Novel Technique for On-Line Monitoring of the Curing Process of Fiber Reinforced Polymer Composites

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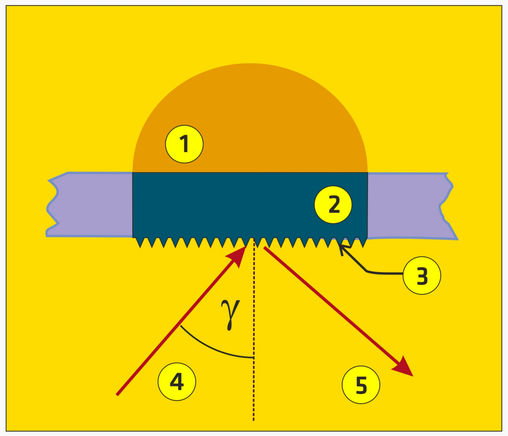
Introductiom

Today glass- and carbon-fiber composite parts are produced by integrating the fibers in a polymer matrix via a curing process. The knowledge of the existing cure situation during the production process of the thermosetting material is of enormous importance since the degree of crosslinking or the chemical conversion respectively is finally related to the performance and properties of composites. Mid- and near- infrared (IR) Spectroscopy as well as THz-Time Domain Spectroscopy in attenuated total reflectance (ATR) geometry are promising techniques for the studies of the chemical reactions during curing. However, these approaches do not fully provide the reproducibility as requested by industry. For this reason a new IR/THz sensor system was developed to investigate its suitability for future online monitoring, controlling and documentation of resin curing processes used in industrial applications.

Principle of Operation



1 - Composite Material
2 - Sensore Plate with
3 - Micro ATR Structure
4 - Incident Infrared beam
5 - Attenuated leaving beam

Experiments

A specially designed sample mount has been integrated in to an FT-IR BRUKER V80 spectrometer to measure the spectra of curing epoxy material @ 300K by using empedded sensor plates as follows:

- *Source:* Syncroton light source or globar
- *Detector:* Liquide He-cooled Si Bolometer or DTGS
- *Material:* Epoxy Adhesive HE-E120 K combined with hardener by a weight ratio of 10:50.

The sensor plates with the material were tempered at different temperatures for one houre to simulate a curing process.

Experiments

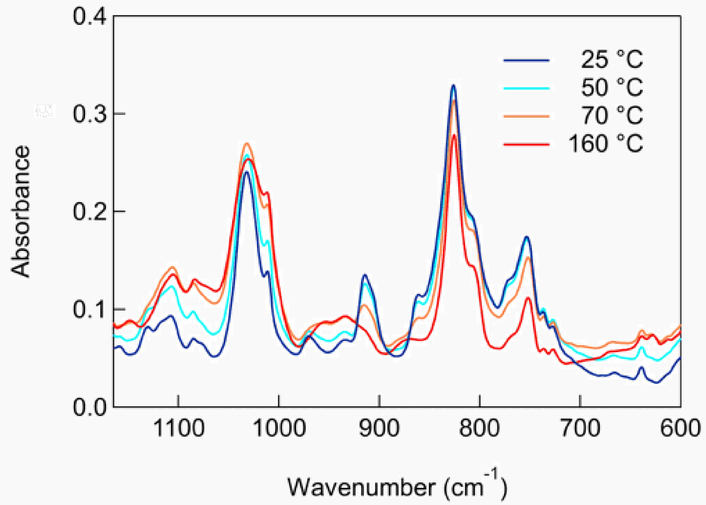


Fig. 1: Absorption Spectra of epoxy resine cured at different temperatures for two hours presented in the wave number interval [1100 600].

Discussion

Representative absorption spectra of a cured epoxy resin are shown in Figure 1. The presence of epoxy groups can be proveided in the IR spectra by the presence of the strong band at 915 cm^{-1} (γ-C-O epoxy). The 1,4-substitution of the aromatic ring can be observed at 830 cm^{-1} for the selected epoxy resin. The corresponding band is getting smaller accroding to the reaction temperature.
This corresponds to the epoxide groups of the resin which react with the hardener.

Conclusions

The sensor plates are appropriate to observe a curing process via IR spectroscopy. Different curing states can be distinguished and classified according to characteristic absorption bands situated in the IR, far-IR and THz region.

Sensor plates

- **are comperatively small and can be located at the surface without disturbance of the component functionality and stability.**
- **permanently ensure an uniform material contact.**
- **allows physical and chemical ageing control.**

The developed optical principle can generally be applied in different online processes to monitor and to control the quality of liquids and solids.

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