Tool box for basic characterization of plastics **INFO** Sheet C6

Description	*Basic characterization of polymeric materials for solar-thermal applications*
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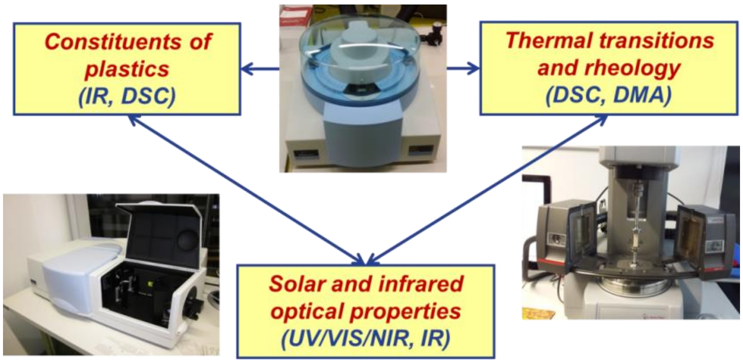
Introduction

Plastics are tailor-made, multifunctional materials based on a variety of organic macromolecules and functional and processing additives. An important prerequisite for the successful selection and use of plastics in solar-thermal systems is the comprehensive definition and description of application-relevant loading profiles and the deduction of property requirements. For specified plastics grades reproducible material quality has to be controlled and assured. In this info sheet a tool box for the basic characterization of plastics for solar-thermal systems is described. Relevant features and properties are exemplarily depicted for absorber materials based on polyphenyleneoxide (PPO) and polyphenylenesulfide (PPS).

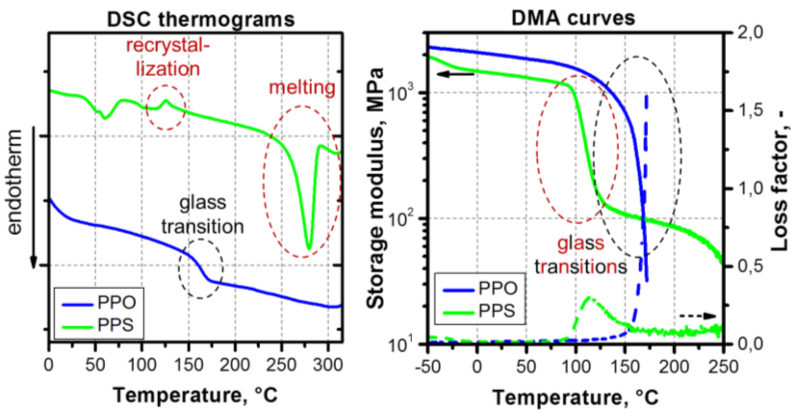
Basic characterization tool box



For the basic analysis of the constituents of polymeric materials infrared spectroscopy (IR) in attenuated total reflection mode (ATR) and differential scanning calorimetry (DSC) are commonly used. By IR spectroscopy the material structure based on e.g., CHON atoms (C..carbon, H..hydrogen, O..oxygen, N..nitrogen) is elucidated. DSC allows for the description of the morphological structure (amorphous or semi-crystalline) and relevant thermal transitions (e.g., glass transition, melting range). A characteristic feature of plastics is their inner mobility which is responsible for time- and temperature dependent mechanical properties commonly characterized by dynamic mechanical analysis (DMA). In the molten state DMA is carried out to describe rheological properties which are affected by the macromolecular structure (e.g., average molar mass, branching or crosslinking). A simple rheological method for quality control of plastics is melt flow index (MFI) testing. For the assessment of application-relevant optical properties in the solar and heat radiation range UV/VIS/NIR- and IR-spectroscopy with Ulbricht globe detectors are well established.

Features and properties of PPO and PPS absorber materials

Polyphenyleneoxide and polyphenylenesulfide are classified as engineering plastics characterized by elevated service temperatures above 100°C. The good heat resistance results from the macromolecular main chain structure based on aromatic rings (phenylene groups (P)) which are linked by oxygen (in PPO) or sulphur (in PPS). For PPO and PPS tailor-made grades were developed which are used for the production of twin wall sheets for solar-thermal absorbers. These grades are pigmented with small amounts of carbon black and modified with another polymer type to adjust the processing and performance property profiles. While PPO is commonly blended with polystyrene (PS), PPS is impact-modified with a polyolefin elastomer (PO). Because of their chemical structure PPO and PPS exhibit significant differences in their morphology and the thermal transitions. These differences can be clearly elaborated by DSC and DMA (see representative figures). PPO+PS blends are fully amorphous materials with a glass transition region between 150 and 175°C. For PPO the glass transition is discernible in the DSC thermogram (endothermic step) and the DMA storage modulus (stepwise transition) and loss factor (peak) curves. The glass transition region is associated with significant softening of the material expressed by the decay in the storage modulus. The maximum service temperature of amorphous plastics such as PPO is usually limited by the glass transition and should be about 20°C below the onset.



For PPS the DSC thermograms and DMA curves indicate the semi-crystalline morphology. In the DSC trace a significant endothermic peak denotes the melting range which is around 280°C for PPS. Due to semi-crystallinity of PPS also a glass transition is observed between 90 and 120°C which can be reliably determined by DMA. A characteristic feature of extruded polymeric components based on slowly crystallizing semi-crystalline plastics such as PPS is an exothermic recrystallization peak between glass transition and melting range. For PPS recrystallization takes place around 130°C. To avoid physical changes in the use phase and to improve the mechanical properties PPS components are commonly tempered at elevated temperatures around 140°C.

Regarding the solar and infrared optical properties black-pigmented PPO and PPS grades are characterized by high absorbance in the solar and heat radiation range (90 to 95%). Due to the higher index of refraction of PPS the reflectance (up to 10%) is slightly higher for PPS.

Summary and conclusions

The presented tool box allows for the material characterization on specimen and component level and provides a basic understanding of specific features and properties of plastics for solar-thermal applications. As to the long-term behavior under service-relevant loading conditions the time and temperature dependent mechanical properties (creep or relaxation phenomena) have to be considered and assessed. Furthermore, the formulation of the material with stabilizer packages is of utmost importance. For the analysis of additives specific separation and detection methods are required.

Recommended literature

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