Impact of rare-earth metal oxide (Eu$_2$O$_3$) on the electrochemical properties of polypyrrole/CuO polymeric composite for supercapacitor application

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Galvanostatic charge-discharge (GCD) plots for the other two ternary nanocomposites viz. PPY/CuO/Eu₂O₃-1 (10 weight % of Eu₂O₃) and PPY/CuO/Eu₂O₃-3 (50 weight % of Eu₂O₃).

**Fig. S1.** GCD plots of (a) PPY/CuO/Eu₂O₃-1 ternary nanocomposite and (b) PPY/CuO/Eu₂O₃-3 ternary nanocomposite at the various current densities.

**Fig. S1** shows the comparative GCD curves of PPY/CuO/Eu₂O₃ ternary nanocomposites with 10 % and 50 % Eu₂O₃ at various current densities denoted by PPY/CuO/Eu₂O₃-1 and PPY/CuO/Eu₂O₃-3 respectively. The specific capacitance PPY/CuO/Eu₂O₃-1 with 10 % Eu₂O₃ was obtained to be 201 F g⁻¹, and PPY/CuO/Eu₂O₃-3 with 50 % Eu₂O₃ exhibited a specific capacitance value of 238 F g⁻¹. Increasing the Eu₂O₃ content in the ternary nanocomposite from 10 % to 30 % resulted in the enhancement of the specific capacitance. However, further increase in the Eu₂O₃ content proved to be deteriorating the optimum synergy availed between the various components of the ternary nanocomposite. Excess addition of Eu₂O₃ results into jamming of the mesoporous conducting network which otherwise facilitated the charge transfer easily. This results into the increased charge transfer resistance (Rct) and eventually to a reduced capacitance value. Also, addition of Eu₂O₃ beyond a certain limit results into increased resistance of the active
material which leads to a decrease in the specific capacitance. Moreover, the charge transfer complex that could have been formed at an optimum amount of Eu$_2$O$_3$ inclusion may have been destroyed due to excessive presence of Eu$_2$O$_3$. This leads to reduction in the electron donating tendency of PPY and protonation of PPY, consequently decreasing the specific capacitance value [1,2].

![Fig. S2 (a) FE-SEM image of CuO particles and (b) Eu$_2$O$_3$ nanoparticles.](image)

**CV and GCD plots for the PPY, PPY/CuO, and PPY/CuO/Eu$_2$O$_3$-2 ternary nanocomposite in three-electrode system.**

CV (at the scan rate of 200 mV s$^{-1}$) and GCD (at the current density of 1 A g$^{-1}$) of the PPY, PPY/CuO, and PPY/CuO/Eu$_2$O$_3$-2 ternary nanocomposite was performed as shown in Fig. S3. The CV was recorded in the potential -0.2 - 0.8 V and the GCD was recorded in the potential of 0 - 0.8 V. Pure PPY and PPY/CuO exhibited specific capacitance (as calculated from the GCD data) values of 130 and 223 F g$^{-1}$, respectively. PPY/CuO/Eu$_2$O$_3$ showed an enhancement in the specific capacitance value i.e. 380 F g$^{-1}$. 
Fig. S3 The electrochemical performances of PPY, PPY/CuO, and PPY/CuO/Eu₂O₃ nanocomposites in a three-electrode system (a) CV curves @ 200 mV s⁻¹ and (b) GCD plots at 1 A g⁻¹.

References
