# Transfer of the flame retardancy and post-fire mechanics from polymer materials to glass-fiber-reinforced plastics


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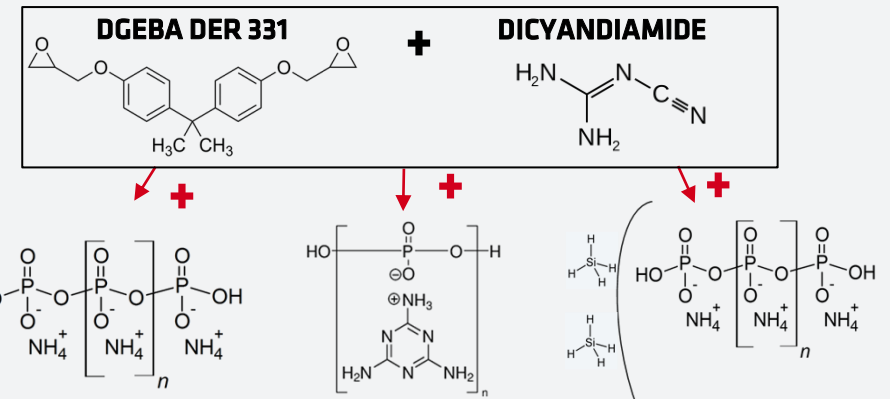
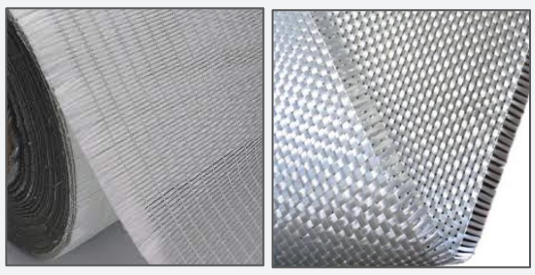
## Motivation and Aim

More knowledge is needed about flame protection more specifically, **the fire resistance and flammability of fiber-reinforced polymeric systems and their fire resistance under mechanical stress.** Furthermore, little is known about the mechanical properties and changes during and after a fire of these types of materials.

This project thus aims to **understand the modes of action in flame retardancy and post-fire mechanics** of phosphorus based flame-retardant polymer materials in fiber-reinforced composites and to compare them with pure epoxy resins.




**Ammonium polyphosphate (APP)** **Melamine polyphosphate (MPP)** **Silane coated ammonium polyphosphate (SiAPP)**



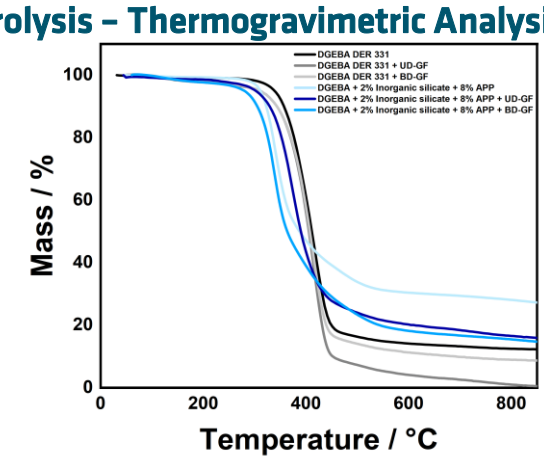
**Unidirectional glass-fiber (UD-GF) 640 g/m² 0/90°**



**Bidirectional glass-fiber (BD-GF) 580 g/m² 0/90°**

## Results

### Pyrolysis – Thermogravimetric Analysis (TGA)




### Flammability

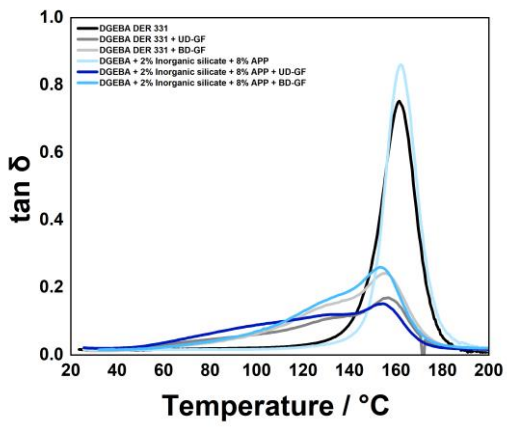
**Limiting Oxygen Index (LOI)**

| | Sample | DGEBA DER331 | DGEBA DER331 + GF-UD | DGEBA DER331 + GF-BD |
|---|---|---|---|---|
| | | OI / vol.-% (± 0.2) | | |
| 1 | DGEBA | 21.1 | 33.0 | 30.9 |
| 2 | DGEBA + 2%InSi + 8%APP | 25.7 | 47.1 | 36.3 |

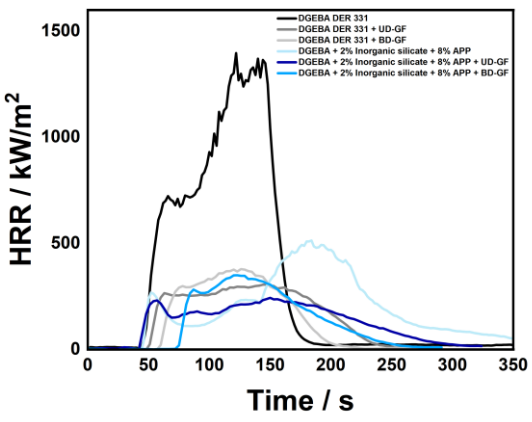
**UL-94**

| | Sample | DGEBA DER331 | | DGEBA DER331+GF-UD | | DGEBA DER331+GF-BD | |
|---|---|---|---|---|---|---|---|
| | | Classification | Burning rate (mm/min) | Classification | Burning rate (mm/min) | Classification | Burning rate (mm/min) |
| 1 | DGEBA | HB40 | 16 ± 4 | HB40 | 0 | HB40 | 0 |
| 2 | DGEBA + 2%InSi + 8%APP | V0 | - | HB40 | 0 | HB40 | 0 |

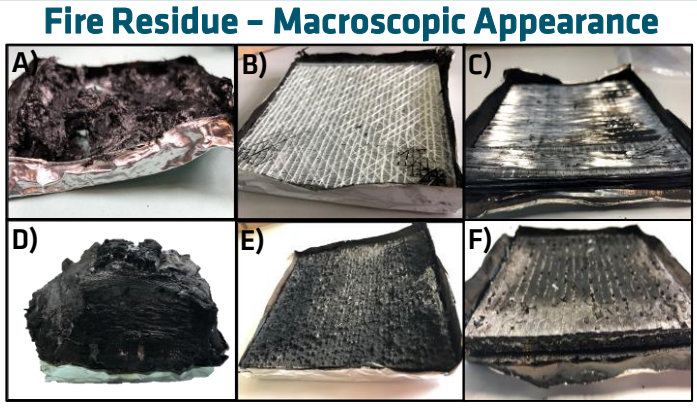
### Dynamic Mechanical Analysis (DMA)




### Fire Behavior - Cone Calorimeter

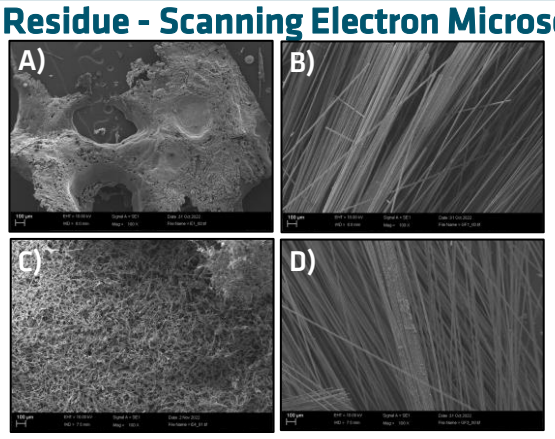



### Fire Residue – Macroscopic Appearance




Fire residue of flame retardant formulations A) in the neat resin and with B) unidirectional and C) bidirectional glass fibers. Epoxy resin with 8% APP D) without glass fibers and with E) unidirectional and F) bidirectional glass fibers.

### Fire Residue - Scanning Electron Microscopy




SEM Images of fire residue of A) neat resin and with B) unidirectional glass fibers. Epoxy with 8% APP C) without glass fibers and with D) unidirectional glass fibers.

## Conclusions

### Pyrolysis

- The amount of residue increases when resins are transferred to glass fiber composites.
- When transferred to glass fiber composites, $T_{5\%}$ increases and $T_{max}$ decreases.

### Flammability

- When transferred to glass fiber composites, the LOI value increase significantly.
- The addition of flame retardants decreases the burning rate.

### Fire Behavior

- The HRR, THR, and PHRR decrease when the resins are transferred to glass fiber composites.
- In addition, the modes of action in gas and condensed phase, decrease significantly.

### Dynamic Mechanical Analysis

- The height of the tan ∂ curve decreases as follows: neat resin >> BD GF composite > UD GF composite indicating lower segmental mobility due to the glass fibers and good interfacial adhesion between the resin and fibers.

### Conclusions

- The mobility of the polymer chains is negligibly affected when FRs are added for the neat resin and composites.
- The value of Tg (peak of the tan ∂ curve) is around 160°C and the presence of the glass fibers only causes a slight decrease in this value.
- When the glass fibers are added, there is a change in the modes of action of flame retardancy.
- There is an increase in intumescence and charring when the FRs are added. When glass fibers are added the charring and intumescence diminishes.

Sicherheit in Technik und Chemie


## Acknowledgements

This project is financed by the DFG (Deutsche Forschungsgemeinschaft) (DFG SCHA730/26-1 and DFG AL 474/53-1). The authors thank Prof. V. Altstädt for his contribution to the research concept.