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Superimposed mechanical-environmental durability of polymeric hybrid laminates

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Polymer/inorganic multi-layer laminate structures are of prime interest to a range of novel technology fields such as in the renewable energy sector, the mobility sector and alike. The near-service conditions in hybrid laminates typically consist of superimposed mechanical stresses and environmental factors. Additional electrical stresses may also be superimposed. In many of the applications of such polymeric hybrid laminates, debonding between the laminate layers is a frequently observed damage and failure mechanism. However, resulting from the multi-layer laminate structure and the overall mechanical-environmental loading conditions, the specific loading conditions at the interfaces are highly complex, and the underlying mechanisms of ageing-induced delamination are as yet poorly understood. Hence, novel environmental fracture mechanics methods allowing for delamination crack growth investigations to determine the kinetics of delamination in hybrid laminates under superimposed mechanical-environmental conditions will be presented and discussed (s. Figure). These methods are applied to a range of laminate materials (electrical steel; silicon glass; epoxy resins; ethylene copolymers) for which the material structure and the processing conditions are varied systematically. Thereby, scientifically sound material structure-processing-property-performance (msp^3) correlations also accounting for ageing effects are deduced. Moreover, the sensitivity and feasibility of the novel methods for characterizing and monitoring long-term ageing and damage processes in an accelerated but service-relevant manner is evaluated. Therefore, the delamination kinetics data are compared to results of commonly used long-term behaviour assessment approaches based on exposure of unloaded laminates under defined environmental conditions and subsequent monotonic mechanical testing at ambient conditions. Regarding the environmental conditions, specific focus is given to dry and damp heat (in air or nitrogen) at temperatures below and above glass transition of the polymeric adhesive layer.

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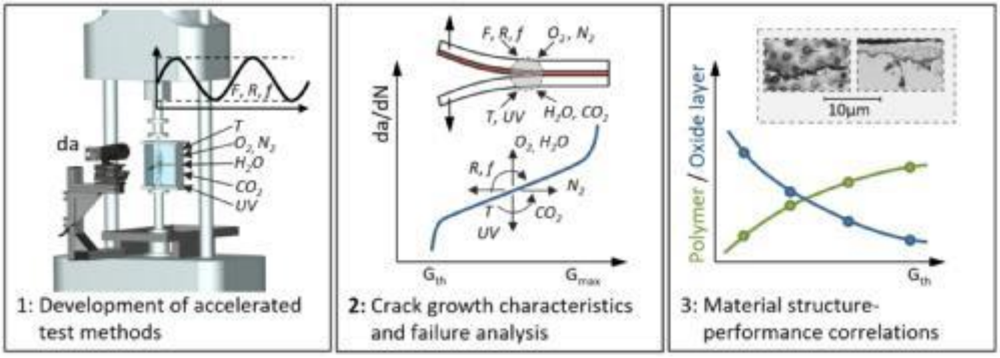
Fracture mechanics-based approach



1: Development of accelerated test methods

2: Crack growth characteristics and failure analysis

3: Material structure-performance correlations