# AUTONOMOUS SELF-HEALING FUNCTIONALITY IN ADVANCED FIBRE REINFORCED POLYMER COMPOSITE MATERIALS

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## ABSTRACT

## 1 Introduction

A bio-inspired 'healing' approach has been developed for fibre reinforced polymer (FRP) composite materials such as carbon fibre reinforced plastic (CFRP) and glass fibre reinforced plastic (GFRP). In the event of an external impact force, reactive agents contained within the material are activated, initiating healing of damaged internal areas (Fig. 1). Taking inspiration from nature, the healing function for maintaining integrity within the load-bearing structure is analogous to tissue repair in the human body and plants.

## 2 Background

There is a strong focus towards a reduction in carbon dioxide ($CO_2$) emissions in the aerospace and transport sectors. The predominant factor in achieving this is a reduction in weight. FRP composite materials can potentially deliver this requirement without compromising mechanical properties. As with any material there are limitations. In this case, composite materials are inherently brittle and thus prone to damage, thereby reducing the overall structural performance. Adding self-healing functionality has the ability to mitigate this limitation by autonomously repairing internal damage without any external intervention.

## 3 Results and Discussion

Self-healing agents (SHA) have been successfully synthesised for embedding into a lightweight FRP composite material. Microencapsulation of a diglycidyl ether bisphenol A (DGEBA) epoxy based monomer in a poly(urea-formaldehyde) shell [1] provides the delivery system for unreacted monomer. A strict qualitative selection process provided the best solid state catalyst candidates to initiate polymerisation of the epoxy system. Initially, a modified tapered double cantilever beam (TDCB) geometry [2] (Fig. 2) was used to quantitatively assess the degree of healing in an epoxy resin test specimen after an initial fracture event. In this study, catalyst loading, microcapsule content, microcapsule loading and healing temperature were all considered as important variables.

The SHA system outlined above was subsequently demonstrated in a FRP composite material by incorporating a microcapsule and hollow glass fibre (HGF) delivery system [3] distributed at various locations in the laminate. This self-healing material system was matched with the requirements for infusing significant crack volume in a damaged material by addressing two separate FRP damage modes. The microcapsule delivery system addressed small scale damage such as matrix microcracking whereas the HGF network addressed larger scale damage such as delamination. Material healing efficiencies (%) and fracture strength recovery were validated after double cantilever beam (DCB) tests.

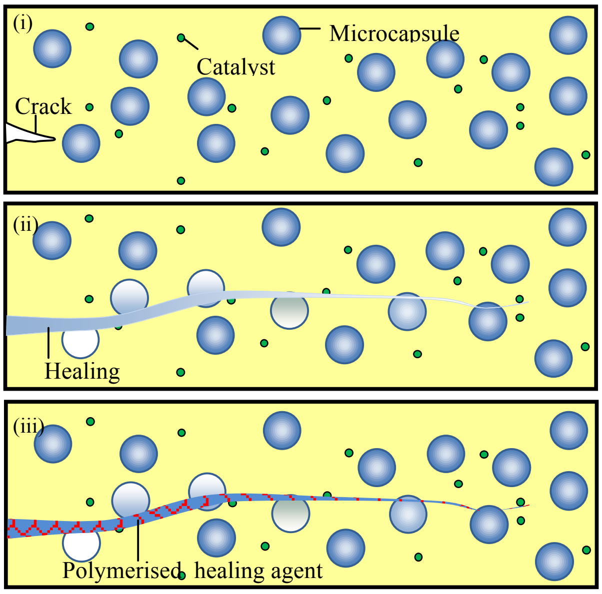


Figure 1: A self-healing polymer system concept containing epoxy-solvent loaded microcapsules and catalyst particles. (i) Crack initiation occurs from a damage event. (ii) Crack propagation releases epoxy monomer, which migrates along the crack by capillary action. (iii) Healing agent polymerises on contact with the catalyst to bridge the two exposed crack planes.

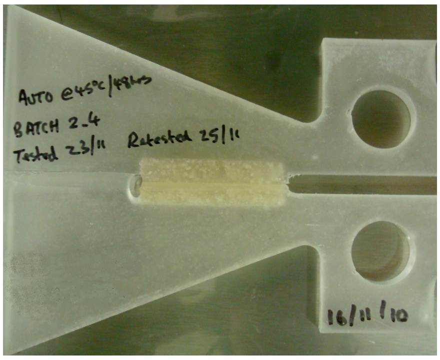

Figure 2: An EPON 828/DETA autonomous test specimen embedded with self-healing agents (SHAs).

## 4 Conclusion

A novel DGEBA based self-healing system has been developed using a stable and active catalyst based on metal salts with weakly coordinating anions. An initial proof of concept study, demonstrated a material recovery value of greater than 80% fracture strength for a pure epoxy resin matrix. This self-healing system was subsequently shown to provide effective recovery of mechanical properties following impact, using a dual embedded microcapsule - hollow fibre approach within a representative self-healing FRP composite material.

## REFERENCES

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