APPLICATION**NOTE**

Metals – Simultaneous Thermal Analysis

One Measurement, Two Signals: c_p Determination and Curie Detection on Iron with the STA 509 *Jupiter*®

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Einleitung

Pure iron is frequently used as a reference and test material in materials science. Due to its well-known thermophysical and metallurgical properties, it is applied for the validation of measurement methods and for investigating fundamental correlations between microstructure, magnetism and thermal behavior. In addition to the temperature-dependent specific heat capacity (cp), the ferromagnetic-paramagnetic transition at the Curie temperature is of particular interest. This transition influences the thermophysical behavior of the material and appears as a characteristic effect in the heat-capacity curve.

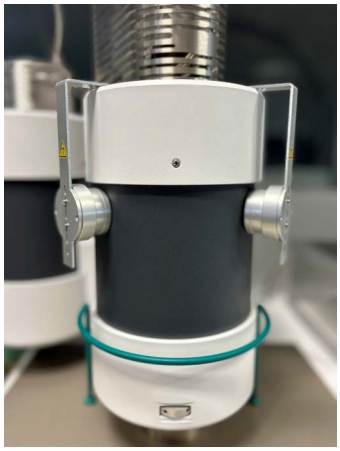
The STA 509 *Jupiter*® enables the simultaneous acquisition of thermal and gravimetric signals (DSC-TGA), providing a powerful basis for comprehensive material characterization. In combination with a magnetic setup, the Curie transformation of pure iron can be clearly detected via the TGA signal in addition to the precise determination of the specific heat capacity— all within a single measurement.

Experiment/Measurement Conditions

The measurements were carried out on a common iron sample using the STA 509 *Jupiter*® under argon. The specific heat capacity was determined by means of DSC-c_p evaluation. In parallel, the TGA signal was recorded. A magnetic setup was additionally used for the detection of the Curie transformation (see Figure 1).

Evaluation of the Specific Heat Capacity

The specific heat capacity (c_p) is determined using a comparative method with a reference material, as described, for example, in DIN EN ISO 11357. The heat capacity is calculated by evaluating three separate measurements:



1 STA furnace with magnetic setup

the baseline, a standard material (sapphire) and the sample itself. For a reliable and meaningful c_p determination, reproducible baseline and sapphire measurements are particularly important, as they form the basis for the subsequent evaluation. From these data sets, the c_p value of the investigated material can be determined according to the stated equation.

$$c_p = \frac{\text{signal difference (sample - baseline)}}{\text{sample mass} \cdot \text{heating rate} \cdot \text{sensitivity}}$$

The result of the evaluation is the temperature-dependent specific heat capacity of the investigated material. This provides a solid basis for material characterization and can also serve as an input parameter for further thermophysical calculations.

At the same time, the measurement is carried out with a magnetic setup (see Figure 1). The combination of both signals (TGA-DSC) enables a particularly clear and well-supported detection of the magnetic transformation.

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An overview of the measurement conditions used is given in Table 1.

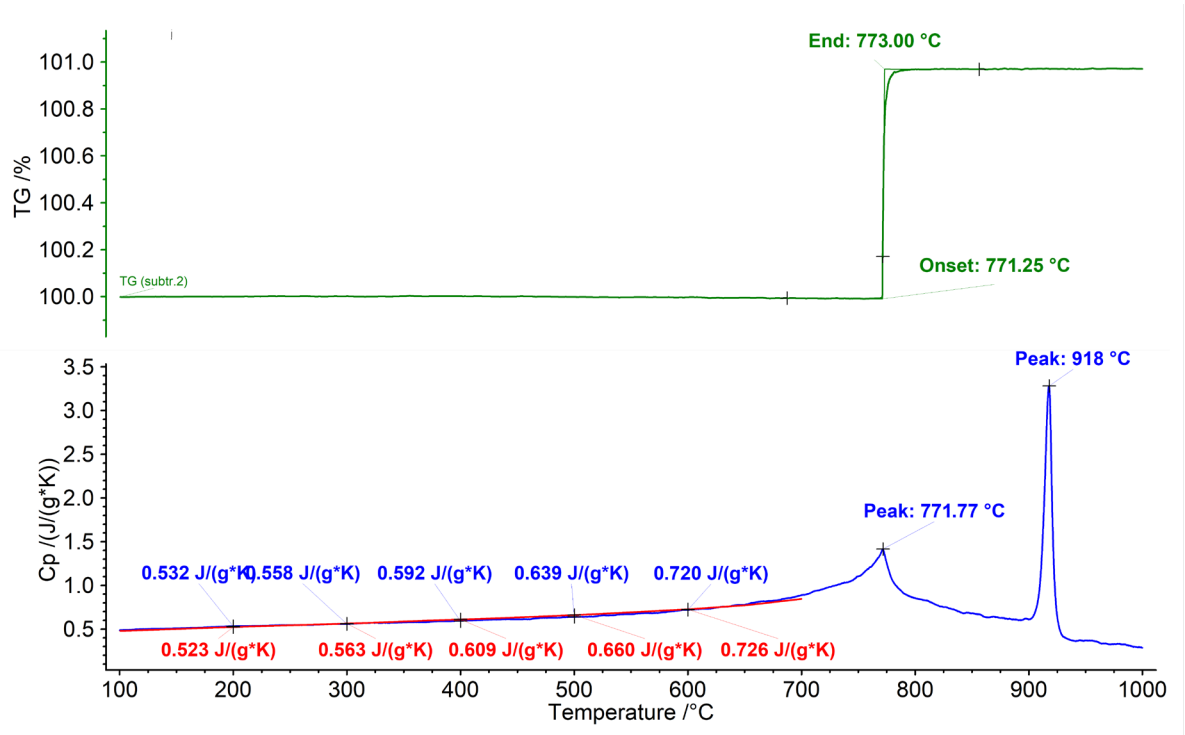
Table 1 STA measurement parameters

Instrument	STA 509 *Jupiter*®
Measuring heat	Type S TGA/DSC
Furnace	Rhodium
Crucible	Pt/Rh with lid (with Al_2O_3 liner)
Atmosphere	Ar with OTS (70 ml/min)
Temperature program	• Isotherm at 25 °C for 10 min • dynamic segment: RT to 1050°C at a heating rate of 10 K/min • Isotherm at 1050°C for 10 min
Sample mass	121.871 mg
Calibration standard	Sapphire (55.203 mg)

Results and Discussion

The measured specific heat capacity of pure iron initially shows the expected continuous increase. Up to approximately 700°C, the experimental values are in very good agreement with literature data. This demonstrates the high quality of the cp determination with the STA 509 and confirms the suitability of the system for precise thermophysical measurements on metallic materials. In the range of the Curie transformation, the c_p curve exhibits a characteristic effect that can be assigned to the ferromagnetic-paramagnetic transition of iron. Furthermore, a transformation effect (solid-state transformation, α-Fe → γ-Fe) is visible at 918°C. This second-order phase transition leads to a pronounced change in the heat capacity curve and allows the transformation temperature to be determined.

Simultaneously with the c_p measurement, the TGA curve was recorded using a magnetic setup. In the ferromagnetic state, pure iron interacts with the applied magnetic field. Upon reaching the Curie temperature, the material changes to the paramagnetic state, causing the magnetically induced force acting on the sample to change



2 Temperature-dependent c_p curve (blue), c_p literature [1] (red), TGA curve (green).

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abruptly and the TGA curve to show an apparent mass increase. This effect is not caused by a real change in mass, but by the change in the magnetic force acting on the sample. Below the Curie temperature, the sample is attracted by the magnet. Above the Curie temperature, iron loses its ferromagnetic properties. As a result, the additional force no longer acts on the sample, which is registered as a signal change in the TGA curve.

The temperature of the characteristic TGA signal correlates excellently with the Curie transformation detected in the cp curve. The magnetic setup therefore provides independent confirmation of the magnetic phase transition. In the absence of the magnetic field, no relevant mass change would be expected in the temperature range investigated, since the sample is analyzed under an inert atmosphere in a gas-tight measuring system and therefore no oxidation-related or other mass-changing processes take place.

Summary

The investigation of iron shows that the specific heat capacity can be reliably and accurately determined with the STA 509 *Jupiter*®. The measured cp values agree very well with literature data. In addition, the Curie transformation could be detected not only in the cp curve, but also simultaneously in the TGA curve using a magnetic setup. The characteristic increase in the TGA signal upon reaching the Curie temperature correlates very well with the transformation effect in the heat capacity curve. This agreement shows that the STA 509 *Jupiter*® is able to visualize the magnetic transformation simultaneously on two different signal levels. This increases the confidence in the interpretation and demonstrates the versatility of the system.

For material characterization, this means that, with a suitable measurement setup, both thermal and magnetically induced material effects can be investigated in a single experiment. This is of particular interest for iron-based materials and for the analysis of magnetic transformations.

References

[1] NETZSCH Gerätebau GmbH: NETZSCH *Proteus*® software: "*cp* Standard – Pure Iron", reference data stored in 2006, accessed via *Proteus*® on June 11, 2026, version 9.9.0, Selb, Germany.

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