Graphene/epoxy nanocomposites for out-of-autoclave thermosets curing through resistive heating and resistive reparation of carbon fibre composites

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Context

Nowadays high-performance thermoset composite materials are increasingly required in a wide range of industrial sectors, such as marine, aerospace and automotive. These composites based on thermoset polymers require thermal energy to activate their polymerization and, thus, be cured, which has traditionally been done using an oven or autoclave. However, there are a number of disadvantages typically associated to the oven/autoclave based thermoset curing, being the geometry limitation and massive energy consumption those that most concern are currently raising [1, 2]. Thus, the development of alternative ways to induce heat and successfully cure thermoset polymers without having to use an oven, that can potentially be used as Out-of-Autoclave (OoA) curing methods, is currently on great demand.

The idea of an OoA thermoset curing method based on Joule heating of a network of electrically conductive nanoparticles, such as graphene, embedded in an epoxy matrix emerges as one of the most promising alternatives. Indeed, it has been recently probed that, above the electrical percolation threshold, when an electric current is applied to an uncured graphene/epoxy mixture, the electrically conductive graphene flakes act as a resistance and transform effectively the electric current into heat, leading to high degrees of curing of the composites through a simple Joule heating effect [3]. This gives light to the development of an OoA curing method through resistive heating based on the Joule heating effect of an electrically conductive network of graphene flakes integrated in the thermoset matrix.

In this work, the electrical and electrothermal performance of epoxy systems based on two different types of commercially available graphene (reduced graphene oxide and graphene nanoplatelets) is investigated and their performance as electrical additives to cure thermosets through resistive heating is evaluated. More specifically, how their different aspect ratio and specific surface area influence the heating rate, distribution of the electrically induced heat, curing degree and mechanical properties is explored. Going one step further, the potential of using these electrothermal graphene/thermoset mixtures for applications such as resistive reparation of carbon fibres (CFs) reinforced composites is also investigated.

Findings & Conclusions

The electrically induced curing method was found to lead to graphene/epoxy composites with improved electrical, thermal and mechanical properties relative to those cured in a traditional oven with similar graphene loadings. This was attributed to different heating mechanism dominating each method, which led to some structural changes, e.g. more compact structures and certain level of alignment of the flakes in the matrix in the direction of the applied current were observed for the electrically cured materials relative to the oven cured ones. In addition, differences on the structure and properties of the composites, as well as on the curing effectiveness, were found depending on
the type of graphene employed. Indeed, a good dispersion of the filler particles in the matrix seems to be key in achieving a homogeneous distribution of the electrically induced heat and, thus, a complete curing degree all over the thermoset composite sample, which can only be controlled by selecting rationally the type of graphene used as electric additive for the thermosets curing through resistive heating.

In addition to the development of novel a highly effective out-of-autoclave thermosets curing method, these high-performance electrically conductive graphene/epoxy composite mixtures were also probed to have an enormous potential as conductive adhesives to successfully repair CFs/epoxy components through resistive heating without compromising their mechanical properties.

References

