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# Multifunctional Epoxy/Carbon Laminates Containing Carbon Nanotubes-Confined Paraffin for Thermal Energy Storage

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**Abstract :** Thermal energy storage (TES) is the storage of heat for later use, thus filling the gap between energy request and supply. The most widely used materials for TES are the organic solid-liquid phase change materials (PCMs), such as paraffin. These materials store/release a high amount of latent heat thanks to their high specific melting enthalpy, operate in a narrow temperature range and have a tunable working temperature. However, they suffer from a low thermal conductivity and need to be confined to prevent leakage. These two issues can be tackled by confining PCMs with carbon nanotubes (CNTs). TES applications include the buildings industry, solar thermal energy collection and thermal management of electronics. In most cases, TES systems are an additional component to be added to the main structure, but if weight and volume savings are key issues, it would be advantageous to embed the TES functionality directly in the structure. Such multifunctional materials could be employed in the automotive industry, where the diffusion of lightweight structures could complicate the thermal management of the cockpit environment or of other temperature sensitive components. This work aims to produce epoxy/carbon structural laminates containing CNT-stabilized paraffin. CNTs were added to molten paraffin in a fraction of 10 wt%, as this was the minimum amount at which no leakage was detected above the melting temperature (45°C). The paraffin/CNT blend was cryogenically milled to obtain particles with an average size of 50 µm. They were added in various percentages (20, 30 and 40 wt%) to an epoxy/hardener formulation, which was used as a matrix to produce laminates through a wet layup technique, by stacking five plies of a plain carbon fiber fabric. The samples were characterized microstructurally, thermally and mechanically. Differential scanning calorimetry (DSC) tests showed that the paraffin kept its ability to melt and crystallize also in the laminates, and the melting enthalpy was almost proportional to the paraffin weight fraction. These thermal properties were retained after fifty heating/cooling cycles. Laser flash analysis showed that the thermal conductivity through the thickness increased with an increase of the PCM, due to the presence of CNTs. The ability of the developed laminates to contribute to the thermal management was also assessed by monitoring their cooling rates through a thermal camera. Three-point bending tests showed that the flexural modulus was only slightly impaired by the presence of the paraffin/CNT particles, while a more sensible decrease of the stress and strain at break and the interlaminar shear strength was detected. Optical and scanning electron microscope images revealed that these could be attributed to the preferential location of the PCM in the interlaminar region. These results demonstrated the feasibility of multifunctional structural TES composites and highlighted that the PCM size and distribution affect the mechanical properties. In this perspective, this group is working on the encapsulation of paraffin in a sol-gel derived organosilica shell. Submicron spheres have been produced, and the current activity focuses on the optimization of the synthesis parameters to increase the emulsion efficiency.

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