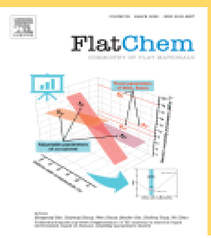
Laser induced incorporation of CNTs in graphene electrodes improve flexibility and conductivity



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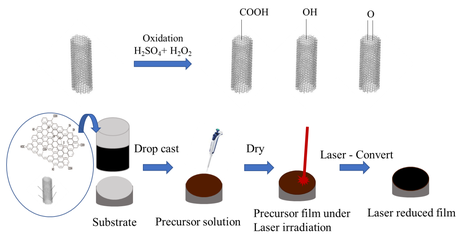
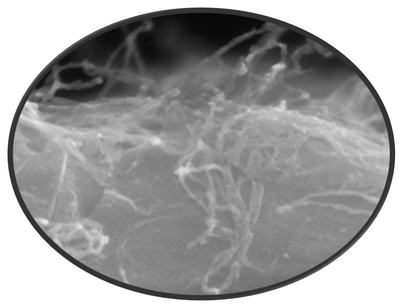
Aims & Objectives

- Laser graphitization emerge as fast, energy saving and low cost material processing technique in recent days.
- Carbonization of carbo precursors is common however, rGO-CNT hybrid composite prepared through laser reduction was not been investigated.
- This is the first report of CNTs involved laser graphitization. The composite films demonstrate high electric conductivity and electrochemical capabilities.
- Electrochemical performance was measured by cyclic voltammetry, showing improvement of retention in capacitance and resistance in both rest and bent alignments.

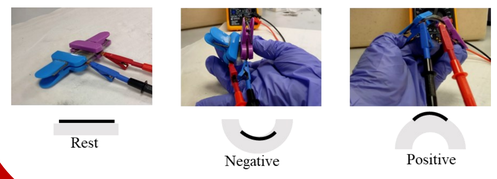
Methods

Sample Preparation

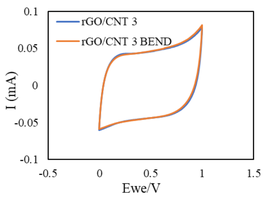




Orientations



Observed cyclic voltammetry

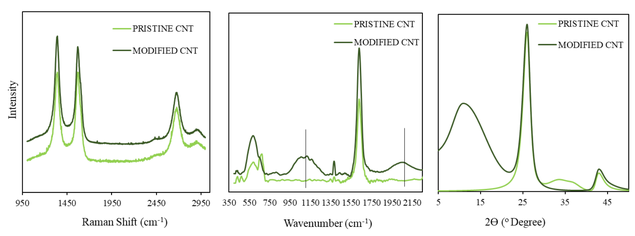


Results

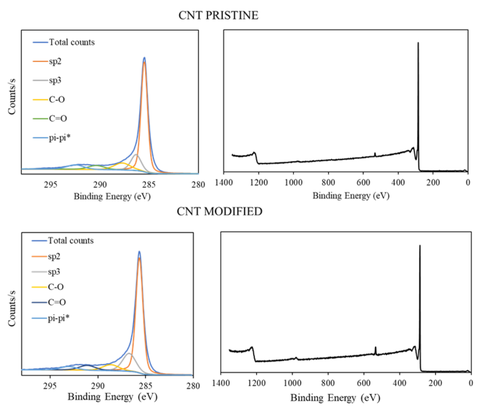
Physical Characterisations

Pristine and Modified CNTs

RAMAN **FTIR** **XRD**

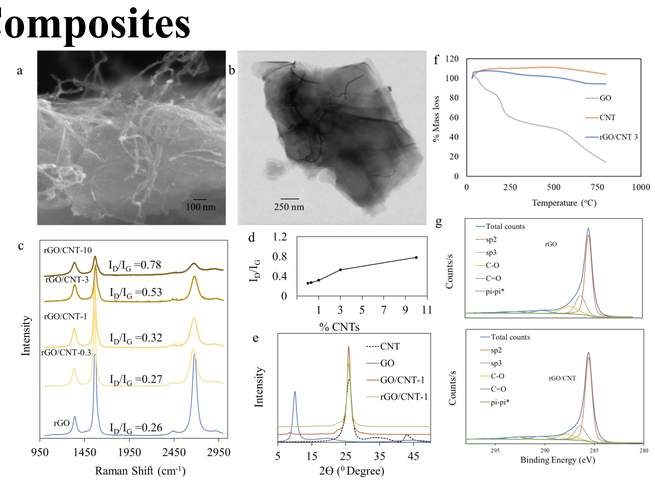


Structural difference between pristine and modified CNTs



XPS of pristine and modified CNTs and full XPS survey

rGO/CNTs Composites

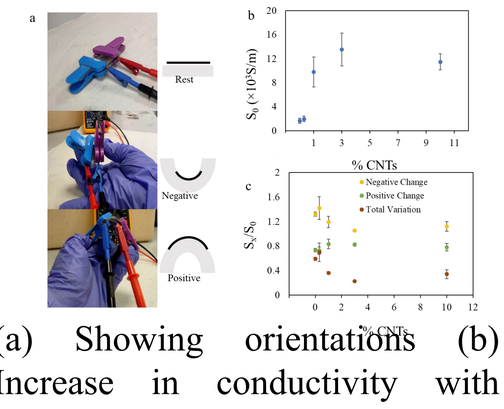


(a) SEM (390kx) image of rGO/CNT-1 (b) STEM image of rGO/CNT-1 (c) Raman Spectroscopy of laser-reduced rGO/CNT-1. (d)I_D/I_G ratio dependence with the number of CNTs. (e) XRD of GO/CNT-1 films. (f) TGA of rGO, CNT and rGO/CNTs. (g) XPS of rGO and rGO/CNT.

Conductivity Studies

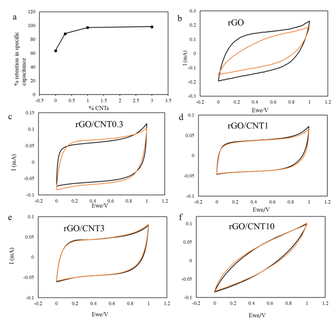
Orientation	Sample conductivities (×10^3 S/m)				
	rGO/CNTs				
	0	0.3	1	3	10
S, Rest	1.80	1.98	12.19	13.51	12.98
S_N	2.44	2.43	13.33	14.08	13.33
S_N/S_o	1.35	1.22	1.09	1.04	1.03
S_P	1.33	1.40	9.25	11.11	9.70
S_P/S_o	0.73	0.70	0.75	0.82	0.75

Conductivity changes during negative and positive bending.



(a) Showing orientations (b) Increase in conductivity with amount of CNTs in rest (c) Change in conductivities with a bending curvature of 90°

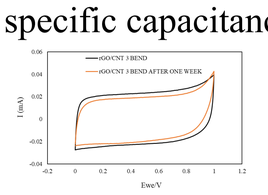
Electrochemical Studies



(a) Percentage retention of specific capacitance with respect to % of CNTs. (b) Cyclic Voltammetry in rest (black) and bend (orange) states at bending curvature of 90° in Na_2SO_4 electrolyte.

Sample	Specific capacitance (Rest), F g^{-1}	Specific capacitance (Bend), F g^{-1}	% Retention in Specific Capacitance
rGO	18	11.5	63.88
rGO/CNT-0.3	6.74	7.52	88.43
rGO/CNT-1	4.75	4.62	97.26
rGO/CNT-3	6.42	6.32	98.45

Specific Capacitance of Samples in rest and in bending state with % retention in specific capacitance.



Long term stability of composite showing 88.36% retention in specific capacitance.

Conclusion

- We have successfully synthesized rGO/CNT composites through laser processing.
- We found that the adding CNTs to the rGO assists the formation of integrated, highly graphitized all-carbon films.
- The addition of CNTs significantly improves the conductivity of the composite samples by 7.5 fold. The overall change in conductivity (positive to negative bending) decreased from 0.62 to 0.19, proving a more stable conductivity upon mechanical stress.
- Furthermore, the rGO/CNT better suits energy storage applications, as demonstrated by electrochemical measurements which supports the effect of CNTs to increase the mechanical strength of the composite material as percentage retention of specific capacitance is 98.45% for the highest CNTs mixed sample.

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