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Identification of polymers by means of DSC, TG, STA and computer-assisted database search

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Abstract This work is about the identification of polymers by means of differential scanning calorimetry (DSC), thermogravimetry (TG) and simultaneous thermal analysis (STA) involving computer-assisted database search. One general limitation depicted is the possibility of multiple interpretations of a single measurement signal which sometimes makes definite identification difficult. It is shown that a consecutive but also simultaneous incorporation of two types of measurements can significantly reduce multiple interpretations and thus increase the odds of correct identification. The latter is furthermore enhanced by using the recently introduced KIMW database which contains DSC curves of 600 different commercially available polymers (about 130 polymer types) including information about trade names, colors and filler contents.

Introduction

The identification of materials such as those from the field of polymers is of great interest, particularly with regard to the quality control of raw materials and the failure analysis of entire building elements [1, 2]. Measurement techniques like attenuated total reflectance Fourier transform infrared spectroscopy (ATR) can for example be applied to characterize the composition of polymers [3]. The most common methods of classical thermal analysis such as differential scanning calorimetry (DSC) and thermogravimetric analysis (TG) are also widely used in order to investigate polymers [4, 5]. Caloric effects observed in the DSC signal, e.g., the glass transition, crystallization and melting, as well as the pyrolytic decomposition and the combustion of the polymer samples studied by means of TG, allow for a detailed characterization. There are furthermore advanced DSC tests like the determination of the oxidation induction time (OIT) which provides information about the thermal stability of polymers [1, 5]. It should be noted that in general two modes of DSC can be distinguished [1, 4, 6]: heat flux versus power compensation; in this work, exclusively heat flux DSC was utilized which should not be put on a level with the simpler DTA (differential thermal analysis) method [6]. Simultaneous thermal analysis (STA) refers in general to the application of two or more techniques to the same sample at the same time [6]; in this work, STA signifies the simultaneous measurement of DSC and TG. The STA technique obviously has important advantages over simply combining measurements performed in different instruments on different samples of the same type: Besides the higher efficiency, the TG and DSC signals from STA measurements can be compared directly without any discussion about possibly different sample compositions, sample preparations or measurement conditions. Stand-alone TG instruments may also offer the possibility of a semiquantitative detection of caloric effects via c-*DTA*® which is a calculated differential thermal analysis (DTA) curve [6–8]. The latter is evaluated from the difference between the temperature–time curve during the sample measurement and

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the temperature–time curve where no sample is measured. Both TG and STA instruments are often coupled to evolved gas analysis techniques such as mass spectrometry (MS) or Fourier transform infrared (FT-IR) spectroscopy in order to enhance the possibilities for a material characterization [9]. Such coupled instruments are, however, not in the scope of this work.

The curve recognition and database system for thermal analysis, called *Identify*, was launched for DSC measurements on polymers [10–13]. A substantial expansion of *Identify* was introduced recently implementing data also from TG, dilatometry (DIL), thermomechanical analysis (TMA) and the specific heat capacity c_p within the same database system [14]. The database—which can be expanded by users—includes currently more than 1100 measurements and literature data from the fields of polymers, organics, food and pharma, ceramics and inorganics, metals and alloys as well as chemical elements. The latest expansion of the database is the recently introduced, optional KIMW [15] library; it contains the DSC curves of 600 different commercially available polymers (about 130 polymer types) including information about trade names, colors and filler contents [16].

For a comparison of a measurement curve with thermoanalytical literature data, printed collections of results were utilized in the past, as published earlier [17, 18]. Furthermore, online databases containing thermoanalytical data [19, 20] were established already a long time before the launch of *Identify*. Nevertheless, *Identify* is still unique because it is significantly different in many aspects and offers possibilities far beyond existing online databases [14]: *Identify* is the only curve recognition system in thermal analysis, especially when *AutoEvaluation* of the measurement is involved. It incorporates advanced effect-based as well as datapoint-based algorithms that can be adapted for such instances as single- or multi-component samples. *Identify* allows not only for one-on-one comparisons between measurements, but also for classification versus groups containing measurements and literature data. One of the biggest advantages of *Identify* is probably the option of simply overlaying the actual measurement with database curves—even of a different measurement type.

This work focuses on the possibilities regarding the identification of polymers using differential scanning calorimetry, thermogravimetry and simultaneous thermal analysis in combination with a computer-assisted database search applying *Identify*. A general limitation regarding the identification of materials via DSC and TG is the known dependence of the measurement curves on measurement conditions such as the heating rate, the sample mass or the type of crucible and lid [14]. Therefore, only measurements with similar measurement conditions should ideally be

considered for comparisons which can be achieved by filtering of the database [14]. Another fundamental limitation of this method of material identification is that sometimes multiple interpretations of a single measurement signal are possible [14]. This situation is significantly improved by the main innovation of this work, which is the consecutive but also simultaneous incorporation of two types of measurements into the database search—as was announced in Ref. [14]. The benefit of the KIMW [15] library with DSC curves of 600 different polymers [16] is furthermore shown.

Experimental

The differential scanning calorimetry measurements shown as well as other DSC database measurements were performed using the NETZSCH DSC 214 *Polyma*, aluminum crucibles (type *Concavus*) with pierced lids, and pure nitrogen as the purge gas at a flow rate of 40 mL min⁻¹. In the case of all of the DSC measurements, each sample was heated at 10 K min⁻¹ to above its melting temperature, cooled down at 10 K min⁻¹ to its individual minimum temperature and heated again at 10 K min⁻¹ to above the melting temperature. Since the second heating results are most meaningful because of a defined thermal history [1], only those curves are considered. The samples with masses typically in the range between 9 and 11 mg were prepared using a *SampleCutter* for good thermal contact to the crucible.
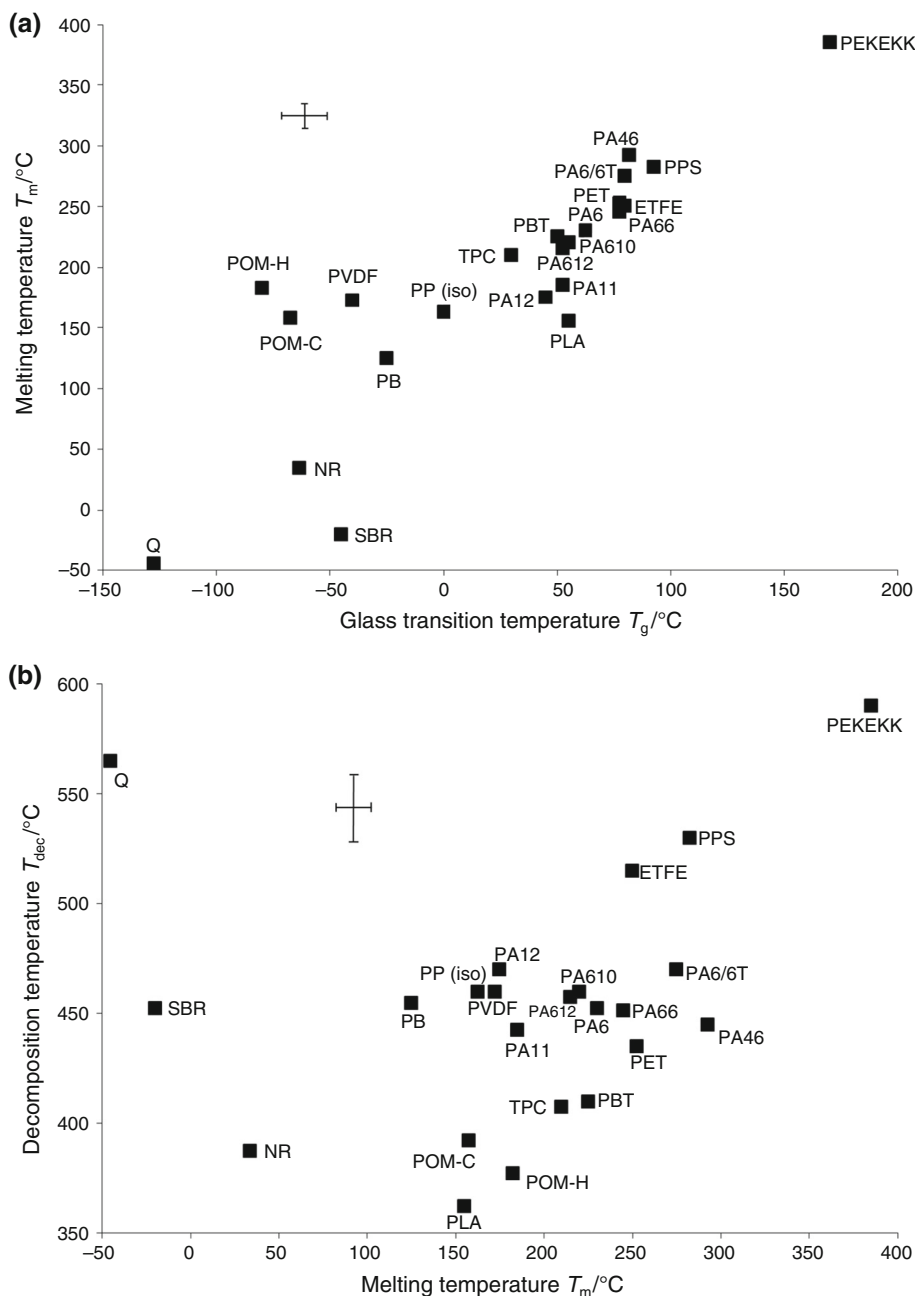
The thermogravimetry measurements included in the database were carried out with the NETZSCH TG 209 *F1 Libra*® using open alumina crucibles and also pure nitrogen as a purge gas at a flow rate of 40 mL min⁻¹. The samples with masses of again about 10 mg were heated at 10 K min⁻¹ to 800 °C.

The measurement of a 30% glass fiber-filled polyamide 66 sample "PA66-GF30_STA" was conducted with a NETZSCH STA 449 *F3 Jupiter*®, which was equipped with a steel furnace with liquid nitrogen cooling, using platinum crucibles with pierced lids and a nitrogen purge gas flow of 70 mL min⁻¹. The initial sample mass was 10.41 mg. A thermogravimetry measurement of a polybutene sample "PB_TGA_new" was performed using again the NETZSCH TG 209 *F1 Libra*® under the same conditions as for the database measurements mentioned above; the sample mass was 10.07 mg. However, the temperature program of the STA and TG measurements of the samples "PA66-GF30_STA" and "PB_TGA_new" were carried out in the same way as for the DSC measurements (see above) where just the second heating results are shown and considered for the database search.

Results and discussion

Figure 1 shows a selection of the glass transition, melting and decomposition temperatures for several polymer types [21]. It is important to emphasize that all polymer types selected exhibit exactly one glass transition and one melting effect in the DSC signal and only one main decomposition step when measured under pyrolytic conditions via thermogravimetry. There are many other polymer types that are for example purely amorphous and do therefore not reveal a melting effect, or types that show several glass transitions or several decomposition steps; such polymers, which will be discussed below, are not illustrated in Fig. 1. Moreover, it must be pointed out that the characteristic temperatures shown in Fig. 1 vary typically between 10 K and 15 K when different grades of the same polymer type are compared. Other polymer types like thermosets not included in Fig. 1 exhibit even much larger ranges in which these characteristic temperatures can be observed.

From Fig. 1, the known correlation between glass transition and melting temperatures [22], $T_g/K \approx 2/3 \cdot T_m/K$, as well as between melting and decomposition temperatures can be seen: a polymer type with a higher glass transition

Fig. 1 Glass transition, melting and decomposition temperatures of selected polymer types (data extracted from [21]). Only those polymer types were selected as examples that exhibit one glass transition and one melting effect in the DSC signal and that furthermore show only one main decomposition step. Additionally, these main characteristic temperatures of the polymer types selected show variations between different grades of one type only within a typical range which is indicated by the uncertainty bars

temperature has by trend a higher melting temperature and a higher decomposition temperature. Clearly, the polymers located at the lower and upper ends of the temperature scales in Fig. 1 can be identified with greater certainty via their DSC and TG signals because there are usually less alternatives. The polymers or polymer blends that exhibit more than one glass transition or several decomposition steps (not illustrated in Fig. 1) can in most cases be identified more easily on the basis of their characteristic temperatures. Identification of such polymer types was already demonstrated earlier [10–14, 23] and should therefore not be highlighted again. This work focuses on more difficult cases where the glass transition temperatures are typically in the range of about 50–100 °C, the melting temperatures in the range of 150–250 °C or the decomposition temperatures around 450 °C, where various polymer types are a possibility, as can be seen in Fig. 1. In those cases, the consecutive or even simultaneous incorporation of DSC, TG and c-*DTA*® is particularly decisive for overcoming or at least improving the situation of multiple possible interpretations [14].

Incorporation of TG in addition to DSC and vice versa

Figure 2 shows the results of an STA measurement of the polymer "PA66-GF30_STA". The DSC curve exhibits a small step at a mid-temperature of about 74 °C, which is due to the glass transition, as well as a broad endothermic effect between about 160 and 280 °C, which is due to melting. The melting temperature of a polymer is usually associated with the peak temperature, about 258 °C in this case. In the temperature range between 350 and 500 °C, several overlapping endothermic and exothermic effects are observed in the DSC signal, which are due to the pyrolytic decomposition of the polymer content of the sample. The latter can be seen from the TG curve, which shows a mass loss step of 66.3% in the same temperature range. A mass loss of 1.3% was detected during the first heating, and another mass loss of 2.3% occurred after switching to oxidative atmosphere at higher temperatures. The calculated residual mass of 30.1% matches with the nominal glass fiber content of the sample. As decomposition temperature, the peak temperature of the calculated derivative of the TG curve, called DTG, is usually designated; it is 456 °C in the case of the sample "PA66-GF30_STA". In addition to peak temperatures, also extrapolated onset- and endset temperatures can be evaluated according to known standards [24–26]; the size of a glass transition is furthermore characterized by the step height Δc_p, and a melting effect by its area which is the enthalpy of melting (see Fig. 2).

In order to evaluate the possibilities for material identification, the STA measurement displayed in Fig. 2 was analyzed by means of *Identify*. The analysis was restricted in the first instance to just the DSC signal in the temperature range of interest below 300 °C where glass transition and melting occur in most polymers. The most similar database entries are summarized in a hit list shown in Fig. 3a. It can be seen that not only were polymers of type PA66 (polyamide 66) found with high similarity values but also ETFE (ethylene-tetrafluoroethylene), FEP (tetrafluoroethylene/hexafluoropropylene copolymer), PET (polyethylene terephthalate) and several other polymer types. This situation of multiple interpretations possible—and thus no definite material identification—is exactly what was expected from the literature data depicted in Fig. 1a. The DSC curves of the two most similar database entries are overlaid with the DSC curve of the polymer sample "PA66-GF30_STA" (see Fig. 3b). Visible are differences

Fig. 2 Temperature-dependent mass change (TG), the corresponding rate of mass change (DTG) and the heat flow rate (DSC) of the polymer sample "PA66-GF30_STA". Not shown are the first heating to 300 °C and the higher temperature range (see text)
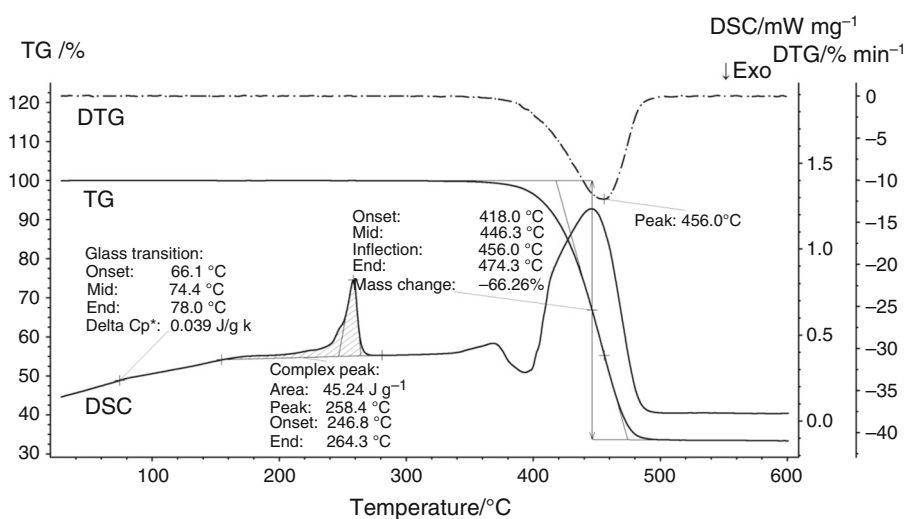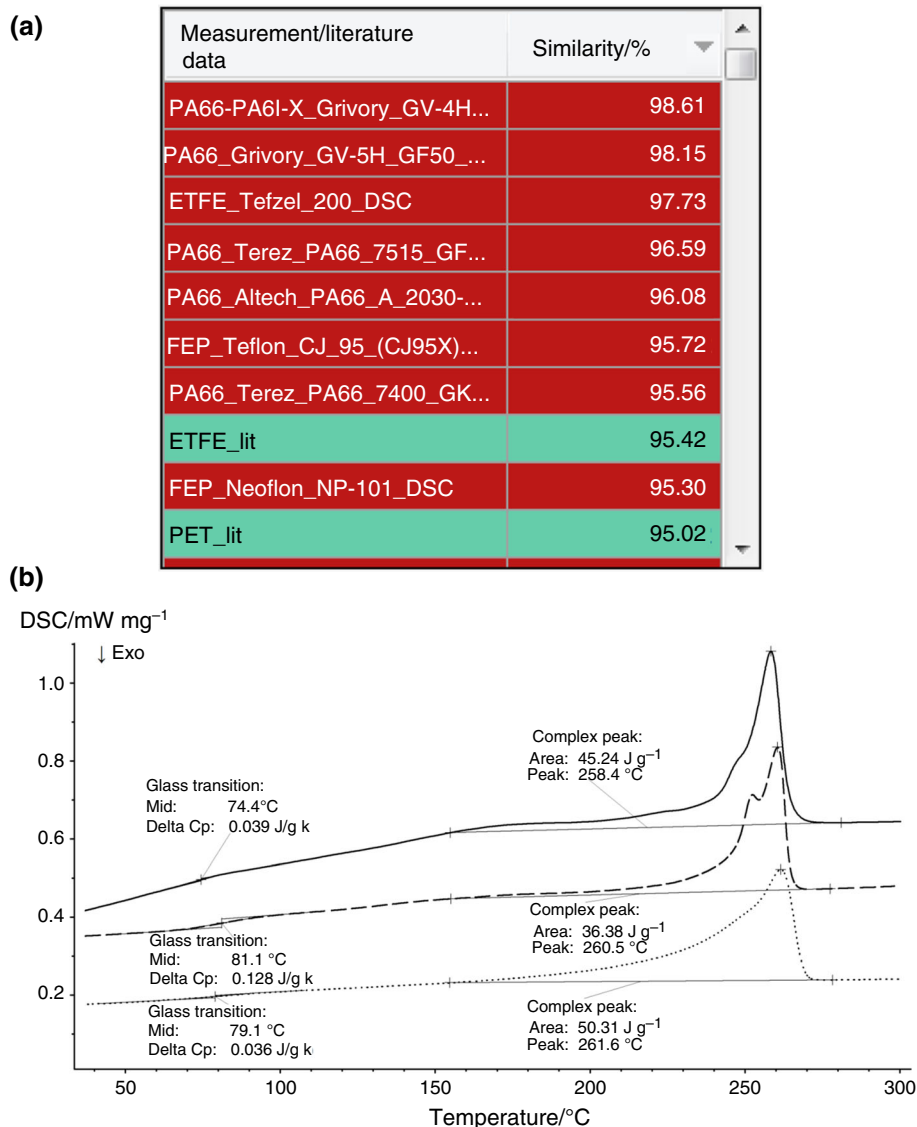
Fig. 3 a Results from *Identify* (hit list) for the STA measurement shown in Fig. 2 (sample "PA66-GF30_STA"). Just the DSC signal was considered, and the search temperature range was restricted to the range of 30–300 °C. The *green color* refers to the library with NETZSCH literature data of about 70 polymer types [21]; the red color to entries of the KIMW [15] database containing DSC measurements on 600 different commercially available polymers [16]. **b** Temperature-dependent heat flow rate (DSC) of the polymer sample "PA66-GF30_STA" (measurement shown in Fig. 2, *solid line*) in comparison with the DSC curves of the database entries "PA66-PA6I-X Grivory GV 4H GF40_DSC" (*dashed line*) and "ETFE Tefzel 200_DSC" (*dotted line*). The latter curves, which are shifted in the *y* direction for clarity, are selected *Identify* search results (**a**). (Color figure online)

(a)

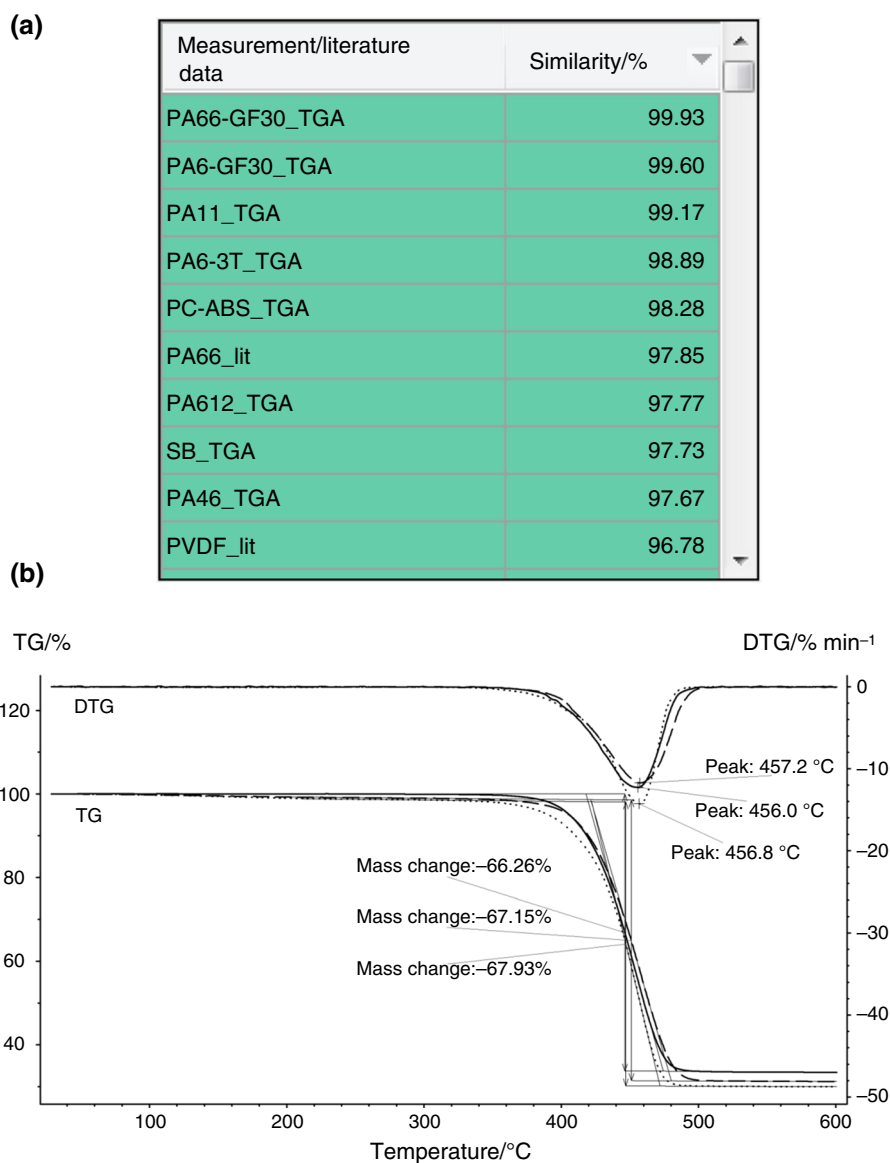| Measurement/literature data	Similarity/%
PA66-PA6I-X_Grivory_GV-4H...	98.61
PA66_Grivory_GV-5H_GF50_...	98.15
ETFE_Tefzel_200_DSC	97.73
PA66_Terez_PA66_7515_GF...	96.59
PA66_Altech_PA66_A_2030-...	96.08
FEP_Teflon_CJ_95_(CJ95X)...	95.72
PA66_Terez_PA66_7400_GK...	95.56
ETFE_lit	95.42
FEP_Neoflon_NP-101_DSC	95.30
PET_lit	95.02

(b)

in the glass transition and melting temperatures as well as in the shape of the endothermic melting effects; there is obviously no perfect match between the DSC curve of the sample "PA66-GF30_STA" and the database curves.

Of course, comparisons between DSC measurements originating from different instruments, especially from STA and stand-alone DSC devices, have to be considered carefully. The glass transition may be less pronounced in an STA measurement due to lower DSC sensitivity and a greater impact of the baseline. Furthermore, temperature and sensitivity calibrations of different instruments and also the time constants of the DSC sensors may differ. Such uncertainties are usual and have to be kept in mind for a database search. In the case of the example of Fig. 3, the algorithm of *Identify* was set to "qualitative", which disregards the size of the effects. This makes sense because a filled polymer was investigated. However, it turns out that

no other algorithm setting available improves the situation of multiple interpretations discussed in this case.

As a next step, the TG information from the STA measurement of Fig. 2 was also analyzed using *Identify*, as is illustrated in Fig. 4a, b. The algorithm of *Identify* was again set to "qualitative". The best hit, "PA66-GF30_TGA", is a TG database measurement on exactly the same material as that of the measurement of the sample "PA66-GF30_STA". Obviously, the database search revealed many further TG curves of various polymer types which have also a high similarity to the TG curve of the polymer sample "PA66-GF30_STA" (see Fig. 4a, b)—which was again expected from literature data (see Fig. 1b). And this means that in the case of this example, the database search regarding the TG curve is again not definite—as was the case for the corresponding DSC curve (see Fig. 3a, b).

Fig. 4 a Results from *Identify* (hit list) for the STA measurement shown in Fig. 2 (sample "PA66-GF30_STA"). Just the TG signal was considered, and the search temperature range was restricted to the range of 300–600 °C. The NETZSCH polymer libraries with measurements and literature data [21] of about 70 polymer types were used for the database search. **b** Temperature-dependent mass change (TG), the corresponding rate of mass change (DTG) of the polymer sample "PA66-GF30_STA" (measurement shown in Fig. 2, *solid line*) in comparison with the TG curves of the database entries "PA66-GF30_TGA" (*dashed line*) and "PA6-GF30_TGA" (*dotted line*), which are selected *Identify* search results (**a**)

(a)

Measurement/literature data	Similarity/%
PA66-GF30_TGA	99.93
PA6-GF30_TGA	99.60
PA11_TGA	99.17
PA6-3T_TGA	98.89
PC-ABS_TGA	98.28
PA66_lit	97.85
PA612_TGA	97.77
SB_TGA	97.73
PA46_TGA	97.67
PVDF_lit	96.78

(b)

The answer to this problem is the combination of the search results for the DSC and TG curves: The only polymer type which revealed a high similarity to both the DSC and TG curves is PA66 (see Figs. 3a, 4a). In contrast, polymer types like PA6 (polyamide 6) and PA11 (polyamide 11), which showed a high similarity to the TG curve (see Fig. 4a), are unlikely because their similarity to the DSC curve is only below about 50% and thus not visible from Fig. 3a. And from the other point of view, polymer types like ETFE and PET, which are a reasonable possibility when regarding the DSC curve (see Fig. 3a), are also unlikely because their similarity to the TG curve is relatively low (ETFE_TGA: 58.2%, PET_TGA: 91.3%). These findings can be expected from the literature data shown in Fig. 1a, b.

In summary, the simultaneous measurement by TG and DSC in combination with the database search for both signal types by means of *Identify* leads to a clear identification and verification of the polymer type as "PA66-GF30" with a relatively high certainty. In this example, the DSC and TG signals of an STA measurement were analyzed using *Identify* consecutively; this implies that exactly this kind of investigation is also possible based on two independent measurements of the same type of sample performed on stand-alone DSC and TG instruments. In addition, *Identify* allows for simultaneous incorporation of DSC and TG signals into the database search which may originate from either two independent measurements or from one STA measurement. This should be demonstrated using the library with literature data for about 70 polymer

types [21]; a library containing STA measurements does not yet exist, but the literature data do contain information about glass transitions, melting and also decomposition temperatures in each individual database entry. As can be seen from Fig. 5, the analysis of the entire STA measurement (DSC and TG at once) by means of *Identify* consistently revealed PA66 as the best hit, while other polymer types were discriminated; the algorithm was again set to "qualitative", thus disregarding the size of all effects.

For the sake of completeness, it should be noted again that there are also polymers like PC (polycarbonate) that are purely amorphous and therefore just show a glass transition but no melting effect. And there are other polymers like PTFE (polytetrafluoroethylene), where the glass transition exists but is typically not observable in the DSC signal because the effect is too weak. In both cases, which are not illustrated in Fig. 1, one of the effect types glass transition or melting is absent in the DSC signal. Such polymers obviously distinguish themselves strongly from polymers that exhibit both effect types in the DSC signal. However, multiple interpretations are possible in comparison with other polymers that have in this case also just a glass transition occurring in the same temperature range. An example would be the two polymer types PS (polystyrene) and PVC-U (polyvinylchloride without plasticizer), which both typically exhibit a glass transition in the range of 80–90 °C. In such a situation, the additional information from the TG signal clearly helps to

differentiate between the two polymers: In this case, PS shows only one decomposition step in the temperature range around 430 °C, whereas PVC-U exhibits two decomposition steps, the first around 300 °C and the second around 470 °C (DTG peak temperatures) as was depicted in Ref. [14].

Incorporation of c-*DTA*® in addition to TG

Usually, the capabilities of TG instruments are restricted to the measurement of mass changes as a function of temperature or time. The TG instrument used for this work, however, is able to also provide information regarding energetic effects in terms of the c-*DTA*® signal. Compared to a true DSC signal, c-*DTA*® has a longer time constant and is certainly less sensitive, which is a drawback especially for the detection of glass transitions. Secondly, c-*DTA*® is just a semiquantitative curve without any enthalpy calibration. Nevertheless, the additional information from c-*DTA*® can also be incorporated for a definite identification of a sample material as was shown for TG-DSC above. Figure 6a displays the results of a TG measurement of the sample "PB_TGA_new" including the c-*DTA*® curve in the relevant temperature range. The latter reveals melting of the sample at a peak temperature of about 122 °C; decomposition of the sample can be seen from the mass loss in the temperature range between about 420 and 470 °C. In Fig. 6b, the results of *Identify* are depicted where TG and c-*DTA*® were simultaneously incorporated into the database search; the algorithm was again set to "qualitative", thus disregarding the size of all effects. The best hits, "PB_DSC" and "PB_TGA", are TG and DSC measurements on exactly the same polymer material as the sample "PB_TGA_new". There are polymer types which have a high similarity to the TG curve, but there is no other polymer type in the database where both the TG and DSC measurements have a high similarity to the measurement "PB_TGA_new" including its c-*DTA*® curve. The definite verification of the polymer type PB (polybutene) and the discrimination of other polymer types is again demonstrated when the search library containing literature data including both, caloric effects and decomposition at the same time, are used (see Fig. 6c).

Incorporation of curve specifics in addition to the main characteristic temperatures

Fortunately, the main characteristic temperatures (glass transition, melting and decomposition temperatures) are not the only information that can be extracted from DSC and TG curves. Glass transitions and melting effects occurring in the DSC signal differ in size and broadness and in some cases also exhibit specific shapes for the

Measurement/literature data	Similarity/%
PA66_lit	94.29
PA6-6T_lit	87.84
PET_lit	86.92
ETFE_lit	75.87
FEP_lit	72.04
(HBA, HNA)-LCP_lit	64.84
EP_lit	64.79
PF_lit	62.61
PA6_lit	59.44
PVAL_lit	58.71

Fig. 5 Results from *Identify* (hit list) for the STA measurement shown in Fig. 2 (sample "PA66-GF30_STA"). Both the TG and DSC signals were considered simultaneously; the search temperature range was restricted to the range of 30–600 °C. The library with NETZSCH literature data of about 70 polymer types [21] was used for the database search

Fig. 6 **a** Temperature-
dependent mass change (TG)
and c-*DTA*® curve of the
polymer sample
"PB_TGA_new" (*solid lines*);
not shown are the first heating to
160 °C and the higher
temperature range where no
significant mass changes
occurred. For comparison, the
TG and DSC curves of the
database entries "PB_TGA"
and "PB_DSC" (*dashed lines*)
are shown, which are selected
Identify search results (**b**).
b Results from *Identify* (hit list)
for the TG measurement shown
in **a** (sample "PB_TGA_new").
Both, the TG and c-*DTA*®
curves were considered
simultaneously; the search
temperature range was restricted
to the range of 30–600 °C. The
NETZSCH library with
measurements of about 70
polymer types [21] was used for
the database search. **c** Results
from *Identify* (hit list) for the
TG measurement shown in
a (sample "PB_TGA_new").
Both, the TG and c-*DTA*®
curves were considered
simultaneously; the search
temperature range was restricted
to the range of 30–600 °C. The
NETZSCH library with
literature data of about 70
polymer types [21] was used for
the database search

(a)
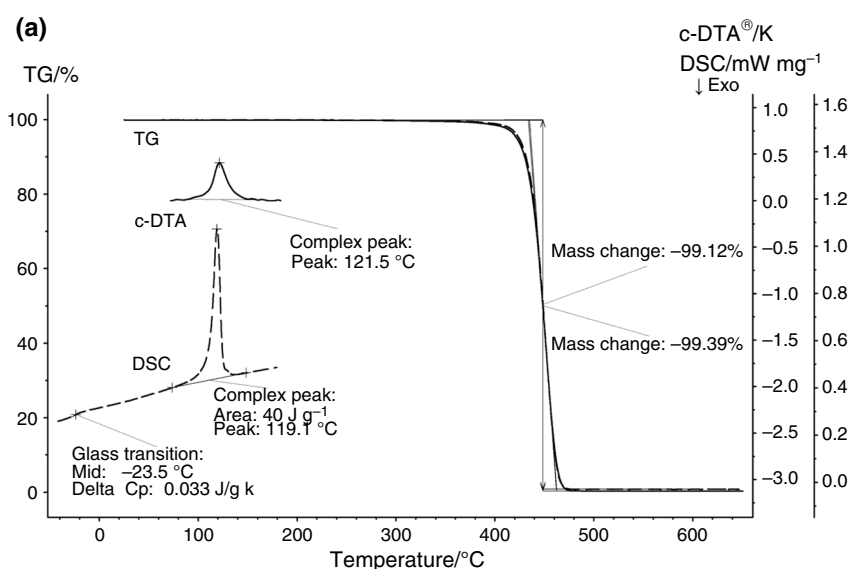
(b)

Measurement/literature data	Similarity/%
PB_DSC	99.30
PB_TGA	98.71
ECTFE_powder_TGA	97.87
PVDF_TGA	96.31
PET_TGA	95.24
SB_TGA	92.19
PE-LD_DSC	87.11
PE-HD_DSC	85.46
PP_TGA	80.72
PE-UHMW_DSC	79.92

(c)

Measurement/literature data	Similarity/%
PB_lit	88.78
PE-LLD_lit	63.91
BR_12_lit	60.49
SBR_lit	59.16
PE-HD_lit	58.69
NBR_lit	55.88
PE-LD_lit	52.43
PE_UHMW_lit	48.31
TPS_lit	46.96
PP__isotactic_lit	46.16

individual polymer types. In addition, even polymer types with one-step decomposition in some cases exhibit preceding effects and after-effects which point to mass loss before and after the main decomposition step. The broadness and the size of the main decomposition step can also vary among different polymer types. All those properties can be partially considered by *Identify* depending on the algorithm settings; the glass transition, melting and decomposition temperatures are nevertheless the most important values. The following example should demonstrate in particular the benefit of the additional information that is gained by simply overlaying the actual measurement with database curves and visually comparing the curves [16]. A DSC measurement of the commercially available polymer "PA6 Durethan BKV30 H2.0" was analyzed by means of *Identify* using its standard algorithm settings, which take into account all properties of the effects occurring in the DSC curve. Exactly the same measurement is also present in the KIMW database and thus appears as the best hit (see Fig. 7a). From the resulting hit lists, it can furthermore be seen that many similar PA6 measurements
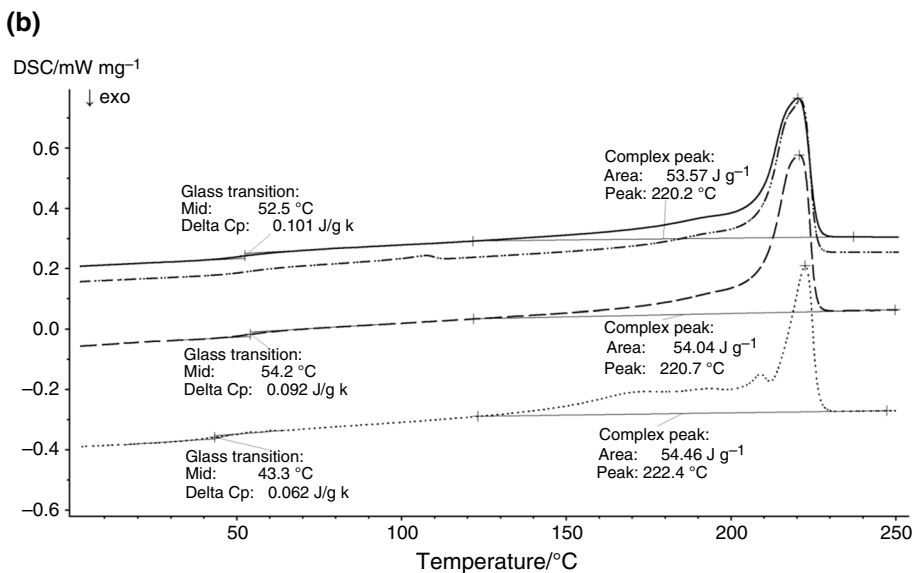
were found, but also the two database measurements of PA610. The slightly different characteristic temperatures, especially the glass transition temperature (see Fig. 7b), already lead to a significant lowering of the similarity between the PA610 measurements and many of the PA6 database entries, and thus also lead to a discrimination between PA610 and the PA6 measurement investigated. The PA610 curves furthermore exhibit a pronounced shoulder around 170 °C and an additional small melting peak at about 210 °C which do not occur in the PA6 measurements, as can be seen from the overlay of the corresponding DSC curves shown in Fig. 7b. Another finding is that the entire PA6 class containing 39 measurements on different PA6 grades has a lower mean similarity than the PA610 class, which contains only two measurements (see Fig. 7a). This is due to the fact that for some PA6 grades, an additional endothermic effect occurs at around 110 °C, which also leads to differentiation among the PA6 database entries (see Fig. 7b). Finally, it can be recognized from the *Identify* results that the similarity of the classes of all other polymer types present in the

Fig. 7 **a** Results from *Identify* (hit lists) regarding a DSC measurement of the polymer "PA6 Durethan BKV30 H2.0". The KIMW [15] database containing DSC measurements on 600 different commercially available polymers [16] was used for the search.
b Temperature-dependent heat flow rate (DSC) of the polymer sample "PA6 Durethan BKV30 H2.0" (*solid line*) in comparison with the DSC curves of the database entries "PA6 Altech PA6 A 2030-109 GF30" (*dashed line*) and "PA610 Terez PA6.10 GF30 H ECO" (*dotted line*). The latter curves are selected *Identify* search results (**a**). The exemplary database curve of the Polymer "PA6 Schulamid 6 GF30 H" is furthermore shown (*dashed-dotted line, see text*). All curves are shifted in the *y* direction for clarity

database is significantly lower than for PA6 and PA610, respectively, which also demonstrates the possibility of differentiation of many polymer types (see Fig. 7a). A prerequisite for these detailed results is of course the existence of the large KIMW database [15, 16].

Conclusions

The main topic of this work is the identification of polymers by means of differential scanning calorimetry (DSC), thermogravimetry (TG) and simultaneous thermal analysis (STA) in combination with a computer-assisted database search using the *Identify* software. The identification can generally be carried out mainly on the basis of characteristic caloric effects of the type glass transition, crystallization or melting and on the basis of mass changes, which reflect the temperature-dependent decomposition of a sample. In general, a single measurement can unfortunately be interpreted in multiple ways limiting this method of material identification [14]. This difficulty is considerably minimized by the consecutive or simultaneous incorporation of two types of measurement signals into the database search: TG and DSC or TG and c-DTA®. As application examples, a definite identification of polymers of type PA66 (polyamide 66) and PB (polybutene) was demonstrated.

The KIMW [15] library available for *Identify* was furthermore used, which contains DSC curves for 600 different commercially available polymers (about 130 polymer types)—also including information about trade names, colors and filler contents [16]. This large database allows for more distinct polymer identification; this is due to the multitude of polymer types present in the database but also due to the availability of several different polymers of the same type which may exhibit significant differences in their DSC curves. The differentiation between PA6 (polyamide 6) and PA610 (polyamide 610) was depicted as an example.

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