Electrochemical properties

Cyclic votammetry and galvanostatic charge-discharge were carried out with a three-electrode system from 0 to 1 V in 1 M H_2SO_4 solution to test the electrochemical performance of the as-obtained rGO. **Figure 8** showed that with the scanning rate increasing from 5 to 100 mV s^{-1}, all CV curves of rGO electrode exhibited the same shape, however, area covered by them increased, which proved its good capacitance behavior and rate capability. On the other hand, no redox peaks were observed throughout the scan region, signaling the typicality of the EDLC for carbon-based materials [1,14].

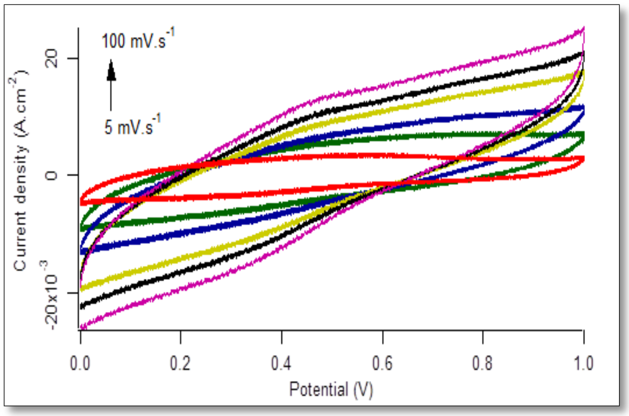

Figure 8. CV cuvres of rGO at different scan rates (three-electrode system).

Figure 9 presents the charge-discharge curves of rGO electrode at various current densities from 1 to 5 A g^{-1}. These charge-discharge curves show triangular forms, which are symmetric and rather slope proving good capacitive quality of rGO electrode. Based on **Figure 9** and the abovementioned equation (1), at the current density of 1 A g^{-1}, the SC value of rGO electrode can be determined, 262 F g^{-1}.

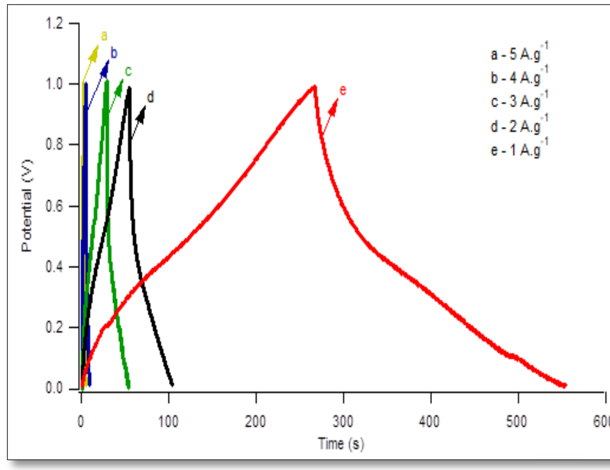

Figure 9. Galvanostatic charge-discharge curves of rGO at different current densities.

Figure 10a demonstrates its different charge-discharge cycles at the fixed current density of 1 A g^{-1}. Obtained graph illustrates series of isosceles triangle curves, which is reasonable with CV behavior of rGO and suggesting that its capacitance can maintain well. **Table 1** shows the comparison of SC of rGO electrode with reported values.

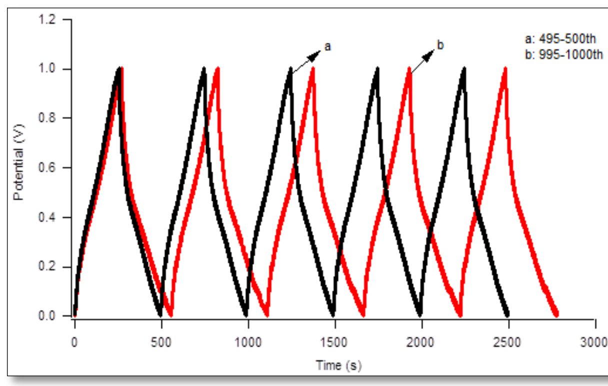

Figure 10a. The different cycles of rGO at 1 A g^{-1}.

Table 1. Comparison of electrochemical performances in terms of specific capacitance of various rGO electrodes.

Sample	Electrode	Current density (A g^{-1})	Specific capacitance (F g^{-1})	Electrolyte	References
EdoX-GO	rGO	1.0	255	6.0 M KOH	[42]
Graphene	Graphene nanosheets	0.5	272	1.0 M H_2SO_4	[23]
GMs	Graphene	0.5	205	30% KOH	[43]
HRGO	rGO	1.0	128	0.1 M Na_2SO_4	[13]
rGO	rGO	1.3	137	1.0 M H_2SO_4	[39]
rGO	rGO	1.0	262	1.0 M H_2SO_4	This work

In comparison with some previous works, it seems clear that rGO has a comparable SC value [23,42] and even much higher than that of HRGO - 128 F g^{-1} [13], rGO - 137 F g^{-1} [39] or rGO - 205 F g^{-1} [43]. Another experiment to reassure about electrochemical stability of rGO electrode is cycling measurement. Still at the fixed current density of 1 A g^{-1}, **Figure 10b** displays the changes of Coulombic efficiency throughout 1000 continuous cycles in the potential range of 0 to 1 V. It is obvious that the SC of rGO electrode shows no significant change after 40 cycles, however, quickly increases to 242 F g^{-1} up to 135 cycles. And then, it slightly increases and reaches the maximum value of 262 F g^{-1} after 400 cycles. Based on the results from the galvanostatic charge-discharge graph, Coulombic efficiency could be calculated by applying equation (2). After 400 charge-discharge cycles are conducted, the SC initiates to slightly decrease and preserves at approximate 90% of the initial value, confirming good electrochemical cyclic stability in consecutive charge-discharge cycles.

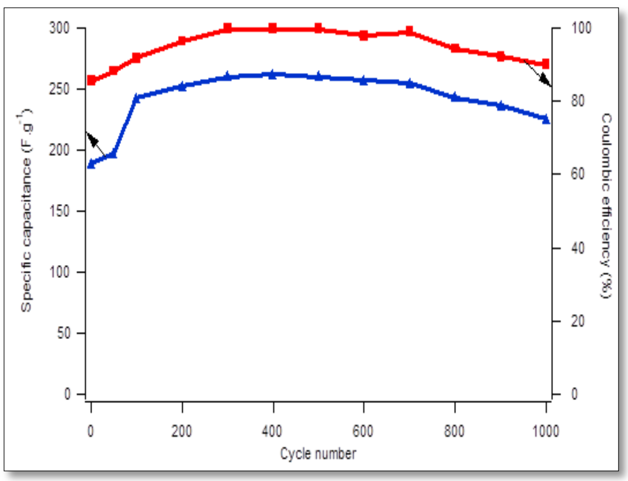

Figure 10b. Charge-discharge cyclic stability of rGO up to 1000 cycles, at a current density of 1 A g^{-1}.

CONCLUSION

To sum up, we introduce the green, easy, and low-cost chemical way utilizing shikimic acid as reducing reagent to fabricate rGO nanosheets, opening up the possibilities in mass production of rGO. The as-prepared rGO was characterized by various physicochemical and electrochemical measurements. The obtained result demonstrates that in 1 M H_2SO_4 electrolyte solution, at the current density of 1 A g^{-1}, the as-synthesized graphene nanosheets exhibit high SC value (262 F g^{-1}). Besides, after completing 1000 charge-discharge cycles, the SC can retain nearly 90%, showing long-term cyclability. In addition, its high power density makes rGO an ideal electrode material for energy storage application.

HIGHLIGHTS

- Graphene oxide was reduced by shikimic acid, an eco-friendly reagent.
- The reduction of the graphene oxide nanosheets was confirmed by various characterization methods.
- The obtained reduced graphene oxide is few layer nanosheets.
- The as-synthesized rGO exhibits high SC value and long-term cyclability.

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