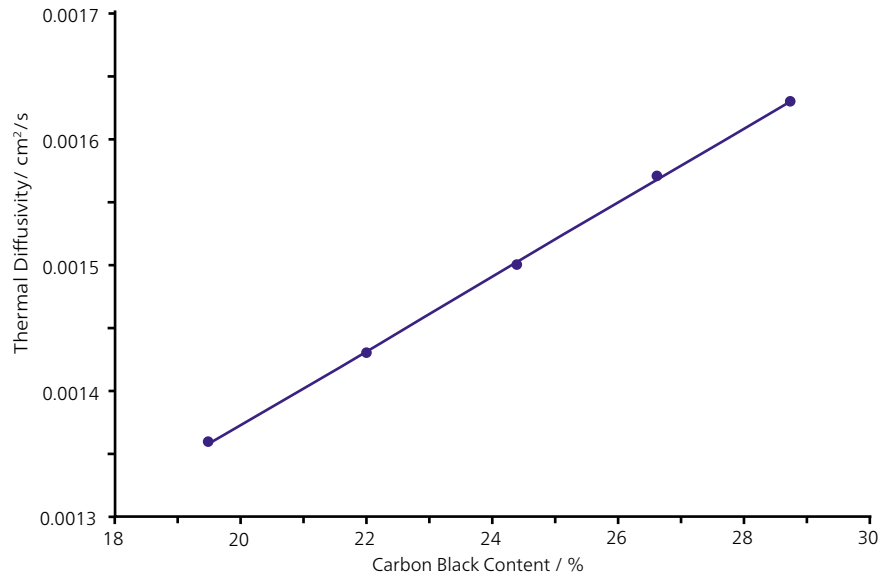
Curing Behavior of a thermoset during molding process; mold temperatures are represented in solid lines, ion viscosity as dotted curves

Elastomers

Laser Flash Analysis

Influence of Carbon Black on Thermal Diffusivity in a Rubber Compound

The flash method also offers a fast solution for determination of the effect of the filler content on the thermal conductivity of a polymer. This example on NR shows the linear correlation of the thermal diffusivity, measured at room temperature, and the carbon black content of a rubber mixture. With an increasing carbon black content, the thermal diffusivity rises.

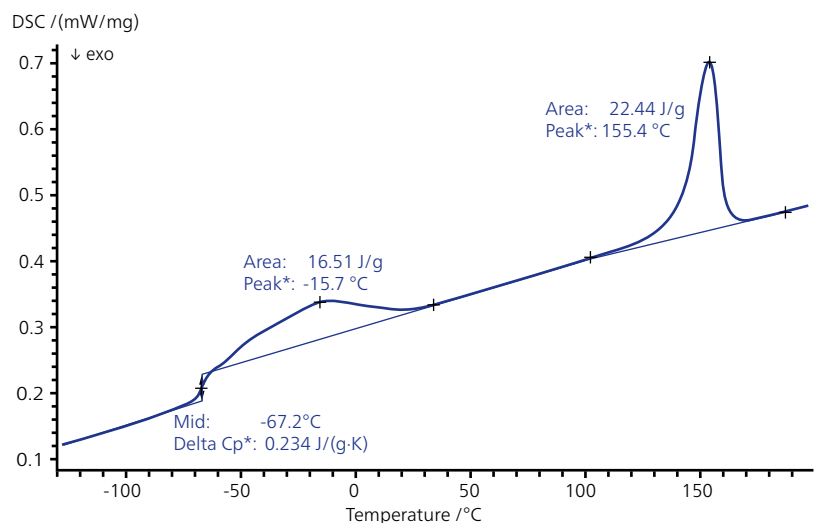


LFA measurement: thermal diffusivity of rubber mixtures filled with different quantities of carbon black at room temperature

Differential Scanning Calorimetry

Brittleness Point

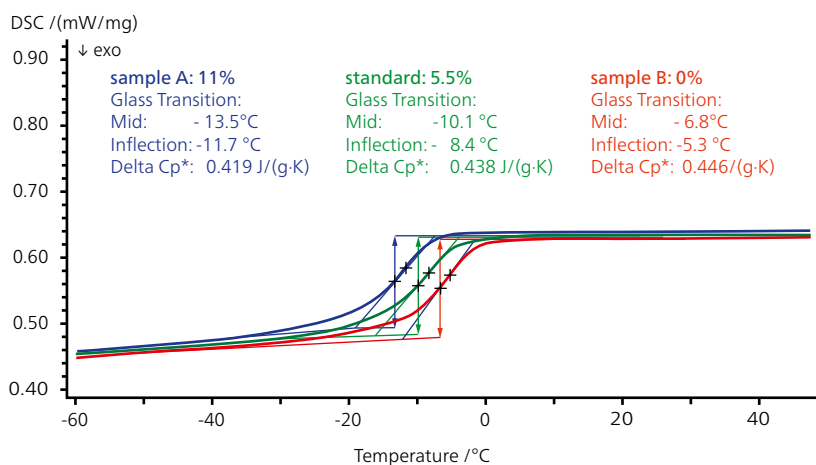
This DSC measurement was carried out on an SEBS+PP blend at a heating rate of 10 K/min. The SEBS component shows the glass transition temperature of the soft segments at -67°C. Melting of the hard segments occurs at -16°C. These effects are followed by melting of the PP component at 155°C. The glass transition temperature correlates with the brittleness point (DIN EN ISO 11357). This is a material property that is required by the automotive industry.



DSC measurement of the thermoplastic elastomer SEBS+PP

Differential Scanning Calorimetry, Thermogravimetry and Gas Analysis

Plasticizer Influence on the Cold Flexibility



DSC measurements on NBR. With increasing plasticizer contents, the glass temperature is shifted to lower values; sample masses ≈ 10 mg; heating rate 20 K/min

Plasticizers or dispersants are additives which increase plasticity or fluidity of a material. When cooled below the glass transition temperature, the viscous chain segments "freeze" into fixed geometries and the rubber abruptly loses its high elasticity, although the process is reversible. The DSC method offers fast and reliable tests for investigating the influence of the plasticizer content in rubbers.

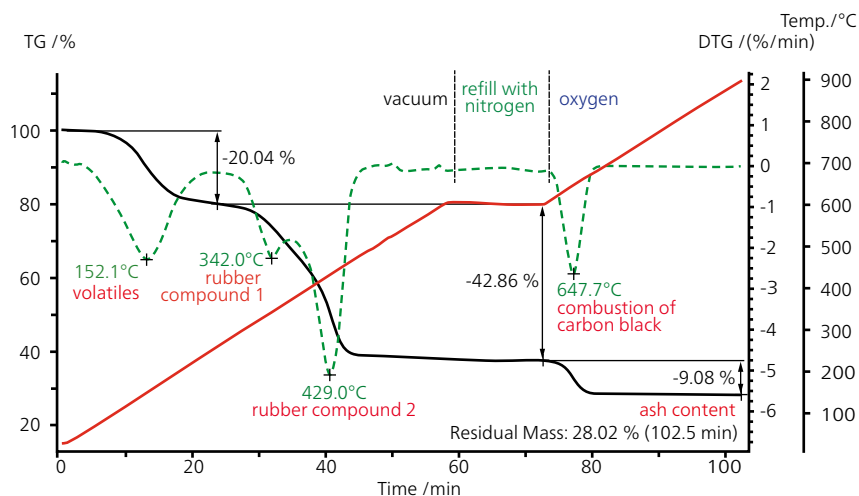
These measurements were carried out on three NBR samples differing in their plasticizer content. It can be observed that modification of the NBR plasticizer content yields different glass transition temperatures. The cold flexibility can be improved by increasing the plasticizer content.



Comprehensive Rubber Characterization

Clear separation and precise identification of rubber compounds can be achieved by using the vacuum capability of the TG 309 *Libra*® series. Under vacuum, the boiling point of the volatiles is reduced, which leads to their release at lower temperatures while the decomposition of the rubber components is shifted by an insignificant amount.

In the first measurement segment, the plasticizer release (152°C, DTG peak) is clearly separated from the decomposition of the two rubber components at 342°C and 429°C (DTG peaks). After decomposition of the rubber components at 600°C, the TGA system is refilled with nitrogen under isothermal conditions. In the following step, the atmosphere is changed to oxygen, which leads to the immediate combustion of carbon black (9%) under increasing temperatures (remaining ash content 28%).

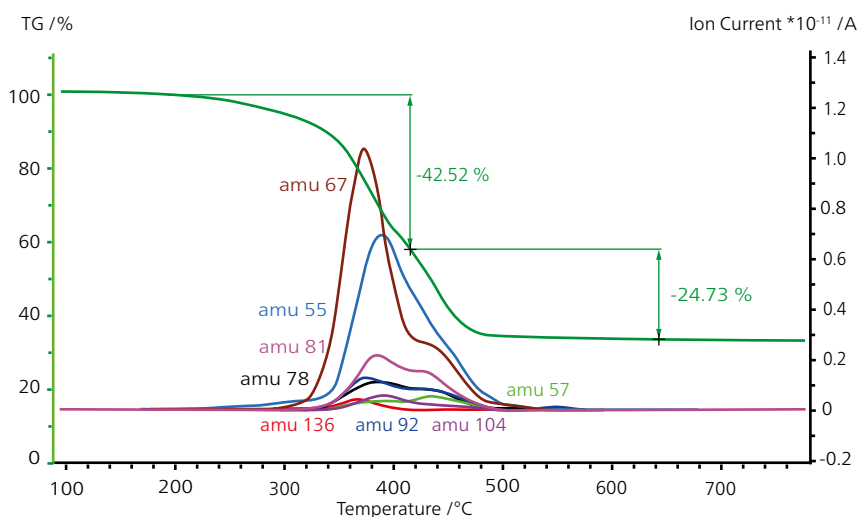


TGA measurement on a rubber mixture under vacuum and back-filling with nitrogen followed by combustion of carbon black in oxygen; sample mass 10.05 mg; heating rate 10 K/min; Al_2O_3 crucible

Classification of the Gases Evolved During Rubber Decomposition: Plasticizer and PAHs by Means of Gas Analysis Coupled to TGA

Coupling of gas analyzers such as mass spectrometers to TA methods allows for the chemical identification of the evolved gases. An example of a question here would be whether the rubber releases potentially carcinogenic polycyclic highly aromatic hydrocarbons (PAHs).

During heating of the rubber sample to 800°C, two mass-loss steps of 42.5% and 24.7% were observed. From the MS signals (only a few exemplary mass numbers are shown), conclusions can be drawn as to which organic molecules evolved at which temperature. For example, at 350°C, mass number 67 (most probably due to C_5H_7) indicates the release of the plasticizer.



STA-MS measurement detects evolved gases during decomposition of a tire sample



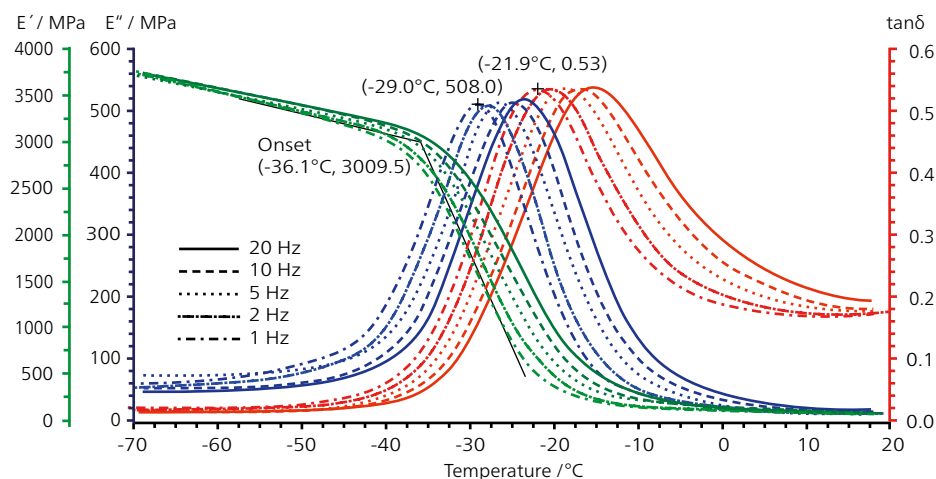
Dynamic Mechanical Analysis

Influence of the Frequency on the Glass Transition Temperature of an SBR Rubber Mixture by Means of DMA

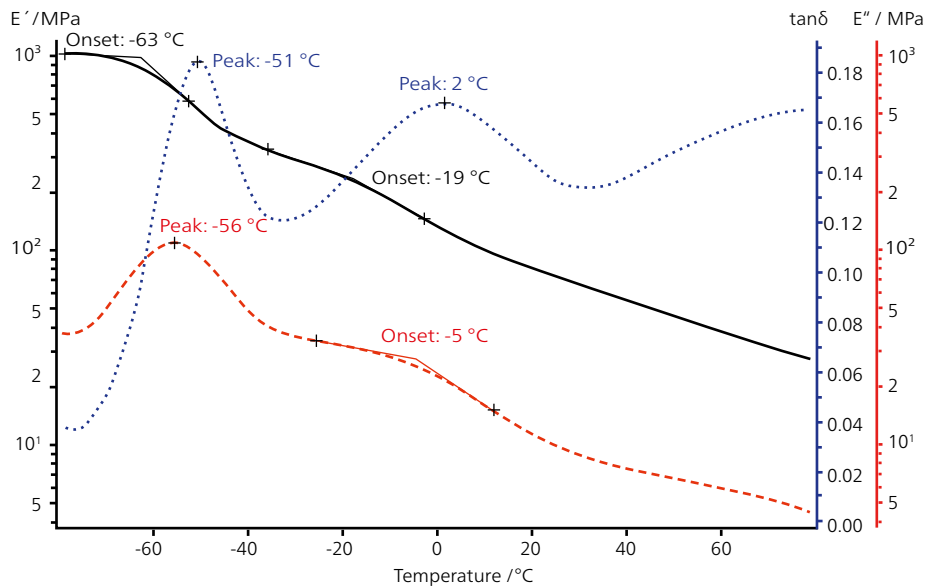
The modulus and damping factor are the main viscoelastic properties of polymers measured by DMA. The storage modulus, E' , is a measure of the stiffness and is temperature-dependent. The mechanical damping ($\tan \delta$, internal friction) of filled rubbers is highly relevant for such functions as the wet grip behavior of a tire or the seal behavior of an O-ring.

This example of an SBR (styrene butadiene rubber) mixture shows that at low temperatures (-70°C to -45°C), the loss factor $\tan \delta$ is also very low, because there is so little free volume in the polymer that polymer segments are not able to move at all. This results in a low energy dissipation and the polymer transitions into the glassy state with a high storage modulus (high elasticity and high stiffness).

As temperature increases, the polymer segments also exhibit increased movement, thus yielding high values for loss modulus (E'') and $\tan \delta$ with a maximum at the glass transition. Increasing frequencies shift these peak temperatures for the glass transition to higher temperatures. Additionally, higher E' values are obtained with increasing frequencies.



DMA measurement of the viscoelastic properties of an SBR rubber mixture: storage modulus (E' , green), loss modulus (E'' , blue) and damping factor ($\tan \delta$, red) as a function of frequency; heating rate 2 K/min



DMA measurement of the thermoplastic elastomer EPDM+PP

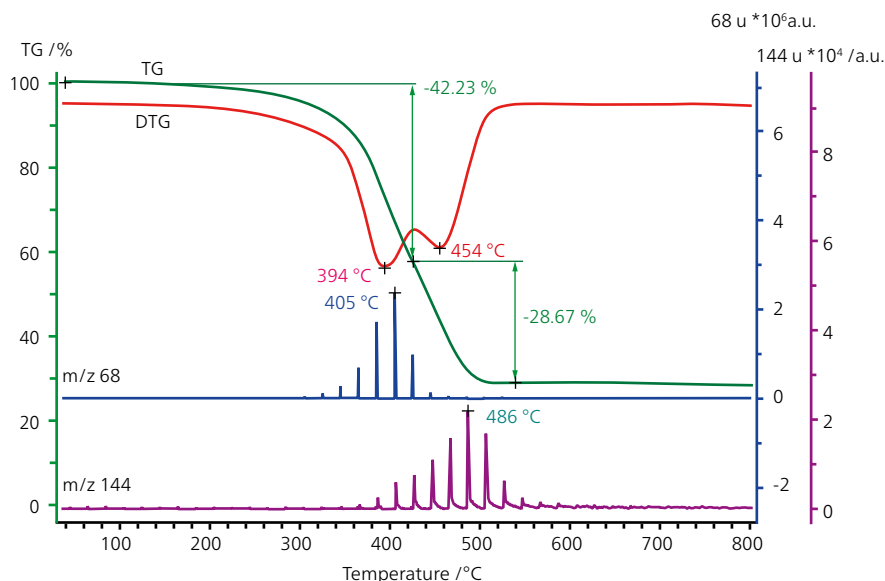
Viscoelastic Properties of a TPE

DMA is a valuable tool for determining the viscoelastic properties of TPE materials. The plot exhibits a DMA measurement on Santoprene®.

This TPE is a blend of EPDM rubber and the semi-crystalline polypropylene (PP) thermoplastic. The DMA measurement was carried out between -80°C and 80°C at a frequency of 1 Hz. Depicted in the plot are the storage modulus (E'), loss modulus (E'') and loss factor (tan δ). The glass transition of the EPDM component can be observed in E' at -63°C (E', onset), again in E'' at -56°C (peak) and finally in tan δ at -51°C (peak). Subsequently, the glass transition of the PP component can be also observed in E' at -19°C (onset), again in E'' at -5°C (also onset), and finally in tan δ at 2°C (peak).

Evolved Gas Analysis

TGA-GC-MS Measurement for Significantly Improved Interpretation of Organic Vapors



Identification of the gases evolving during decomposition of a rubber mixture; sample mass 5.28 mg; heating rate 20 K/min; 1 min injection intervals

The very high-sensitivity TGA-GC-MS coupling yields information on the composition of evolved gases. Separation of the volatiles is made possible by use of the GC column.

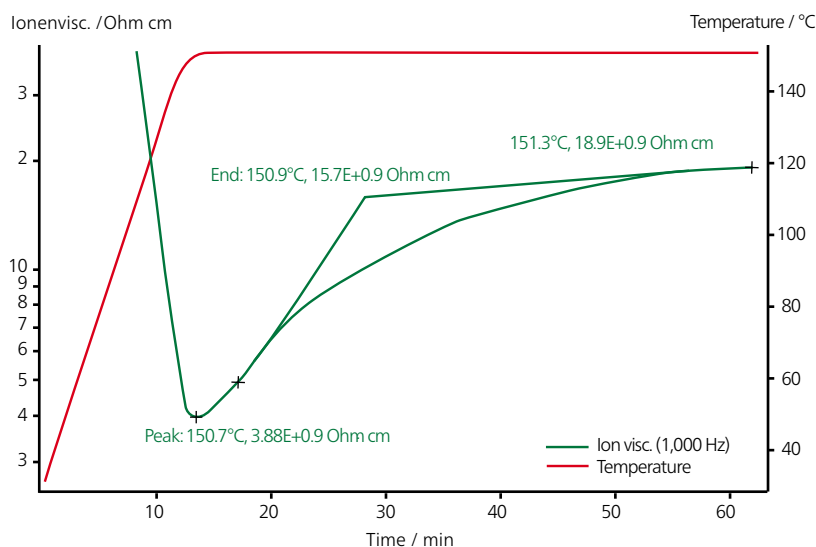
The plot depicts a measurement on NR/SBR rubber. The GC-MS was operated with a fixed column temperature (250°C) and short injection intervals of 1 min. The TGA and DTG curves indicate an overlapping decomposition of the individual rubber components. However, the evolved gases can be identified in good temperature and time correlation with the TGA and DTG results. The DTG peak at 394°C is due to the release of isoprene (1,3-butadiene, 2-methyl, m/z 68) which is typical for NR. The DTG peak at 454°C corresponds to the release of C₁₁H₁₂ (1-cyclopentene-1-yl-benzene, m/z 144) which is representative of the SBR component.

Dielectric Analysis

Cure Monitoring of EVA

The EVA copolymer is used for encapsulation of electric devices. As the polymerization reaction is irreversible, the thermal treatment is crucial in the encapsulation process.

The plot presents the sample behavior of the ion viscosity at 1 Hz. The cross-linking reaction from using peroxide was observed under isothermal conditions at 150°C. The subsequent increase in ion viscosity correlates with the increase in the degree of cure. After 60 min, the ion viscosity remains nearly constant, which indicates that the cross-linking reaction has practically terminated.



Multi-frequency test on EVA was carried out at frequencies between 1 Hz and 10000 Hz while monitoring the ion viscosity (Ωcm). The plot shows the measurement at 1 Hz at 150°C.

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NETZSCH-Gerätebau GmbH
Wittelsbacherstraße 42
95100 Selb, Germany
Tel.: +49 9287 881-0
Fax: +49 9287 881-505
at@netzsch.com
<https://analyzing-testing.netzsch.com>



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www.netzsch.com