

# CNT fiber veils for CFRP-hybrids with enhanced interlaminar fracture toughness and integrated multifunctionalities

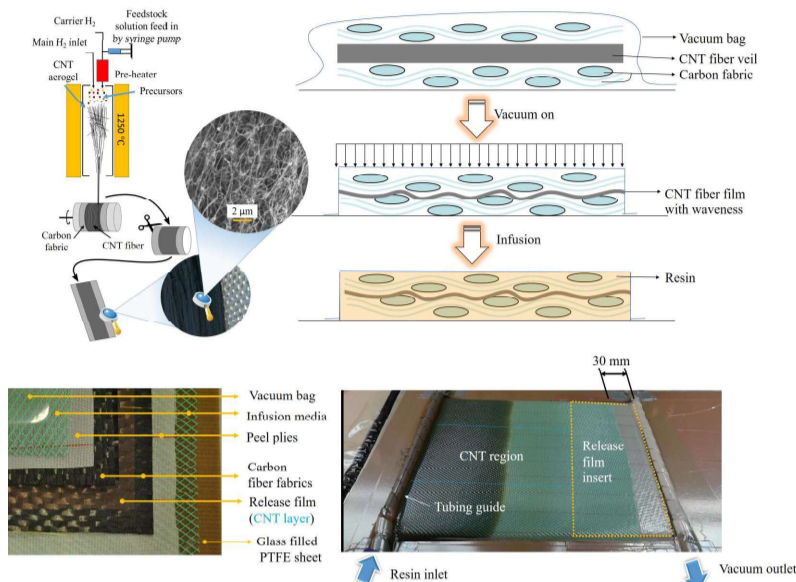
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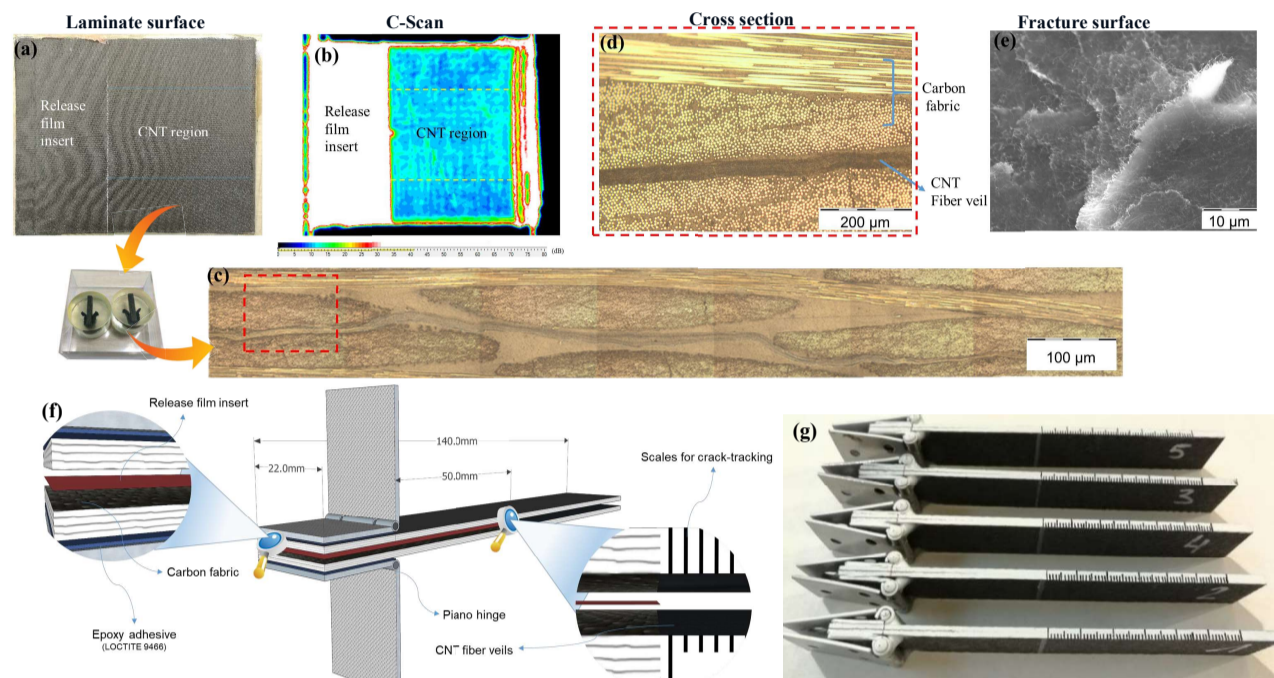
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## A new protocol for producing CNT veils/CF/epoxy hybrids



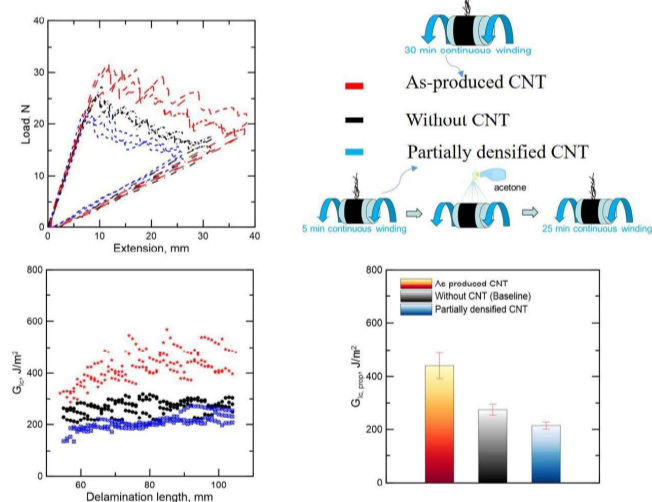
Schematic illustration of a new protocol for the production of epoxy-based hierarchical composite containing tailored CNT layer. Fluffy CNT fiber veils were directly affixed to a sheet of wavy carbon fabric by which thick CNT veils can be pressed into a thin film with a wavy configuration under vacuum pressure; Infusion media were used to promote the resin flow but its length was designed to be 30 mm shorter than that of fabric in order to slow down the speed of flow front before it reaches the outlet and leave enough time to complete infiltration of z-direction.

## Laminate examination and DCB specimen manufacturing



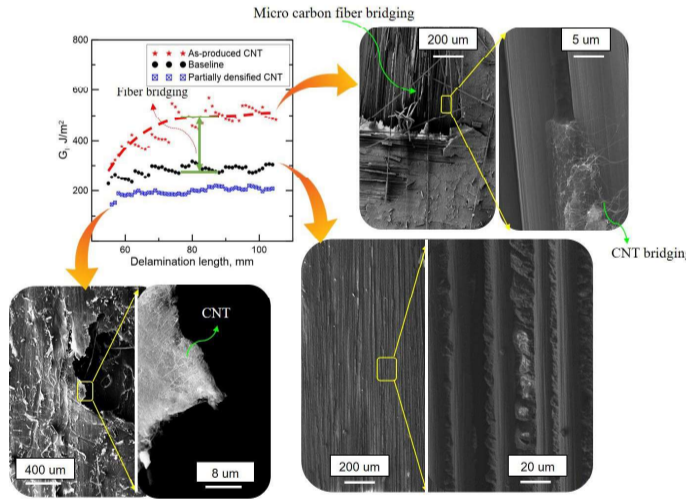
(a) resulted laminate with perfect surface; (b) C-scan result manifested that there is no void inside and it was reconfirmed by the cross-sectional image of laminate created by optical microscope (c); (d) A partial enlarged view of (c) showed CNT veils is full of the resin layer between two fabric layers and (e) SEM image of fracture surface indicated the good distribution of resin within CNT veils; (f) Schematic configuration of the DCB specimen and (g) real ones

## Mode I interlaminar fracture toughness



By the incorporation of fluffy as-produced CNT veils, the rising R-curve behavior was observed, and the propagation value of fracture toughness ( $G_{IC,prop}$ ) increased ~50% compared with the initiation value ( $G_{IC,ini}$ ), which can be attributed to the hierarchical fiber-bridging toughening mechanism. It is noteworthy that the  $G_{IC,prop}$  value of as-produced CNT samples on average enhanced by as high as 60% compared with the baseline. However, interleaving partially densified CNT veils resulted in 28.4% decrease of  $G_{IC,prop}$ .

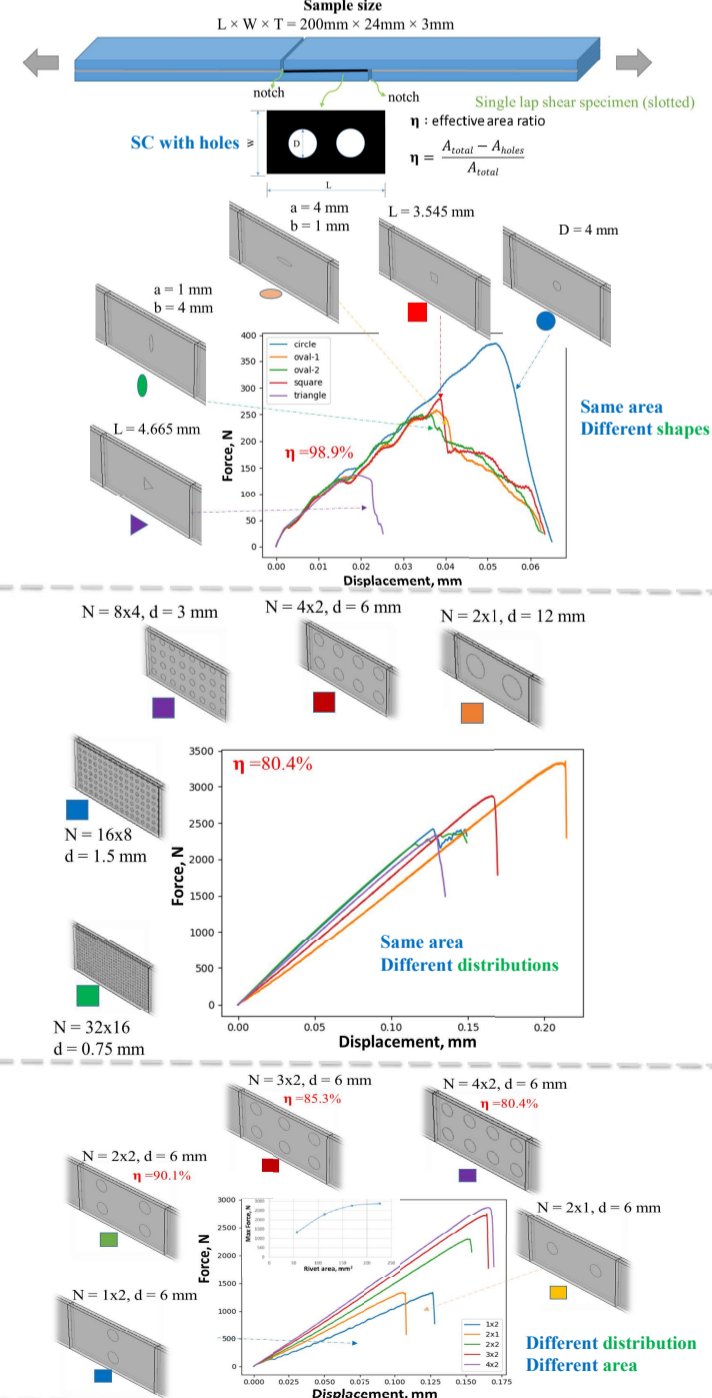
## Comparison of fracture surfaces



Typical features of brittle Mode-I fracture were observed in the baseline specimen, showing a very smooth matrix fracture surface and no fiber-bridging. When interleaving as-produced CNT, the fracture surface is quite rough, which is beneficial for the energy dissipation. If we look closely, we can notice that there actually exist two level of fiber bridging: Microscale carbon fiber bridging and nanoscale CNT bridging. When integrating with partially densified CNT veils, extensive sheet-like peeling were observed and carbon fiber bridging was blocked.

Y. Ou et al. Composites Part A. 2019

## Simulation for tailoring the pin structure and distribution

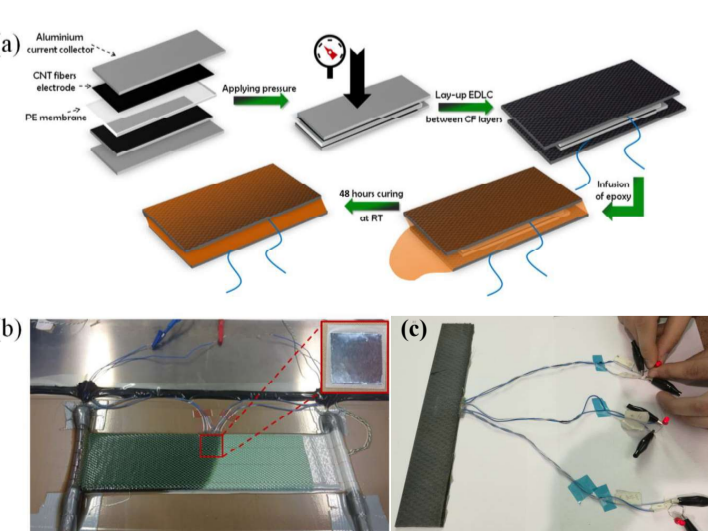


## ACKNOWLEDGEMENTS

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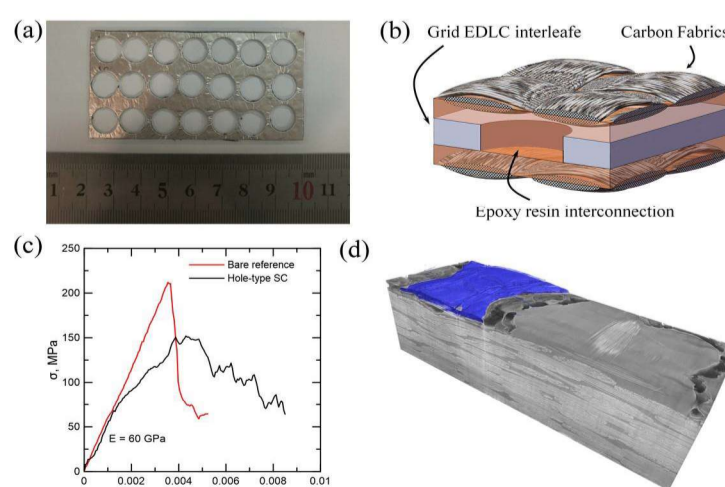
## Energy storage in structural composites by introducing CNT fiber/polymer electrolyte interleaves

### Fabrication



(a) Scheme of the fabrication of structural supercapacitor composite by stamping a CNT fiber-based EDLC interleaf, embedding it between CF plies and infusion/curing of epoxy resin. (b) Photographs of a CF/EDLC/CF lay-up during epoxy infusion and of the 4 cm<sup>2</sup> EDLC interleaf embedded in it; (c) Photographs of the structural supercapacitor powering red LEDs

### Structural optimization



Structural supercapacitor composite with mechanically interconnected plies via the use of grid EDLC interleaves. (a) Photograph of a 32 cm<sup>2</sup> grid EDLC interleaf. (b) Schematic of the envisaged structure. (c) Bending stress-strain curves obtained for reference composite and structural supercapacitor containing a grid EDLC interleaf. (d) 3D tomography images confirming penetration of epoxy resin through channels in the interleaf.

E. Senokos, Y. Ou et al. Scientific reports. 2018