Integration of Microsensors in Fiber Composites

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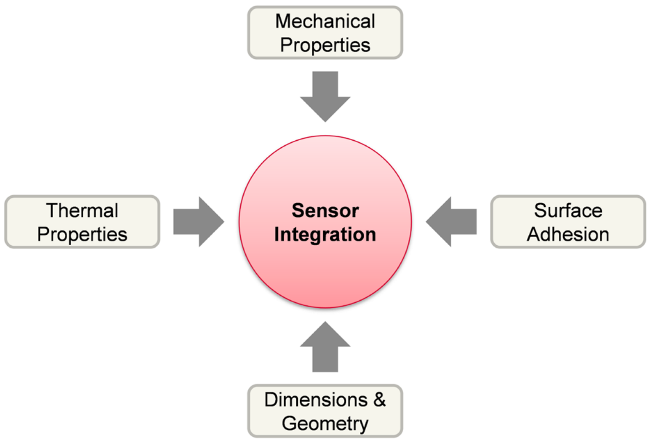
Fiber reinforced polymer composites (FRPCs) are characterized by a high stiffness to weight ratio, for this reason, FRPCs are appropriate in a wide range of applications. For example, carbon fiber/epoxy resin are suitable for aeronautical and aerospace fields, where weight and fuel savings have to be achieved without sacrificing mechanical performance of structural elements in aircrafts. Given the above, it is important to control the manufacture quality of fiber composites in order to guarantee their mechanical properties according to the target application. At the same time, considering the complexity of mechanical behavior of FRPCs it is also desirable to achieve a continuous assessment of loads and strain applied to the composites during their life service. This diagnosis is often called structural health monitoring.



Among the current approaches for health monitoring, self-sensing materials can be obtained by means of embedded sensors for real-time measurements. For this aim, several type of sensors like optic fibers, piezoelectric sensors, electrically conductive fibers and capacitance probes can be considered. However, there are some drawbacks by working with embedded sensors, since a sensor with large dimensions, higher stiffness compared to FRPCs and poor adhesion with the host material may lead to stress concentration and reduced load/strain transfer to the sensor. Theoretical works regarding the integration of sensors within FRPCs have pointed out that some of the most important parameters to be considered during their design are their dimensions, geometry, mechanical/thermal properties, and adhesion to the FRPCs. In order to fulfill such conditions, current research is focused in the development of highly flexible and minimal invasive microsensors. Such miniaturization level is expected to promote a reduction in the downgrading effect on the composite macroscale pro perties. However further studies are required regarding the sensors/FRPCs interphase in order to promote a better integration in the host composite.

Research Question

The development of flexible microsensors are currently aimed to monitor the resin curing process of FRPCs and perform strain measurements. In order to reduce the "wound effect" during their integration within fiber composites, current technology focuses in the use of thin metal/polymer layers with thickness of few micrometers. However, materials commonly used for their fabrication do not offer an intrinsic capability for chemical bonding to host FRPCs. One approach to overcome this is the use of perforation patterns in sensor body to allow the FRPCs resin to flow though these cavities during the fiber composite manufacture. Although improvement of the integration of the microsensor in the host material is achieved, not the entire cross section of the sensor allows the resin to flow through it. Therefore, an amount of sensor surface area remains with no chemical bonds with the resin.

On the other hand, different materials layers are used for fabrication of the microsensors and this may cause that mechanical stiffness of the entire sensor may be higher than the surrounding FRPC resin, leading to non-optimal sensing capabilities. Given these limitations of current technology, the present research project aims to investigate methods for

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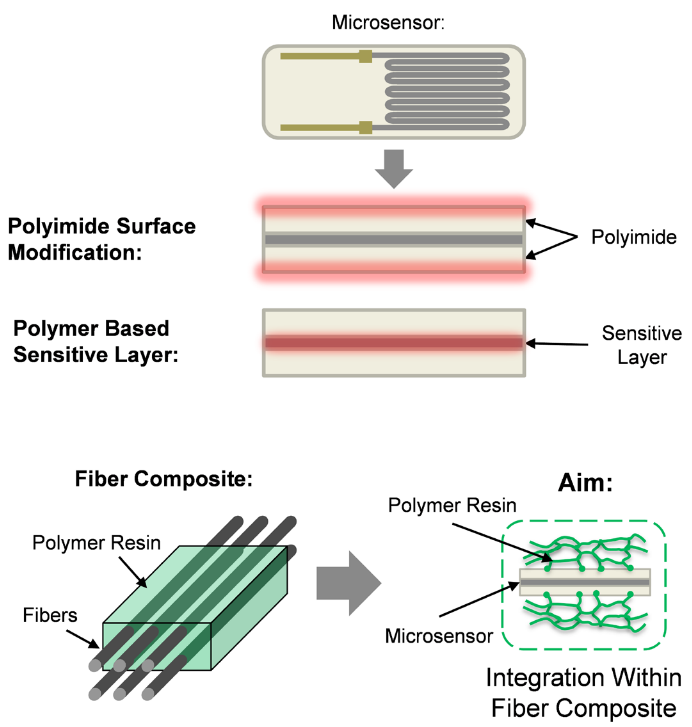
improvement the integration of microsensor for strain measurement of FRPCs. Therefore, the main research questions are the following:

- How to improve the adhesion between the sensor and the host FRPC?
- How to reduce the effect of stiffness mismatch of the constituent layers of the microsensor?

The selected polymer for sensor substrate in this research is the polyimide, as it is currently the most suitable material due its thermal stability and mechanical properties. To improve the adhesion between of the polyimide and the target composite, it is necessary to modify its surface. Functional or chemical groups can be grafted on polymers surface by means of plasma treatments or by some sort of wet chemistry. The treatments conditions should be selected according to the chemical nature of the resin used for the target FRPC. Therefore, the chemical functionalization of the microsensor surface may lead to a covalent bonding with the host composite, improving the adhesion.



Regarding the mismatch stiffness between sensor and host composite, it is necessary to consider that current microsensors are fabricated using different materials layers. Therefore, a replacement of metal layers by electrically conductive polymers should help to reduce mismatch among different constituent layers of the sensor. The proposed method for achieving this conductive polymer is by means of a load of electrically conductive particles. By using this approach, it is expected that total stiffness of the sensor would be similar to an entirely polymer based sensor. The proposed method for achieving this conductive polymer is by means of a load of electrically conductive nanoparticles. By using this approach, it is expected that total stiffness of the sensor would be similar to an entirely polymer based sensor, since it is know that a very low amount of nanoparticles may be enough to produce an electrically conductive composite.

It is also important to consider the interaction between the Polyimide layers; the process for producing thin polymer films is based on spin coating of prepolymer that is later thermally cured. However, in order to promote an adhesion between consecutive polymer layers it also necessary to modify the surface of the previous one. This can be done by either grafting of functional groups on the previous layer or by reversing the Polyimide to its precursor before coating with the next layer.

Possible Contribution to Praxis or Application

The current research project aims to improve the integration of microsensors within fiber composites, to reduce the "wound effect" caused by a foreign body. Current strain sensors are typically located on the materials surface and not inside them; however, fully integrated sensors within the materials can give measurements that are more accurate. Therefore, the results of the project may help to the development of new techniques for structural health monitoring in aeronautic/space fields. The potential improvement in microsensor integration within fiber composites may also be used for techniques related to the control of composites manufacture quality, since the sensors could be left inside the materials after the resin curing process. The proposed strategies can also provide a step forward for micro sensors packing for other applications where, the adhesion of different layer of polymers is desirable.