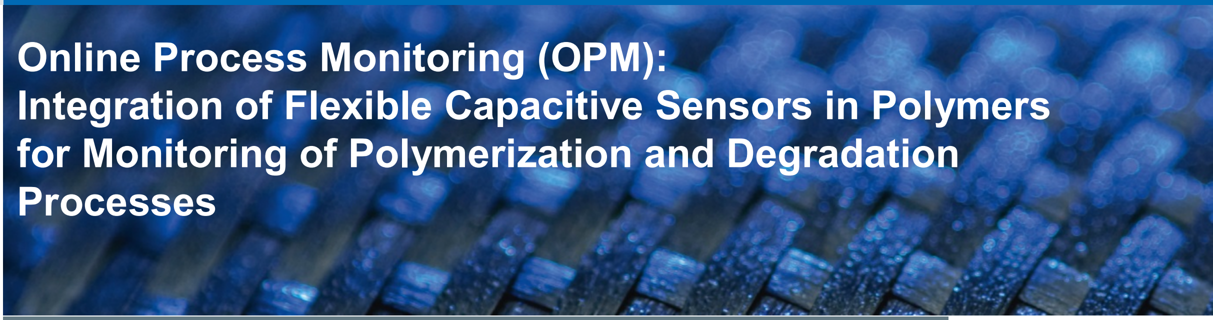
FASERINSTITUT FIBRE BREMEN

PROJECTS

Online Process Monitoring (OPM): Integration of Flexible Capacitive Sensors in Polymers for Monitoring of Polymerization and Degradation Processes

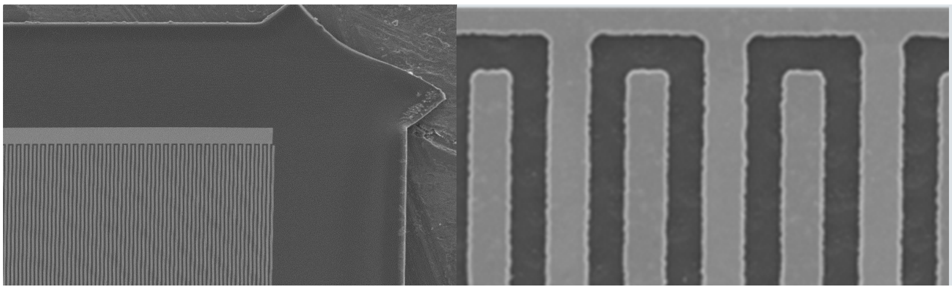


Motivation and Goal

Crosslinked plastics are used for multilayer composites such as coatings and adhesive bonds as well as for fiber-reinforced plastics (FRP) such as e. g. carbon fiber reinforced polymers (CFRP). For the metrological recording of the manufacturing process of these materials and also their long-term behavior methods with potential excitation as impedance spectroscopy have proven. These methods allow e. g. to monitor the polymerization of a component made of CFRP with an embedded dielectric sensor. In the process of polymerization the movement of ions is inhibited, resulting in a change of permittivity and the resistive properties of the material. These measurements make it possible to monitor online the process of curing. This guarantees a consistent quality through an online process monitoring (OPM) and minimizes process times. Sensors for this task exist, but these are relatively large, so that the elements represent a foreign body in the material, which cannot be tolerated in the continuous operation of a component. That is why these sensors are only usable in laboratory tests for component development. If the sensors would be very small and well-adapted to the polymer matrix then it should be possible to let the sensors embedded in the material during the continuous operation of the composite structure. In the project minimally invasive film sensors are developed and embedded in FRP composite materials in order to obtain important information about the condition of the materials with these sensors. At the same time, these sensor structures should be designed in such a way that no significant weakening of the composite material structure arises by the embedded foreign body, so that the sensors can remain in the composite structure over the entire product life-cycle. The goal of the project is the verification of this approach. The processes for preparing the appropriate sensor structures and for their embedding as well as the procedures for analysis and evaluation of sensor data are still unknown today. The required basic scientific investigations are carried out in the project.

Approach

Suitable sensors with comb structures and techniques for their preparation are followed. Simulations of the sensor structure and corresponding experiments are needed. Test structures with different geometries and carrier materials / surface treatments are generated in order to find out what is the relevance of size and surface characteristics. These test structures are embedded in composites and analyzed by means of destructive testing methods such as quasi-static and cyclic load tests. The mutual adhesive strength between the carrier and the matrix material plays a major role which is why alternatives to the common polyimide substrate should be examined.



Scanning electron microscope images of a dielectric miniature sensor

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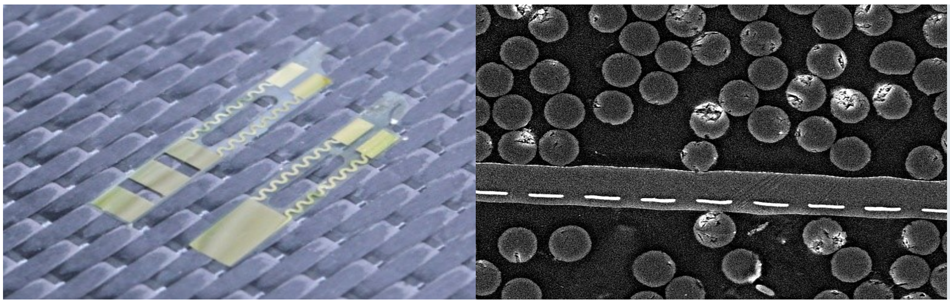
The project has to strike new path in packaging and mounting technology. The sensor and also its electrical connection are generated with the polymer metal polymer foil technology. If the sensor is integrated in a thin foil and the foil is embedded in a polymer matrix, there will be no housing any more. To put it in other words: the matrix material of the fiber composite must become the first order housing material and forms directly the first packaging material of the sensor. The example scenario of the project is the embedding of a sensor in CFRP. In this scenario the monitoring of the curing process has the priority. Reference methods are used for verifying the state of cure measured by means of the dielectric sensors. Known methods of analysis of CFRP materials are, in particular, the differential scanning calorimetry (DSC) and the dynamic mechanical analysis (DMA). The possibility of using the embedded sensor for monitoring the moisture absorption and in the field of structural health monitoring will be shown.



Flex foil sensors for monitoring the product life-cycle of carbon fiber reinforced composites

Possible Applications

Applications for embedded film sensors are the online monitoring of the resin flow front and the process of polymerization during production with the aim of improving the production quality, the process reliability and simultaneously reducing processing times. While previous ultrasound-based methods provide only a single measured value, which is averaged over the entire thickness of the laminate, a height resolution can be obtained with the targeted new sensors by local measuring between single layers. The online process monitoring (OPM) by dielectric sensors continues to allow the validation of simulation models to predict the flow front and curing in the development phase of new complex polymer composite components. Furthermore, it allows the detection of water penetrating the material.

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Project Partner

- Institut für Mikrosensoren, -aktoren und -systeme (IMSAS), Bremen, Germany (joint research lead)

Faserinstitut Bremen e. V.

The Faserinstitut Bremen e. V. is active in research and development tasks in areas of testing, development and processing of fibres, textile preforms and carbon fiber reinforced plastics. The department of Composite Structures and Processes focuses on the examination of continuous process chains and the design of components for aircraft and automotive industry and other industrial fields.

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