Abstract:
Polymers with a triggered decomposition are attractive for an array of applications ranging from patterning to transient packaging materials as well as for environmental protection. This work uses UV and thermally triggered transience in fiber mats using poly(propylene carbonate) (PPC) composites. The electrospun PPC-composite fiber mats combine excellent decomposition performance (due to the high surface to volume ratio) with high stiffness and thus represent a new class of materials enabling innovative applications such as transient filter materials, short-time plant protection materials, as well as temporary lightweight materials for aerospace engineering. Thermally and UV-triggerable additives (protected acids or base) have been used in different concentrations to tune the transience performance of the fiber mats over a wide range (75-212°C). The addition of organo-modified clay (OMMT) enhanced mechanical stability and prevented shrinkage at room temperature. Different annealing methods have been used to improve the mechanical properties even further (tensile strength: 2-12 MPa, Young’s modulus: 55-747 MPa) making these fiber mats attractive for a broad field of applications. An Ashby plot of Young’s modulus versus degradation temperature for electrospun fiber mats is shown, revealing much lower degradation temperatures with higher moduli for PPC composites compared to other electrospun polymers.

Summary of Research:
We report novel electrospun transient fiber mats whose decomposition is triggered by UV irradiation and heat treatment. Beside a fast decomposition, these fiber mats also showed excellent mechanical strength. The latter is important for the major application of electrospun nonwovens as filter materials [1]. Furthermore, the transient properties demonstrated enables innovative vanishing filters for highly toxic materials. However, due to the high mechanical strength of these transient fiber mats further applications such as temporary plant protection materials in agriculture, packaging materials and lightweight materials for aerospace engineering can be envisaged. We recently demonstrated thin film decomposition of poly(propylene carbonate) (PPC) catalyzed with a thermal acid generator (TAG) or a photo acid generator (PAG) under mild conditions [2]. These findings along with the accessibility and mechanical toughness of PPC motivated us to produce transient fiber mats with this material. Inspired by the research of Jung, et al., on base-catalyzed hydrolyses of PPC [3], we also investigated the effect of a photo base generator (PBG) on the decomposition of PPC in addition to PAG and TAG. The ratio of acid or base generator to PPC has been varied to minimize the degradation temperature of the composite fiber mat.
Our studies on transient polycarbonate films imply that the mechanical strength of pure PPC fibers is probably still too low for many applications (e.g. transient filters), although the processing via electrospinning will influence mechanical stiffness due to polymer chain alignment. Organo-modified montmorillonite (OMMT) was selected to improve stiffness and to increase the glass transition temperature \( T_g \) of PPC in fiber mats. OMMT worked well for our PPC-composite films due to the preparation of the polymer/OMMT composite not requiring high temperatures (no release of the protected acids/bases). The amount of OMMT was kept to a minimum that guarantees stable fiber mats at room temperature without significantly affecting the decomposition temperature. Composite preparation, electrospinning conditions, as well as post-processing have been modified to tailor the mechanical properties of the PPC-composite fiber mats for the desired applications.

Blends from poly(propylene carbonate) with organo-modified montmorillonite (OMMT) and a thermal/UV-triggerable additive, which release either a strong acid or base, were electrospun successfully. The use of 5 wt% (relative to PPC) photo base generator, which releases the strong base TBD, reduces the thermostability of PPC significantly and enables the transience of PPC under relatively mild conditions. Fiber mats that have been irradiated with UV light (254 or 365 nm, for either 10 min before annealing or the entire time during annealing) showed full decomposition within 25 minutes at 75°C. Besides this behavior, the addition of OMMT enhances the mechanical stability and prevents shrinkage at room temperature. Tensile strength and Young’s modulus were improved by pre-annealing of the spinning composition, electrospinning at ≥ 40°C as well as post-annealing of the fiber mats. Post-annealing showed the best improvement.

A 30 min post-annealing at 50°C while fiber mat remained on the collector plate covered by a thin aluminum plate showed no shrinkage or folding and led to a tensile strength of ~ 12 MPa and Young’s modulus of ~ 747 MPa. Consequently, these transient composite fiber mats are suitable for a wide range of applications in the field of transient packaging materials, transient plant protection material, transient filter systems for toxic materials, and any application where a lightweight transient material with good mechanical strength is needed (e.g. in aerospace engineering).

SEM micrographs of 3 nm gold sputtered samples were captured on a ZEISS SUPRA 55VP SEM using the ZEISS SmartSEM software with an accelerating voltage of 1.5 kV and the SE2 detector. For additional information on solution preparation and spinning parameters, please contact the author.

References: