APPLICATION NOTE

Alloys – DSC

Energetic Effects of a Granulate Mixture of Aluminum and Manganese Ore

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Introduction

The granulate made of aluminum manganese ore is mainly employed in the metallurgical industry. It serves as a raw material for the production of aluminum-manganese alloys. These alloys are used for various applications in the automotive, aerospace, construction and electronics industries. In some cases, aluminum manganese ore granules are also employed in the steel industry as an alloying additive for certain types of steel, to improve properties such as strength and corrosion resistance.

Measurement Conditions

The energetic effects were measured with a dynamic high-temperature differential calorimeter, NETZSCH model DSC 404 ***F1*** *Pegasus*®. The top-loading system allows for measurements from room temperature to 1650°C. Depending on the application, different DSC or DTA sensors can be employed; these can be easily exchanged by the operator. For the corresponding sensors, various thermocouple types (E, K, S, and B) are available, the selection of which is dependent on the temperature range and the sensitivity required. The instrument is vacuum-tight and thus allows for measurements under a pure inert gas or oxidizing atmosphere. Heating rates of up to 50 K/min are possible. The software enables calculations of onset and peak temperature, inflection points, peak area integration and more. The measurement parameters are listed in table 1.

Table 1 Measurement parameter

Instrument	DSC 404 ***F1*** *Pegasus*®
Sensor/sensor type	DSC c_p, type S
Furnace	Rhodium
Crucibles	Boron nitirde (BN) with pierced lid and Al_2O_3 disks between outer crucible bottom and sensor area
Temperature program	RT to 1650°C
Heating rate	20 K/min
Sample weight	30,748 mg
Calibration standard	Sapphire

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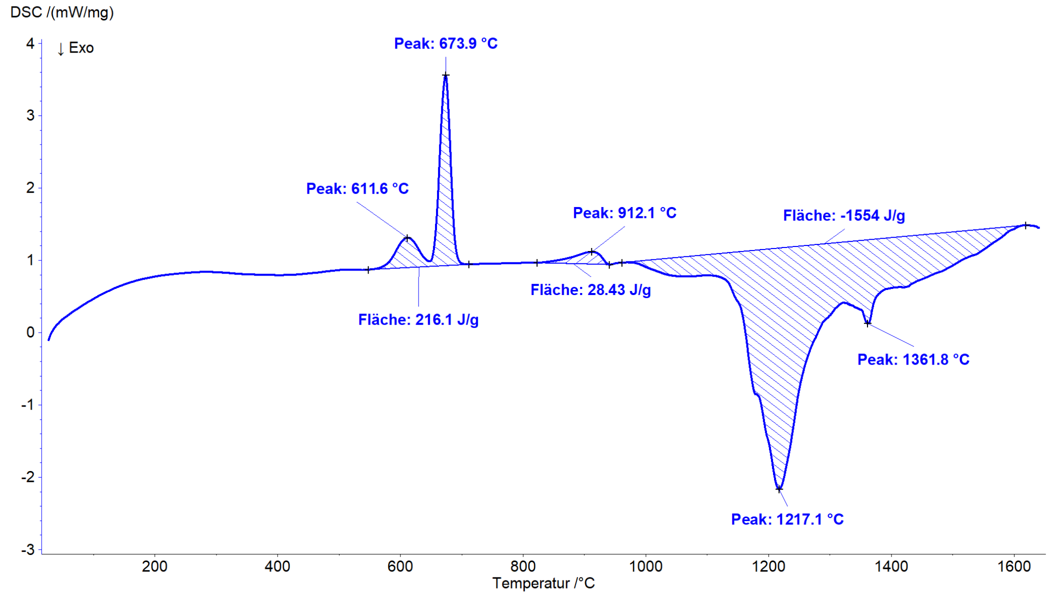
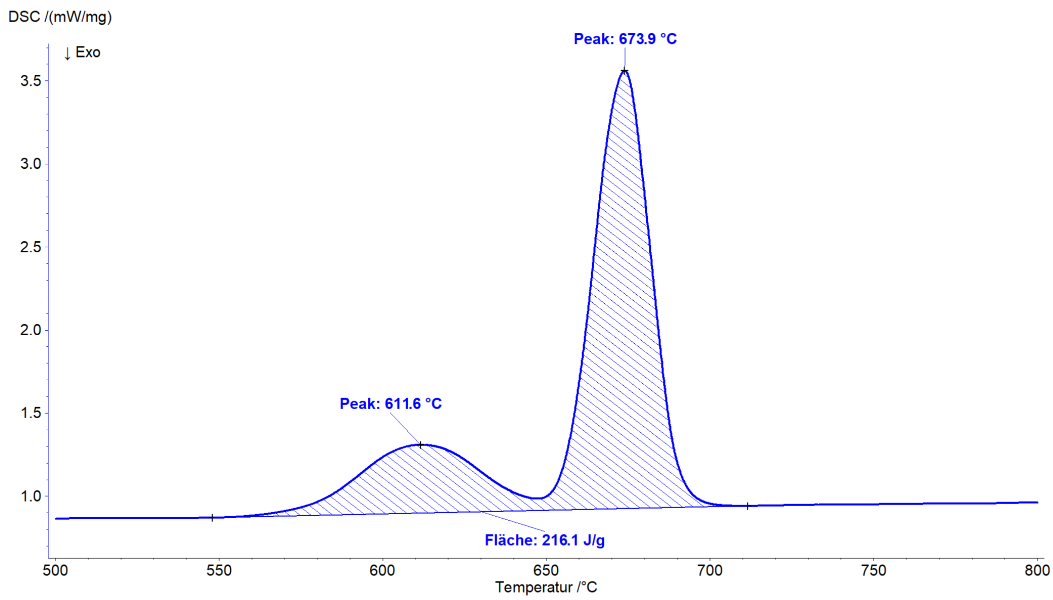
Measurement Results and Discussion

For the measurement, aluminum and manganese ore (ground) were mixed at a ratio of 1:1 and heated to 1650°C at a heating rate of 20 K/min using an argon atmosphere and a BN crucible with pierced lid. Figure 1 shows the DSC signal exhibiting clearly visible energetic effects with increasing temperature.

Two slightly overlapping endothermal effects are observed at the peak temperatures of 612°C and 674°C (see enlarged view in figure 2). The total enthalpy of these endothermic effects amounts to 216 J/g. This total effect is probably due to melting of the aluminum granulate or portion. Another endothermic effect is detected at a peak temperature of 912°C.



1 DSC curve of the sample mixture of manganese ore and aluminum granulate (at a ratio of 1:1) at a heating rate of 20 K/min.



2 Section of the DSC curve in the temperature range from 500°C to 800°C.

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Above 1000°C, a large overlapped exothermal effect with a total enthalpy of -1554 J/g can be seen at the peak temperatures of 1217°C and 1362°C. The overlapping, recognizable as shoulders, is most likely due to a reaction within the sample mixture. A thermite-like reaction occurs [1]. Manganese ore reacts with molten aluminum at higher temperatures by being reduced. This means that manganese reacts with aluminum, removing oxygen to form metallic manganese. The reaction takes place in accordance with the thermodynamic reactivity between the elements.

$$MnO_2 + Al \rightarrow Mn + Al_2O_3$$

The specific reaction conditions depend on the exact composition of the manganese ore and the temperature.

This exothermal effect with an enthalpy of -1554 J/g expands over a broad temperature range of over 500°C. At the end of the measurement, the sample is reweighed. A mass loss of ~ 5% is determined.

Summary

With the capability of performing thermoanalytical investigations at high temperatures, the DSC 404 ***F1*** *Pegasus®* allows for analyses on materials under extreme thermal conditions. Furthermore, the imaging and characterization of large reaction enthalpies, as shown with the example above, is possible with this robust, but also very sensitive instrument.

Energetic effects and state changes can be precisely measured and analyzed, providing researchers with valuable insights into the thermal behavior and stability of a wide variety of materials over a broad temperature field.

This instrument is widely used in areas like the material and geo sciences or metal/steel and ceramics industries; i.e., in areas in which understanding and knowledge of both the thermal and thermophysical properties of materials is decisive for product development, process optimization and quality control.

Literature

[1] Artur Kudyba, Shahid Akhtar, Inge Johansen and Jafar Safarian: Aluminothermic Reduction of Manganese Oxide from Selected MnO-Containing Slags (Materials 2021, 14, 356. https://doi.org/ 10.3390/ma14020356)

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