

Thermal Analysis Excellence



**STAR® System**

Innovative Technology

Versatile Modularity

Swiss Quality

**The Future**  
of Thermal Analysis

**METTLER TOLEDO**

# Materials Characterization

## Tailored Exactly to Your Needs

**METTLER TOLEDO's thermal analysis Excellence line offers tailor-made solutions for a wide-range of academic and industrial applications. Including techniques such as DSC, TGA, TMA and DMA, its unrivalled performance and innovative technology will propel you to the forefront of your field and guarantee you the highest level of Swiss quality, accuracy and efficiency.**

**Features and benefits of METTLER TOLEDO thermal analysis instrumentation:**

- **Modular concept** – tailor-made solutions for current and future needs
- **High performance instruments** – accurate analysis of a wide variety of samples
- **Reliable automation** – high sample throughput with result assessment dramatically improves efficiency
- **High-level competence and support** – training courses and applications literature fosters knowledge sharing and growth
- **Global Services** – prompt response and maintenance contracts guarantee maximum system uptime





METTLER TOLEDO sets the standards in thermal analysis for DSC, TGA, TMA and DMA.

► [www.mt.com/ta-techniques](http://www.mt.com/ta-techniques)

# Intelligent Innovations for Modern Materials Analysis

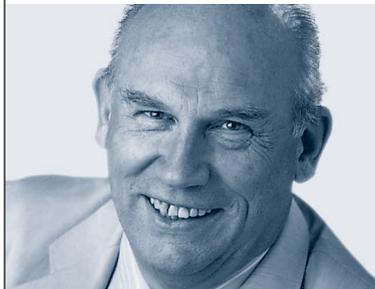
**METTLER TOLEDO is a global manufacturer of precision instruments for use in laboratory, industrial and food retailing applications. Our products and services are available worldwide in over one hundred countries. With more than 16,000 employees, most of them in sales, service and development, we guarantee customers unique products and the highest level of support.**

## **METTLER TOLEDO foundation**



In 1945, Dr. Erhard Mettler, a Swiss engineer, founded a precision mechanics company, which ultimately became the now renowned METTLER TOLEDO company. He laid the foundation for the successful balance business and invented the substitution principle with a single-pan balance. In 1973, the company introduced the first electronic balance with electromagnetic force compensation.

## **History of thermal analysis**

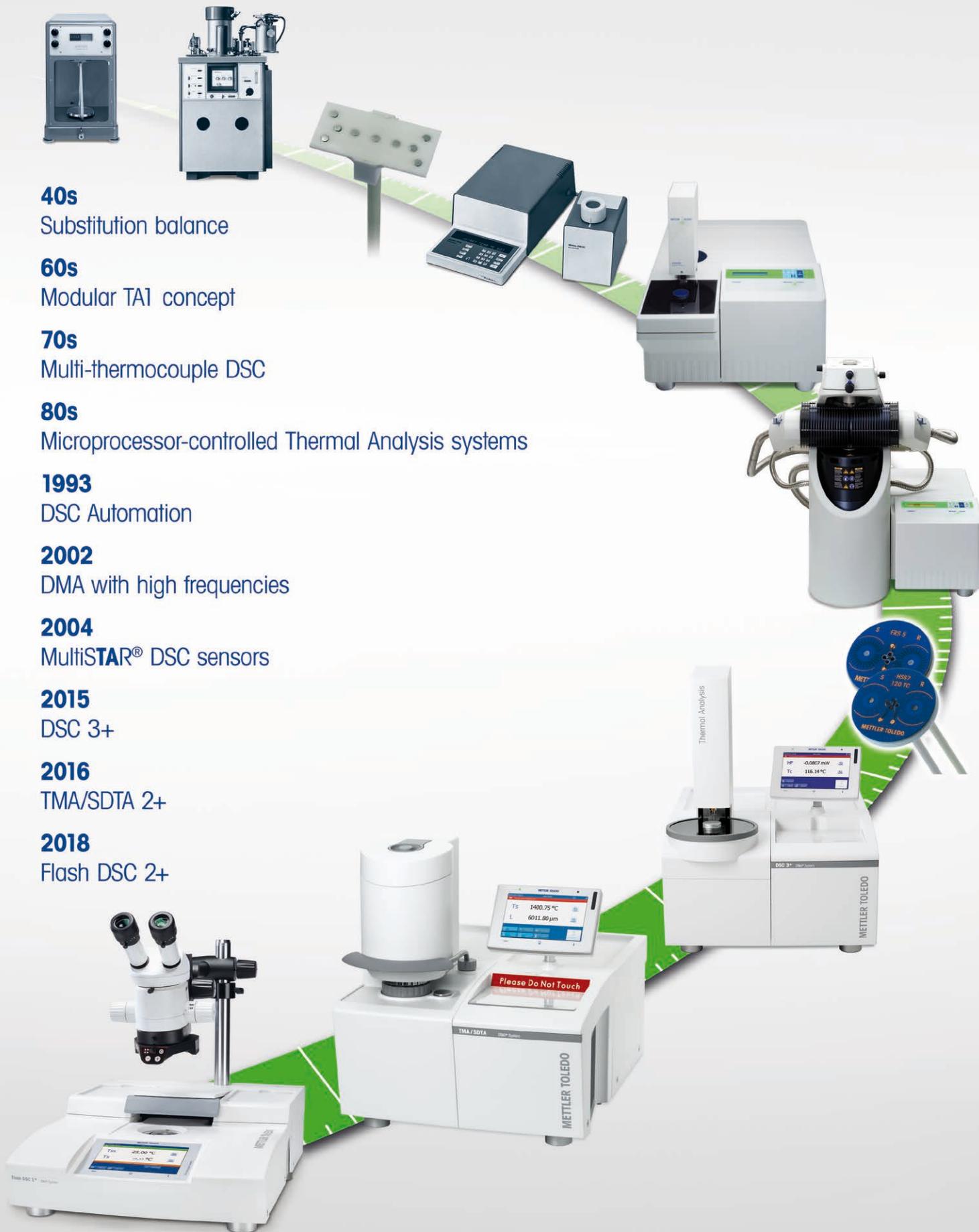


Dr. Mettler also strongly promoted thermal analysis. In the early 1960s, Dr. Hans-Georg Wiedemann, an East German scientist, convinced him to combine the advanced weighing technology with a furnace in order to measure weight changes as a function of temperature. This led to the introduction of the first commercially available TGA/DTA system, the TA1, in 1964.

## **Technology and innovation**



The first commercially available thermal analysis system, the TA1, was a sweeping success. Its modular construction allowed it to be used in many different fields of application. Attention to detail and commitment has shaped thermal analysis at METTLER TOLEDO right through to the present day and has led to unique products and services in the market place.



**40s**

Substitution balance

**60s**

Modular TAI concept

**70s**

Multi-thermocouple DSC

**80s**

Microprocessor-controlled Thermal Analysis systems

**1993**

DSC Automation

**2002**

DMA with high frequencies

**2004**

MultiSTAR® DSC sensors

**2015**

DSC 3+

**2016**

TMA/SDTA 2+

**2018**

Flash DSC 2+

Thermal analysis has played an important role in METTLER TOLEDO since the early 1960s. Since the beginning, we have offered customers innovative thermal analysis solutions, products and services. Our dedicated worldwide team of highly qualified sales and service engineers are ready to assist you.

► [www.mt.com/ta](http://www.mt.com/ta)

# Unmatched TA Performance

## Tailored Exactly to Your Needs

**Face your new analytical challenges with an open mind: Based on a modular concept, the STAR<sup>e</sup> systems can be configured according to the needs of the intended application. Should your requirements change after installation, the device can be individually upgraded as needed.**

### Performance



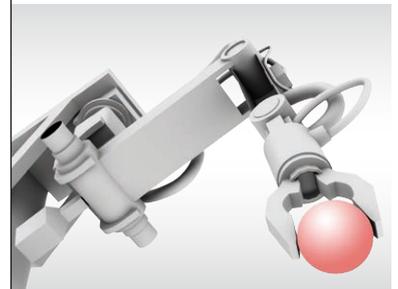
Put your trust in METTLER TOLEDO's world-leading sensor technology: Whether DSC, Flash DSC, TGA, TMA or DMA, we guarantee unmatched sensitivity for highly accurate measurement results.

### Competence



Benefit from our 50 years of experience: attend one of our sought-after training courses, download free educational material and take advantage of the possibilities offered by our amazing solutions.

### Automation



Have total confidence in our robust and reliable automation solutions. Unattended measurements and automatic evaluation of results and report generation greatly simplify laboratory workflows and enhance efficiency.



The DSC and TGA automatic sample robot runs reliably and precisely, 24 hours a day, day in, day out, just like a Swiss watch.

► [www.mt.com/ta-automation](http://www.mt.com/ta-automation)

# Differential Scanning Calorimetry

## Unsurpassed DSC Performance

Differential scanning calorimetry (DSC) measures the heat flow produced in a sample when it is heated, cooled, or held isothermally at a constant temperature. From all thermal analysis techniques, DSC is the most frequently used in routine and high performance-applications alike.

### DSC sensor technology



The benchmark for DSC sensors is the widely used TAWN test. The test confirms the excellent sensitivity and high temperature resolution of the HSS 9+ and FRS 6+ sensors.

### High versatility

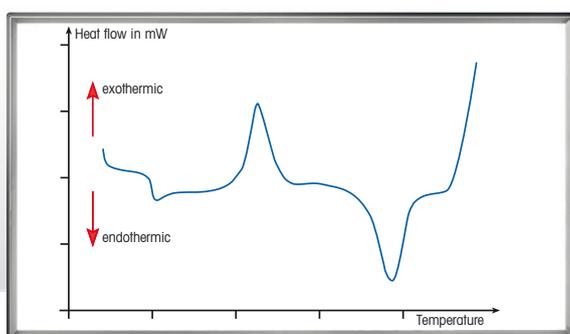
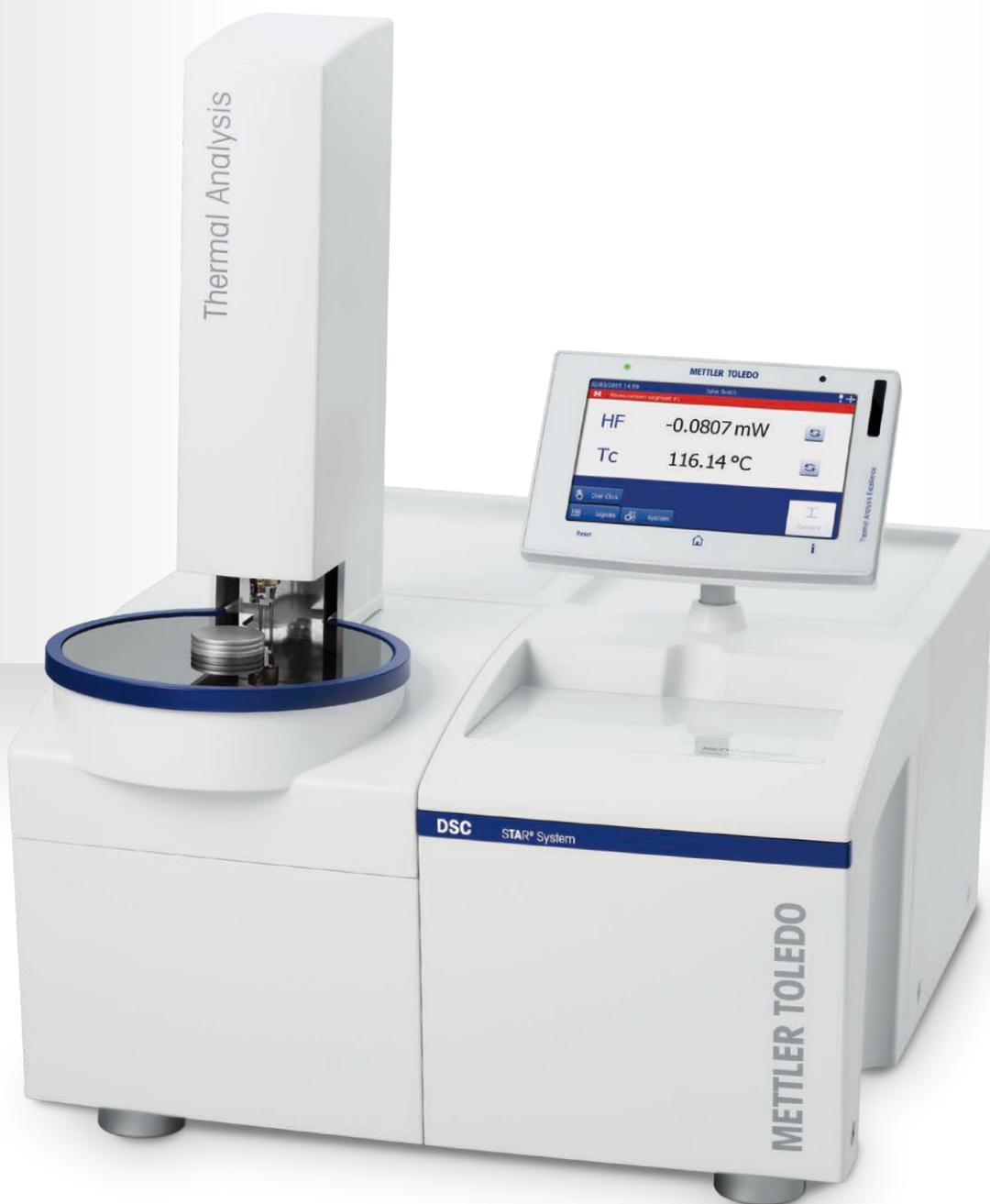


DSC instruments can be combined with several options such as photocalorimetry, microscopy, or chemiluminescence.

### Unique lid piercing device



Hermetically sealed crucibles are automatically opened prior to measurement.



Differential scanning calorimetry (DSC) allows you to determine the energy absorbed or released by a sample as it is heated, cooled or held at constant temperature.

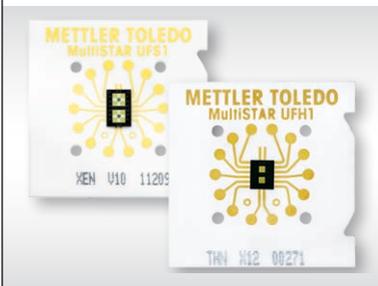
► [www.mt.com/ta-dsc](http://www.mt.com/ta-dsc)

# A Quantum Leap in Innovation

## Revolutionary Chip Sensor Technology

**Flash DSC revolutionizes the field of rapid-scanning DSC; the instrument can detect reorganization processes that were previously impossible to measure and is thus the ideal complement to conventional DSC. Heating rates now cover a range of more than 7 decades.**

### High-temperature UFH 1 and standard UFS 1 sensors



The UFS 1 sensor is equipped with 16 thermocouples for high sensitivity and excellent temperature resolution. The newly developed UFH 1 sensor permits measurements in a wide temperature range from  $-95$  to  $1000$  °C. Due to the extremely short time constant of about  $0.2$  ms, much higher heating and cooling rates of  $3'000'000$  and  $2'400'000$  K/min, respectively, are achieved.

### Oxygen-free conditions

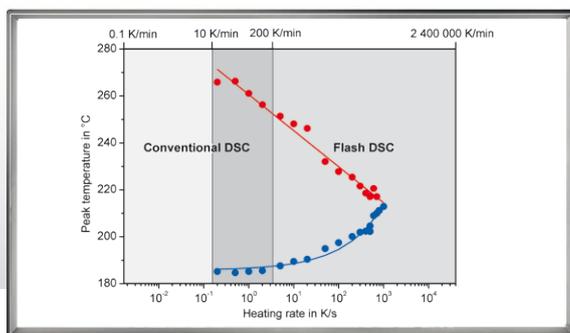


The wide operating temperature range allows transformations in various materials to be investigated. Some of them, for instance metals, react with oxygen (especially at high temperatures).

### Reusable chip sensors



Sensors with the adhered sample can be changed in less than a minute and afterward safely stored in the chip sensor box supplied.



In Flash DSC, the sample is placed directly onto the MultiSTAR™ chip sensor. The patented dynamic power compensation control circuit allows measurements to be performed at high heating and cooling rates.

► [www.mt.com/ta-flashdsc](http://www.mt.com/ta-flashdsc)

# Thermogravimetric Analysis

## With Balances from the Market Leader

**TGA/DSC is an exceptionally versatile instrument for the characterization of physical and chemical material properties under precisely controlled atmospheric conditions. It provides valuable information for research, quality control, and development. The TGA is equipped with a top-of-the-line METTLER TOLEDO ultra-micro balance; this includes unique built-in calibration ring weights for unparalleled accuracy.**

### MultiSTAR™ TGA/DSC sensors



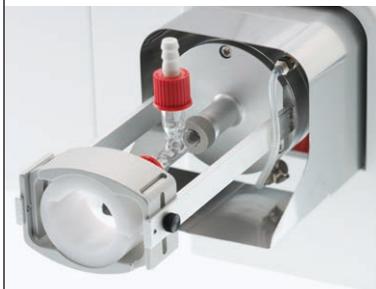
METTLER TOLEDO's TGA/DSC system can be equipped with one of three MultiSTAR sensors to permit simultaneous capture of DSC heat flow data and TGA weight loss data.

### METTLER TOLEDO "Inside"

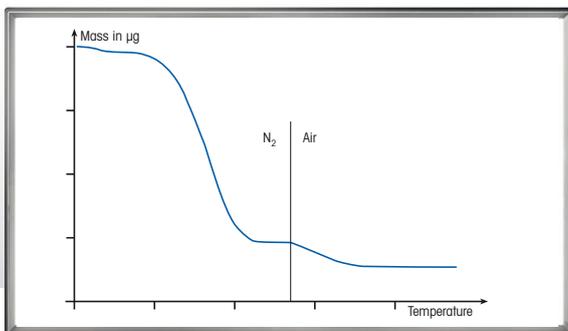


The heart of a TGA is the balance cell. Our TGA instruments use the world's best METTLER TOLEDO micro and ultra-micro balances.

### Hyphenated solutions



Acquire more information from a single run: All TGA models can be coupled to a humidity generator, a mass spectrometer, an FTIR spectrometer, a GC/MS-system or a Micro GC/MS to enable greater insight into a material's thermal properties and behavior.



Thermogravimetric analysis (TGA) measures the mass of a sample as it is heated, cooled or held at constant temperature in a defined atmosphere.

► [www.mt.com/ta-tga](http://www.mt.com/ta-tga)

# Thermomechanical Analysis

## Accurate, Straightforward and Fast

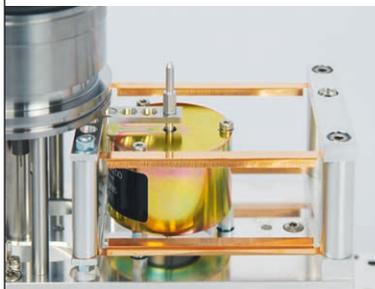
**METTLER TOLEDO's Thermomechanical Analyzer (TMA) incorporates Swiss precision mechanics and is available in four versions with furnace systems optimized for measurements between  $-150$  and  $1600$  °C.**

### **SDTA – simultaneous measurement of thermal effects**



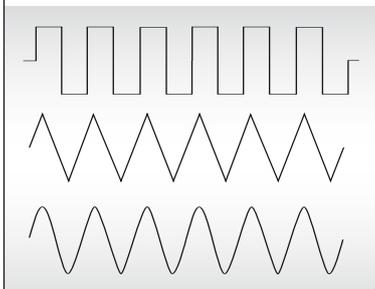
The TMA/SDTA 2+ is the only instrument on the market that measures the sample temperature very close to the sample in all operating modes.

### **Parallel-guided measuring sensor**

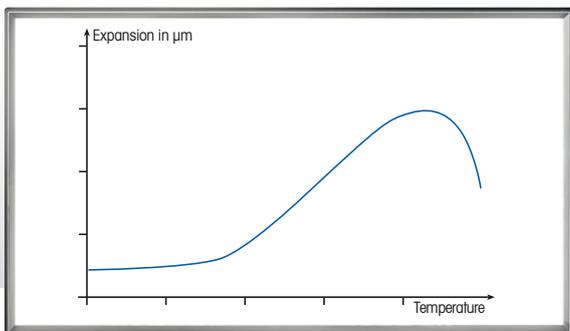


Thanks to this patented mechanical design, the parallel-guided measuring probe moves up and down without friction, ensuring that the results are of high quality.

### **DLTMA mode measures weak effects**



The DLTMA mode is very sensitive to changes in Young's modulus caused by the thermal effects of the sample such as the glass transition, curing, and melting.



Thermomechanical analysis (TMA) measures the dimensional changes of a sample as it is heated or cooled in a defined atmosphere.

► [www.mt.com/ta-tma](http://www.mt.com/ta-tma)

# Dynamic Mechanical Analysis Sets New Standards

The dynamic mechanical analyzer (DMA) with its revolutionary technology provides previously unattained performance and offers time-saving external sample clamping.

## Unsurpassed measurement results



The DMA/SDTA 1+ measures both force and displacement; this guarantees high accuracy because the instrument records the force actually applied to the sample.

## Flexible positioning of the measuring Head



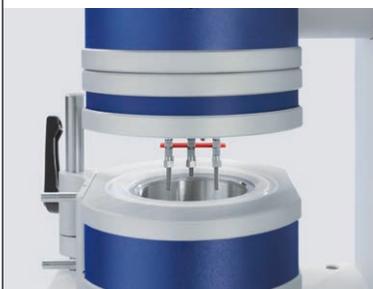
A unique aspect of the DMA 1 is its rotatable measuring head. Measurements can be carried out in all standard deformation modes, even in liquids or at defined relative humidity levels.

## Force measurement using a piezoelectric crystal



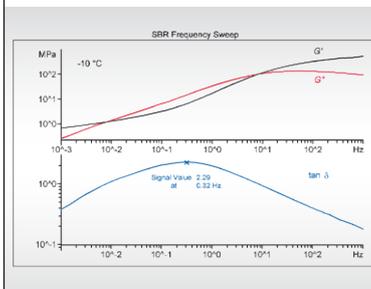
Force is measured directly by means of a piezoelectric crystal and is not set using a force-current graph as in conventional DMA instruments.

## Unmatched versatility



The unparalleled versatility of the DMA 1 allows applications to be performed in the optimum measurement configuration. The DMA 1 is quick and easy to set up, whether for conventional DMA analyses, static-force experiments or measurements in liquids.

## Wide frequency range from 0.001 to 1000 Hz

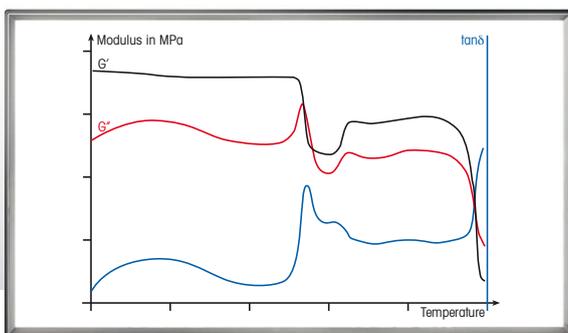


The frequency range has been extended to the kHz region for the first time ever in a DMA instrument. In the shear mode, six decades are available.

## Unsurpassed cooling capability



The DMA 1 boasts an impressive cooling performance: Samples can be cooled from room temperature to  $-190^{\circ}\text{C}$  in less than 10 minutes with an extremely low consumption of liquid nitrogen – less than 1 liter for 3 cooling cycles to  $-100^{\circ}\text{C}$ .



Dynamic mechanical analysis (DMA) measures the mechanical properties of viscoelastic materials as a function of time, temperature and frequency when they are deformed under a periodic stress.

► [www.mt.com/ta-dma](http://www.mt.com/ta-dma)

# Extremely Wide Application Range For All Possible Sample Types

**Thermal analysis includes a number of versatile techniques and is firmly established as an analytical method for materials characterization.**

Thermal analysis solves problems and answers questions from re-search and development to quality control.

The table illustrates the diversity of thermal analysis applications. A number of applications are de-scribed to support this.

	<b>Organic compounds</b>	<b>Technology</b>
	Chemicals Intermediates	Composition Content Purity Content and influence of fillers Effects of moisture Storage stability Safety investigations Process control
	<b>Inorganic compounds</b>	
	Minerals Ceramics Metals	
	<b>Pharmaceuticals</b>	<b>Chemical changes</b>
	Drugs Formulations Excipients	Decomposition Pyrolysis Oxidation Stability Reaction process Reaction enthalpy and kinetics Curing Vulcanization
	<b>Petrochemicals</b>	
	Oils Fats Bitumens	
	<b>Plastics</b>	<b>Phase changes</b>
	Thermoplastics Elastomers Thermosets	Melting/Crystallization Vaporization Drying Adsorption Polymorphism Crystalline transitions Glass transition Liquid-crystalline transitions
	<b>Foodstuffs</b>	
	Fats Proteins Carbohydrates	
	<b>Materials</b>	<b>Physical properties</b>
	Composites Adhesives Coatings	Specific heat capacity Expansion coefficient and behavior Viscoelastic behavior Elastic modulus

# Thermal Analysis Applications

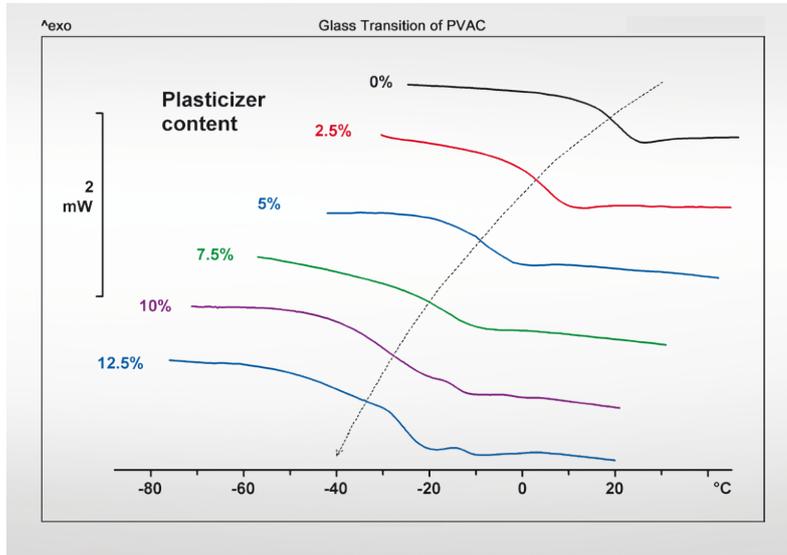
Hundreds of interesting articles on thermal analysis



More than 600 applications can be downloaded from our searchable database.

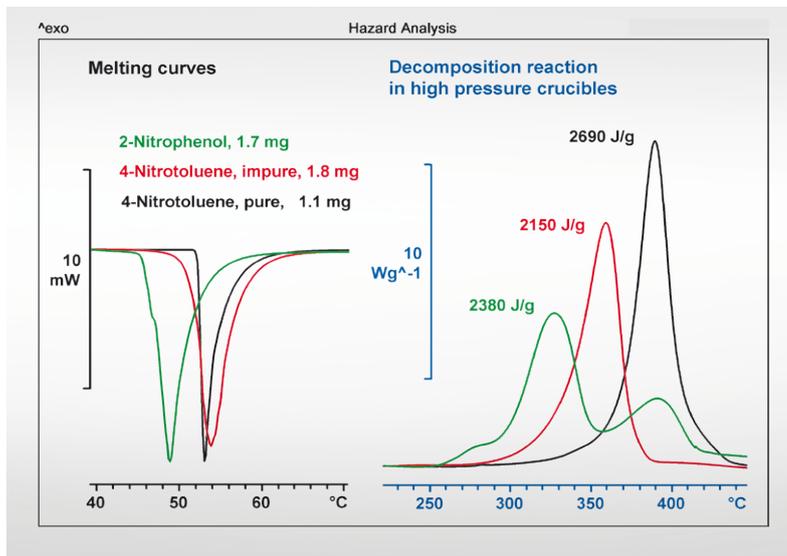
► [www.mt.com/ta-applications](http://www.mt.com/ta-applications)

### Influence of plasticizers by DSC



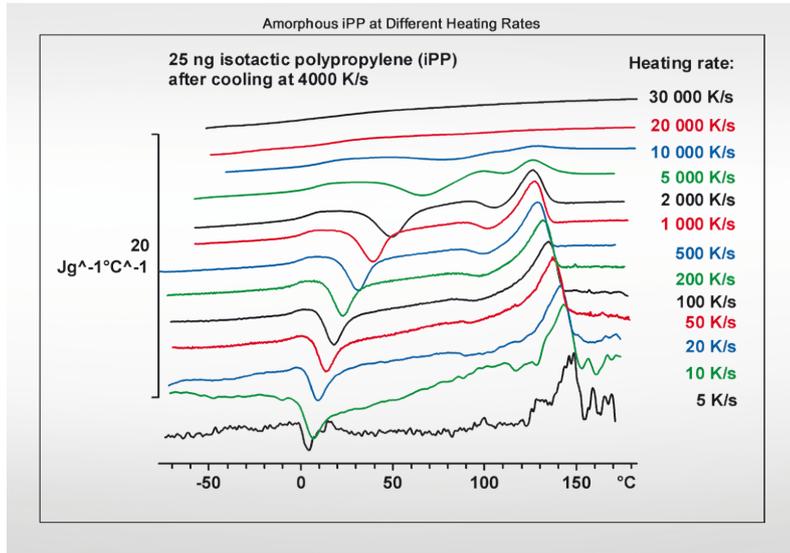
Plasticizers modify the mechanical properties of amorphous materials such as polymers. The DSC heating curves of polyvinylacetate (PVAC) show how the glass transition temperature decreases with increasing plasticizer content. Above the glass transition, the material is in a rubbery-elastic state. The results were obtained by measuring several samples containing different concentrations of plasticizer. This approach allows materials to be optimized for their specific use. It also shows the effect that the loss of plasticizer has on the glass transition temperature and material stability.

### Safety investigations by DSC



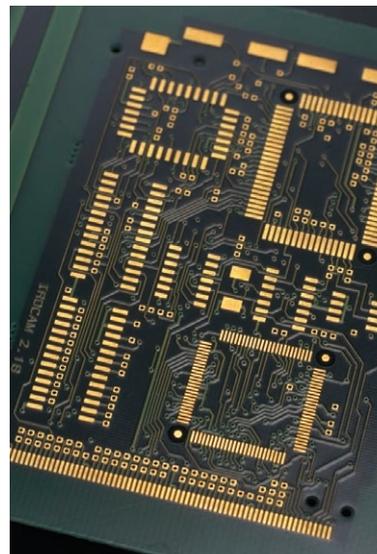
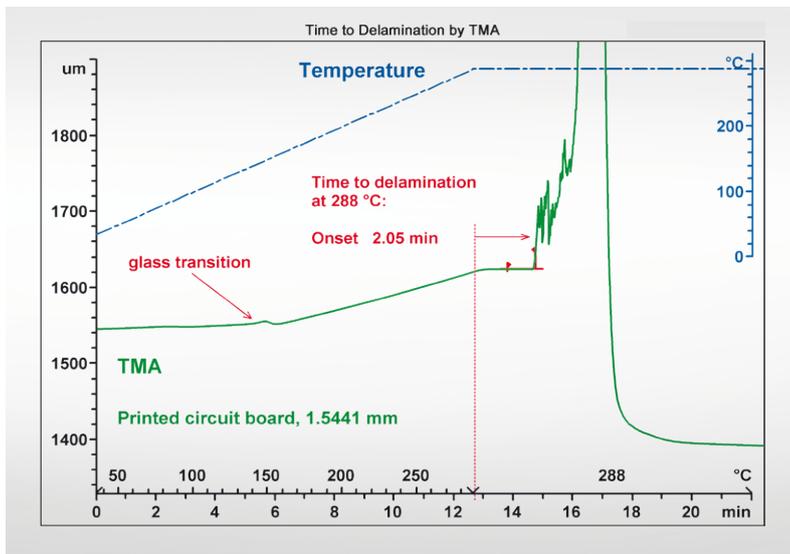
The potential hazards associated with chemical reactions can be routinely investigated with the aid of DSC experiments. The melting peaks serve to identify substances and determine their purity. Besides this, decomposition peaks frequently occur. Exothermic peaks with enthalpies above 200 J/g indicate a certain degree of risk. Enthalpies greater than 500 J/g point to the potential danger of an explosion. The DSC measurements are performed with small amounts of material in special 30- $\mu$ L high-pressure crucibles to prevent vaporization. The example shows the results obtained from heating three nitro-compounds from 25 to 450 °C at 10 K/min.

### Measurements of amorphous iPP by Flash DSC



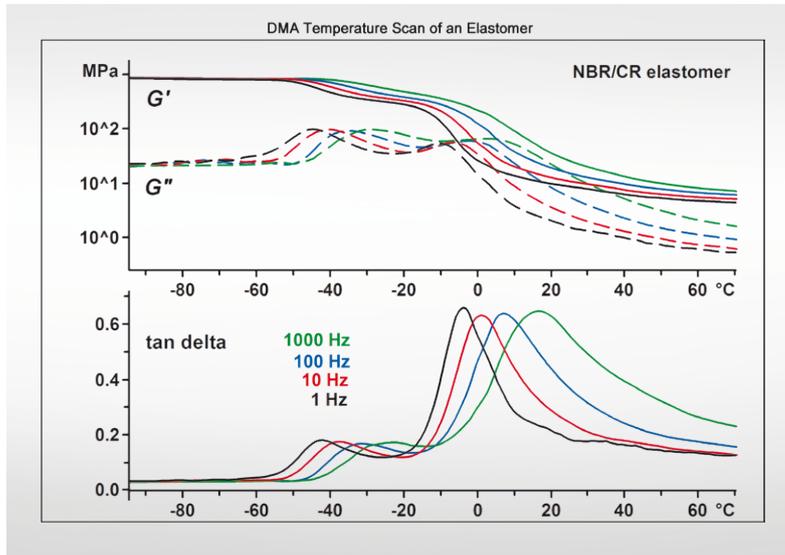
Amorphous isotactic polypropylene (iPP) is produced by cooling from the melt at 4000 K/s. The material obtained was measured at heating rates between 5 and 30 000 K/s. The glass transition occurs just below 0 °C followed by an exothermic event due to cold crystallization. The crystallites melt above 100 °C. At higher heating rates, the cold crystallization peak is shifted to higher temperatures and the melting peak to lower temperatures. From 1000 K/s onward, the peak areas become significantly smaller; at 30 000 K/s reorganization processes cease altogether.

### Delamination of printed circuit boards by TMA



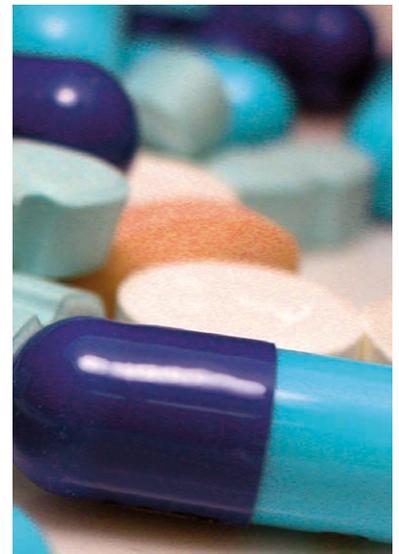
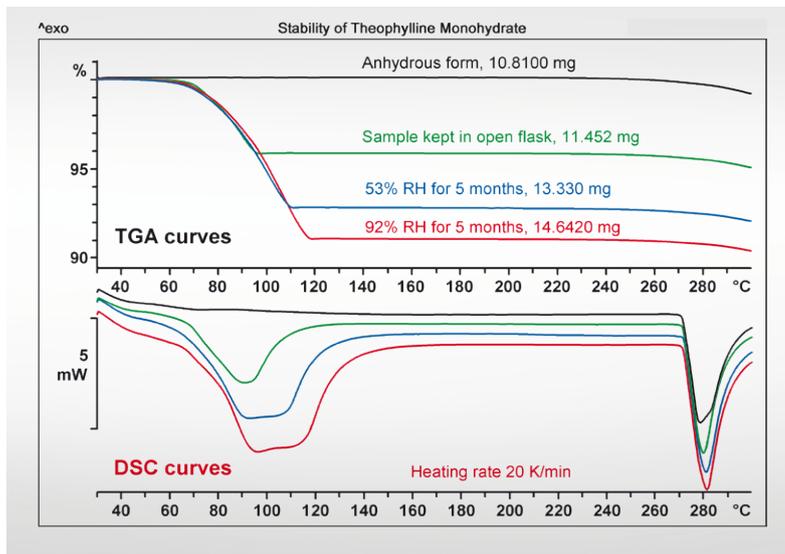
The IPC-TM-650 standard No. 2.4.24.1 describes a TMA test method to determine the time taken for a printed circuit board to irreversibly delaminate at a particular temperature. The glass transition and the expansion coefficient of the laminate material can also be determined while the sample is heated to 288 °C as defined in the standard. The TMA curve shows that the thickness of the printed circuit board suddenly increases 2.05 min after reaching the end temperature. The board, which is made of glass fibers and epoxy matrix, showed no signs of delamination at the usual test temperature of 260 °C.

### DMA of incompatible elastomer blends



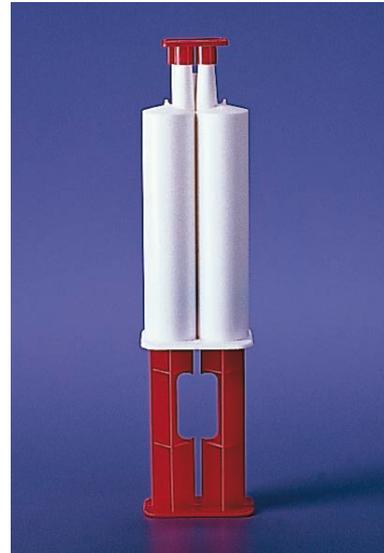
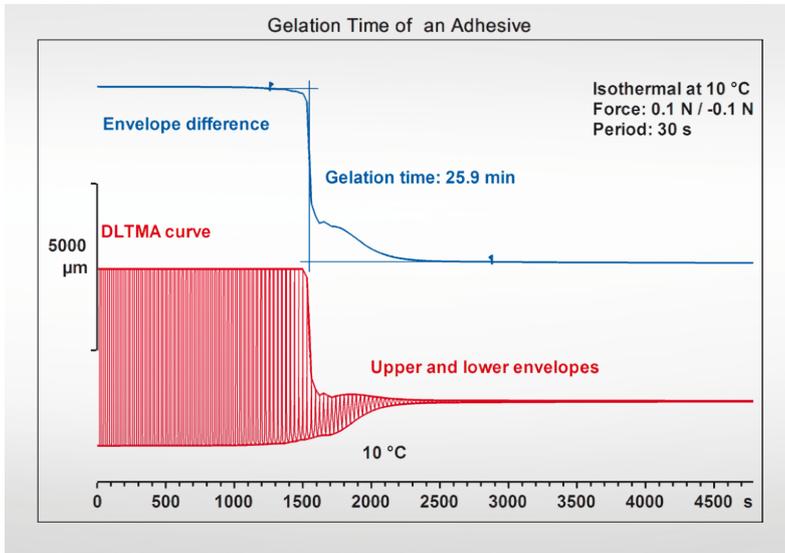
The polymers of blends of different elastomers are often incompatible. The material then exhibits two glass transitions. The DMA curves show the dynamic-mechanical behavior of an NBR/CR elastomer (each 24%) with 33% filler and 9% plasticizer at four different frequencies. The glass transition of CR is observed at about -40 °C and that of NBR at about 0 °C. The transition exhibits characteristic frequency dependence. This is illustrated in the storage and loss module ( $G'$  and  $G''$ ) and tan delta curves of the shear measurement.

### Hydrate stability of an active pharmaceutical ingredient by TGA/DSC



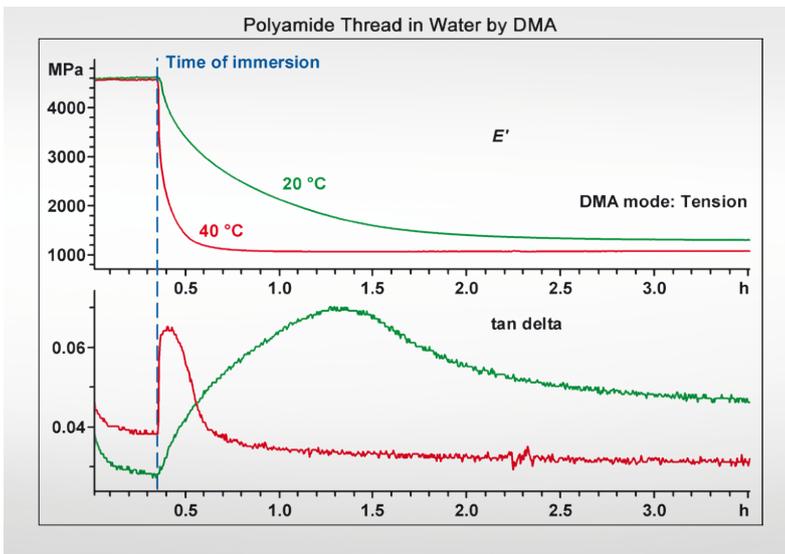
Hydrate stability is important for correctly setting the content of pharmaceutical ingredients in production. Theophylline monohydrate is only stable at a relative humidity (RH) above 92%. Other conditions lead to a reduction in the content of water of crystallization. The TGA curves show the loss of water of crystallization from samples of theophylline monohydrate stored under different conditions. Only the sample stored at 92% RH exhibits the content of water of crystallization expected from stoichiometry. The DSC curves show the endothermic elimination of water and the melting of the anhydrous substance at 270 °C.

## Gel formation by DLTMA



The gelation time (or pot life) is the time needed for the molecules in a thermosetting resin to form a gel. After gelation, the initially liquid resin can no longer be molded. Information about the gelation time is therefore of great practical importance regarding the workability of resins. The gelation time can be easily determined by DLTMA. While the sample is liquid, the probe switches between its highest and lowest position under the alternating load. After the gelation time, the probe sticks to the sample and the displacement amplitude rapidly decreases.

## Polyamide thread in water by DMA



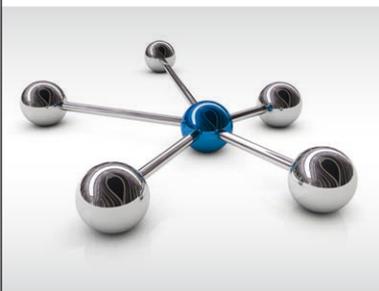
The mechanical properties of materials can change drastically when in contact with liquids. Polymers become hard and brittle in some liquids whereas other liquids act as plasticizers. The DMA 1 allows the mechanical behavior of a sample to be measured while it is fully immersed in a liquid. The example shows measurements of a polyamide thread in water at 20 and at 40 °C. The glass transition temperature decreases due to the absorption of water. The modulus curves show that the softening process occurs more quickly at 40 °C than at 20 °C.

# STAR<sup>e</sup> Software

## The Standard in Thermal Analysis

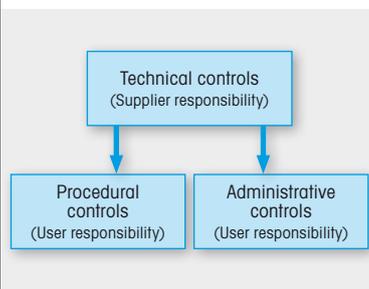
The powerful and versatile STAR<sup>e</sup> software is the product of continuous development activities aimed at exceeding customer expectations worldwide in supporting the entire thermal analysis investigation of materials – from sample preparation, method definition and experimental setup, to measurement, evaluation and result interpretation.

### Server option



The heart of the server system is the centralized database where all data is stored with the highest level of security, while allowing easy data sharing among users. In addition, the STAR<sup>e</sup> software provides powerful administrative tools for finance, calibration and service purposes – ideal for managing multiple instruments located in different laboratories.

### 21 CFR Part 11 compliance



This option provides the technical controls to support 21 CFR Part 11 compliance. This includes:

1. Access control (password)
2. User level management (user roles or profiles)
3. Electronic records (file integrity)
4. Electronic signature (status of electronic records)
5. Audit trail (change and system history)

► [www.mt.com/ta-cfr](http://www.mt.com/ta-cfr)

### Modular concept



The flexible STAR<sup>e</sup> software consists of the base software and a large number of application-specific options to satisfy your current and future requirements.



**STAR<sup>®</sup>** is the most complete and comprehensive thermal analysis software on the market and provides unrivalled flexibility and unlimited evaluation possibilities.

► [www.mt.com/ta-software](http://www.mt.com/ta-software)

# World-Class Service and Support Provide Results You Can Trust

**METTLER TOLEDO's portfolio of services is designed to ensure the continuous performance and reliability of your thermal analysis systems. Factory-trained in Switzerland, our worldwide teams bring the professional expertise and know-how needed to provide you with the highest level of after-sales support, as well as the experience necessary to optimize services for your own particular needs.**

## Large library of overview and how-to videos



Increase your productivity by learning from our video libraries and more than 600 applications.

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## Comprehensive training courses



We offer effective classroom training sessions.

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For self-training purposes, you may purchase the tutorial kit consisting of 23 well-chosen application examples and their corresponding test substances.

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## Bi-annual application magazine



Every year, thermal analysis generates a large number of scientific results and discoveries. Interesting examples from different application fields and industries are published in our UserCom magazine.

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A large number of scientific results and discoveries are made every year based on thermal analysis. Interesting examples from different application fields and industries are published in our UserCom magazine.

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# Leader in Laboratory Solutions

**METTLER TOLEDO manufactures a wide array of balances and solutions for routine applications, research and development, and quality control. This is supported by innovative accessories, competent assistance and extensive applications know-how.**



## Microbalances, Analytical and Precision Balances

Innovation, reliability and quality have made METTLER TOLEDO famous for its balances. These qualities still determine balance standards today. A comprehensive range of accessories is available to solve every weighing task.



## Titration

The Excellence family of titrators provides highly automated state-of-the-art solutions for a wide range of routine to complex titrations and Karl Fischer moisture content determination.



## pH Meters and Electrodes

METTLER TOLEDO offers a wide range of bench and portable meters and electrodes for the determination of pH, conductivity, dissolved oxygen and ion concentration. There is a solution for every application, whether in the field, in production or in the laboratory.



## Density, Refractometry, Melting Point, Dropping Point

Performance meets simplicity with our instruments for the measurement of physical values. Advanced solutions for the QC of incoming, intermediate and final products.



## Materials Characterization

The METTLER TOLEDO Thermal Analysis Excellence includes DSC, Flash DSC, TGA, TMA, DMA and microscope hot-stage systems and offers tailor-made solutions for research and development, quality control, and all kinds of academic and industrial applications.

[www.mt.com/ta](http://www.mt.com/ta)

For more Information

## METTLER TOLEDO Group

Analytical Division

Local contact: [www.mt.com/contacts](http://www.mt.com/contacts)

Subject to technical changes

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Marketing MatChar / MarCom Analytical



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**Environmental management system** according to ISO 14001.



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