

Supporting Information

Electrochemical properties of micron-sized, spherical, meso- and macro-porous Co_3O_4 and CoO-carbon composite powders prepared by two-step spray drying process

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This file includes:

- Schematic diagram of the spray drying process.
- XRD patterns of the powders post-treated in nitrogen and air atmospheres.
- Nitrogen adsorption and desorption isotherms and pore size distribution curves of the Co_3O_4 and CoO-carbon composite powders.
- Rate capabilities of the Co_3O_4 and CoO-carbon composite powders, acquired by step-wise increment in the current densities from 500 to 10000 mA g^{-1} for successive cycles in the voltage range of 0.01-3.0 V.
- Cyclic voltammograms of the CoO-C composite powders for the first tenth cycles at a scan rate of 0.1 mV s^{-1} in the voltage range of 0.01–3 V.
- TEM images of the precursor powders prepared by spray drying process after post-treatment at 400 °C under nitrogen atmosphere.
- TEM image of the CoO-carbon composite powders prepared by second-step spray drying process.
- Initial discharge/charge curves and cycling performance of the CoO-carbon precursor powders before milling.

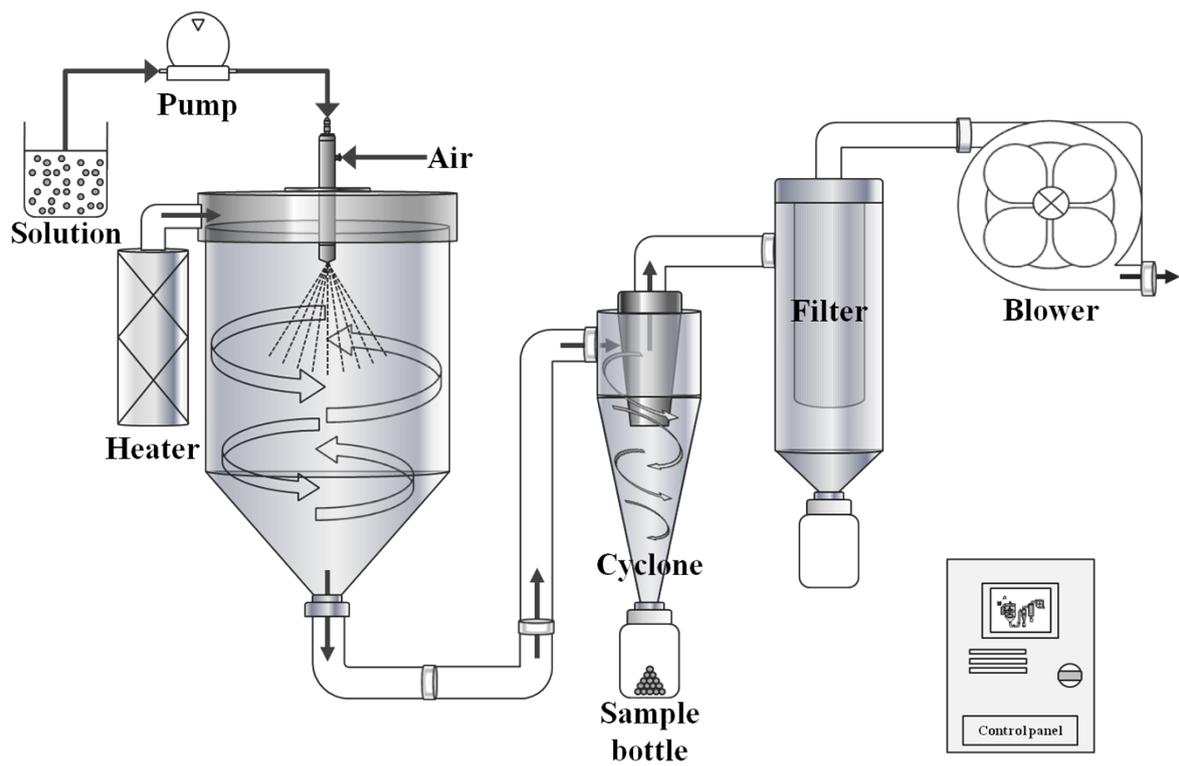


Fig. S1. Schematic diagram of the spray drying process.

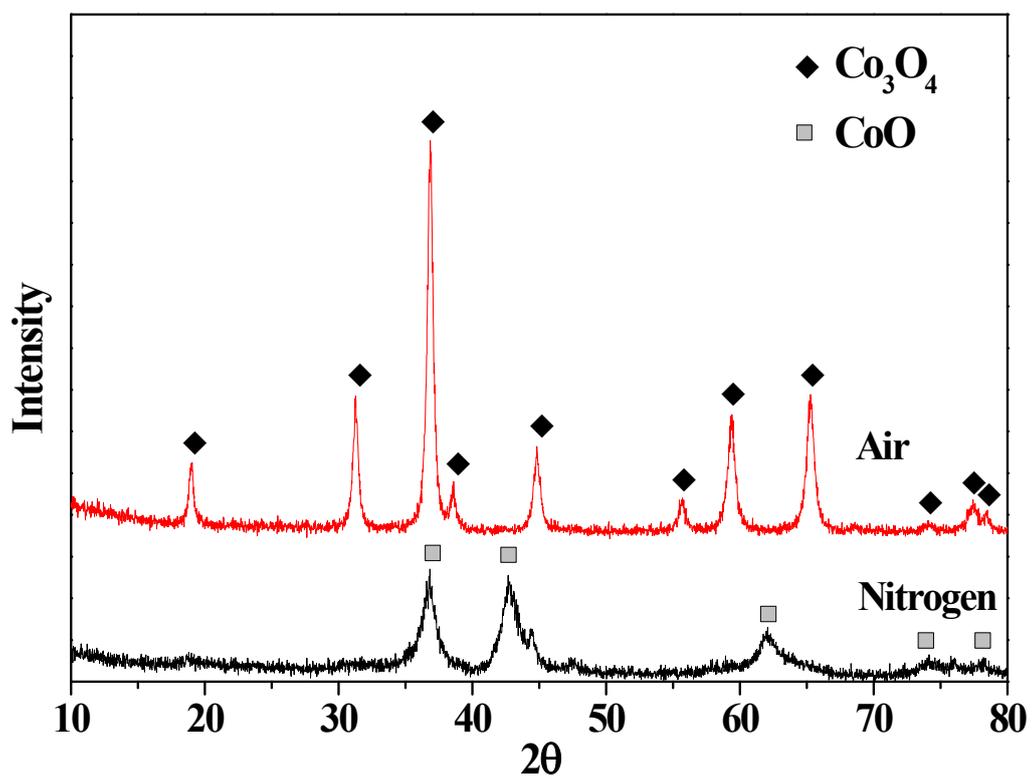


Fig. S2. XRD patterns of the powders post-treated in nitrogen and air atmospheres.

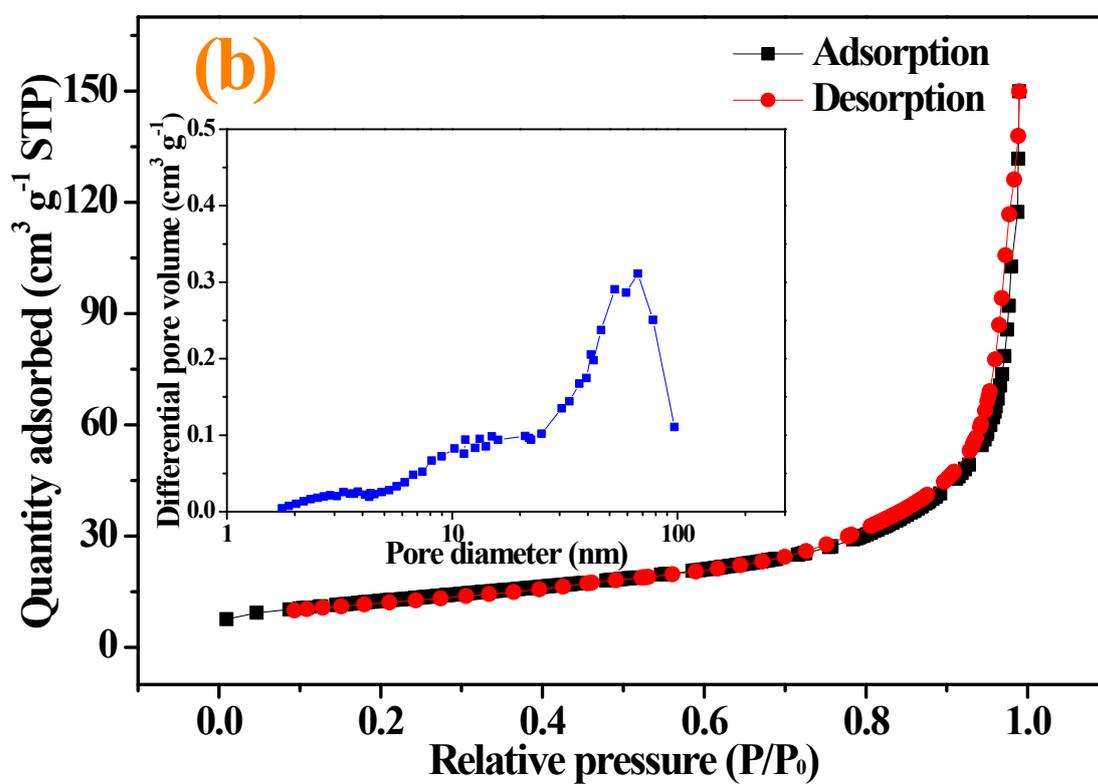
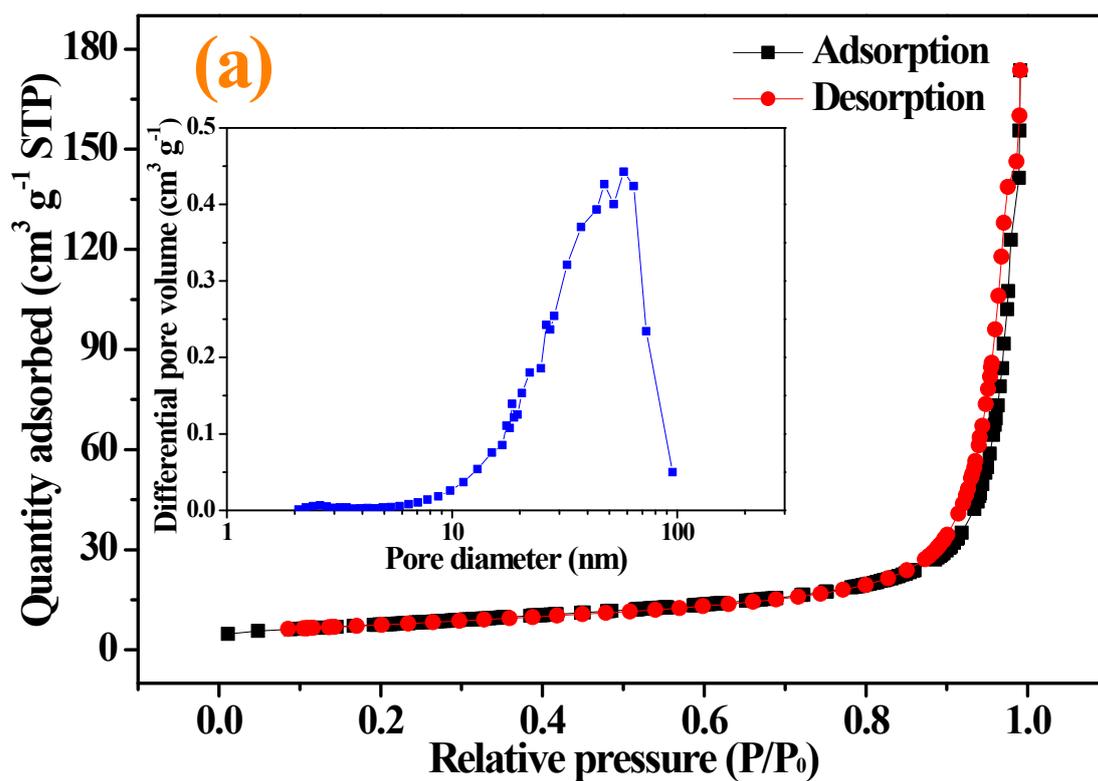


Fig. S3. Nitrogen adsorption and desorption isotherms and pore size distribution curves of the Co_3O_4 and CoO-carbon composite powders.

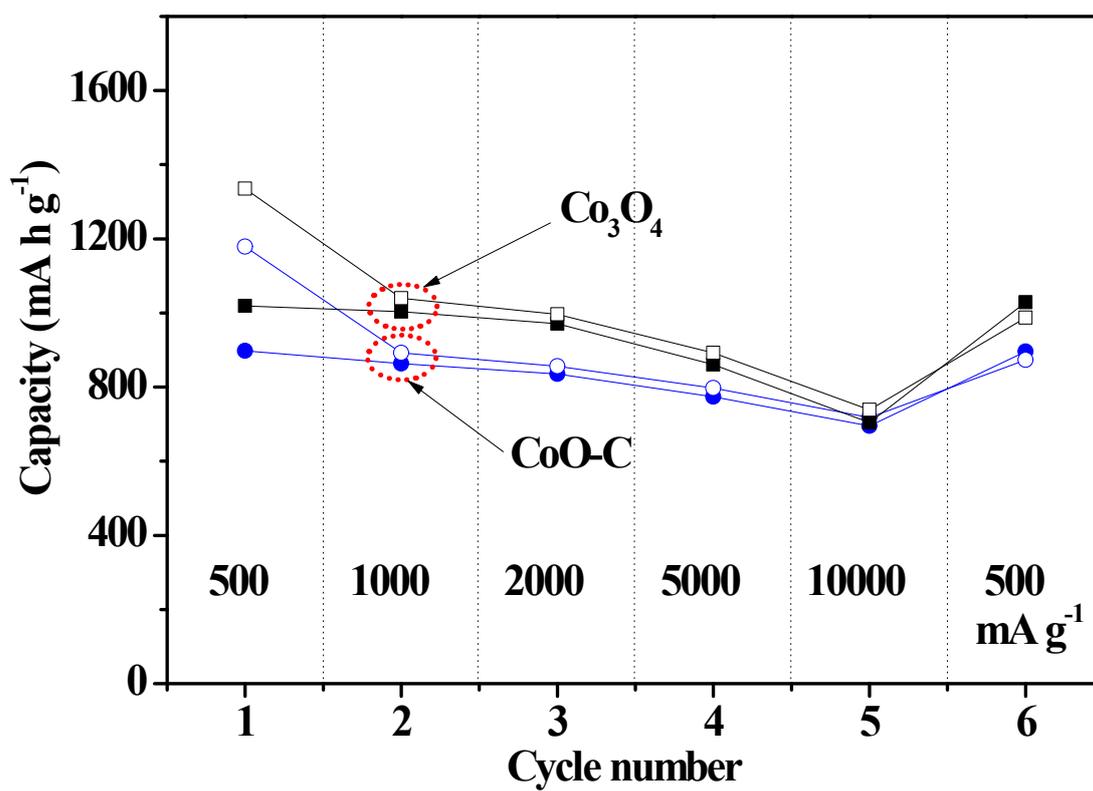


Fig. S4. Rate capabilities of the Co₃O₄ and CoO-carbon composite powders, acquired by step-wise increment in the current densities from 500 to 10000 mA g⁻¹ for successive cycles in the voltage range of 0.01-3.0 V.

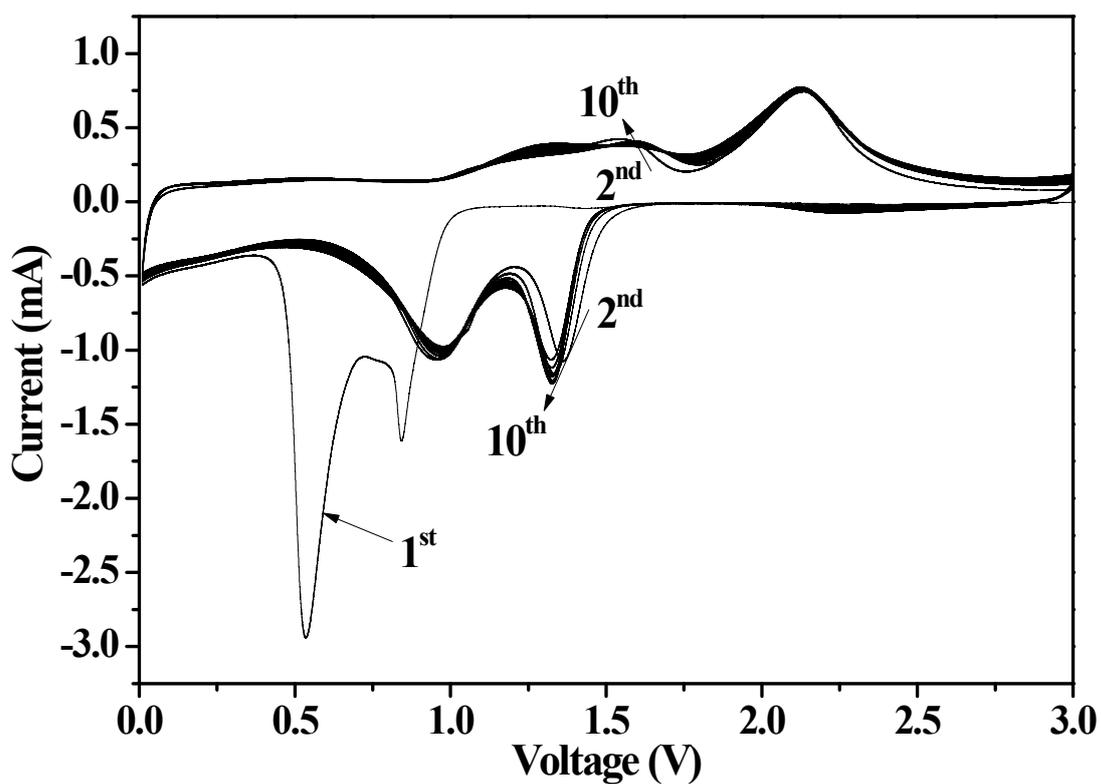


Fig. S5. Cyclic voltammograms of the CoO-C composite powders for the first tenth cycles at a scan rate of 0.1 mV s^{-1} in the voltage range of 0.01–3 V.

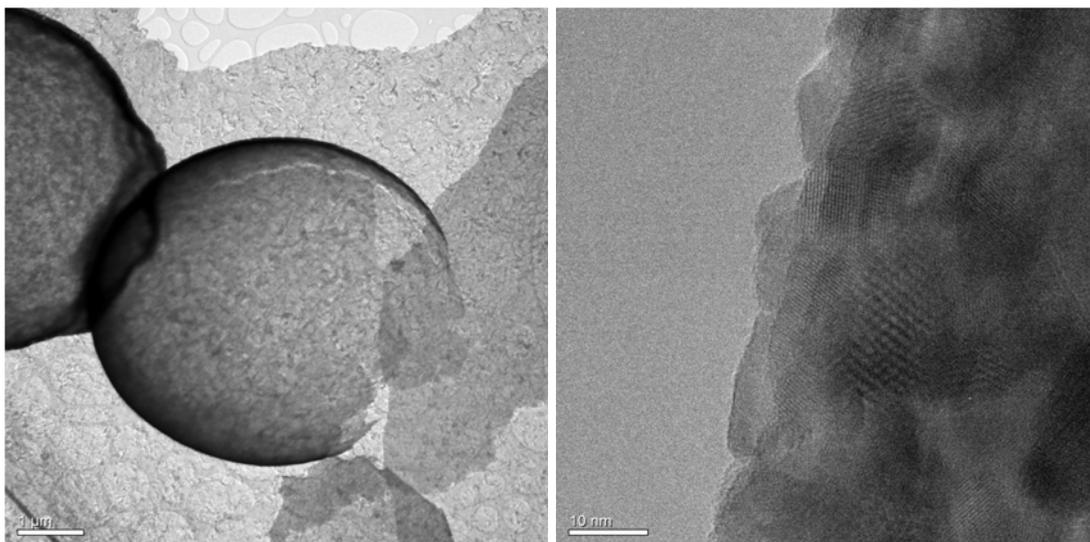


Fig. S6. TEM images of the precursor powders prepared by spray drying process after post-treatment at 400 °C under nitrogen atmosphere.

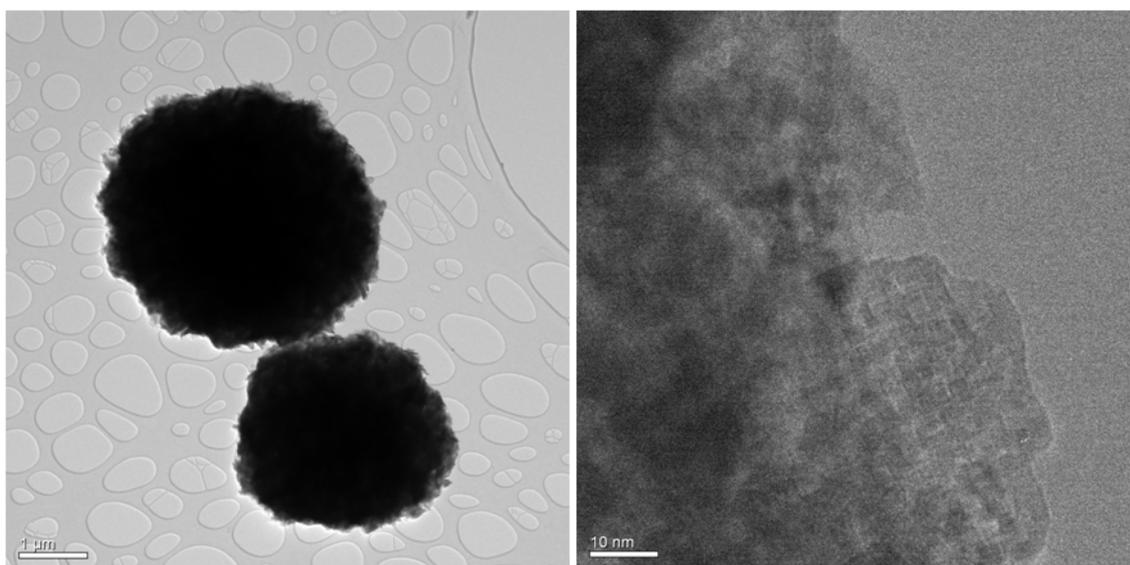
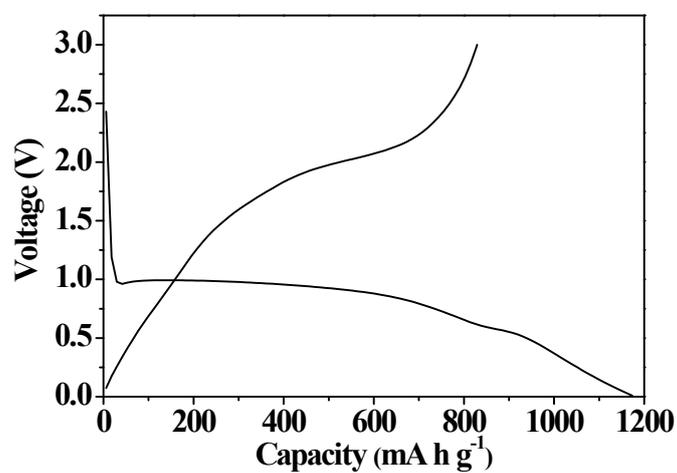
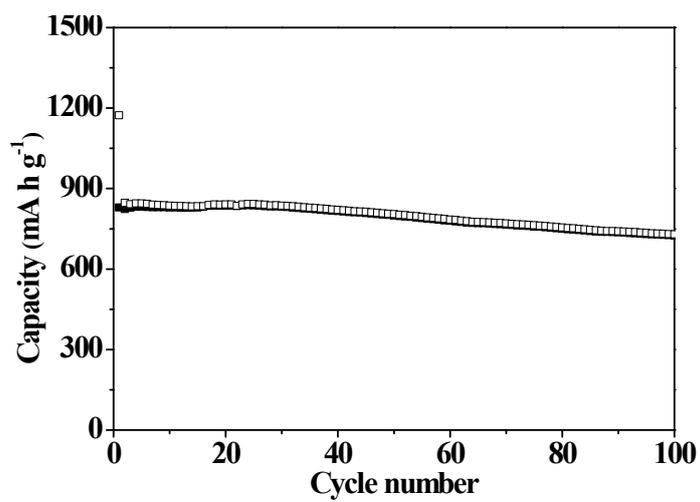


Fig. S7. TEM image of the CoO-carbon composite powders prepared by second-step spray drying process.



(a) Initial discharge/charge curves



(b) cycling performance

Fig. S8. Initial discharge/charge curves and cycling performance of the CoO-carbon precursor powders before milling.

Table S1. Electrochemical properties of cobalt oxides prepared by various methods from literature.

| Material | Morphology | Preparation method | Voltage range [V] / Current rate | Initial C_{dis}/C_{cha} [mA h g ⁻¹] | C_{dis} [mA h g ⁻¹] / cycles | Ref. |
|--|----------------------------------|---|---------------------------------------|---|--|------|
| Co ₃ O ₄ | Flower-like porous spheres | Hydrothermal process | 0.01 – 3.0 / 50 mA g ⁻¹ | 1316 / 899 | 300 / 20th | [2] |
| Co ₃ O ₄ | Nanostructured fibers | Electrospinning | 0.01 – 3.0 / 50 mA g ⁻¹ | 816 / - | 741 / 20th | [4] |
| Co ₃ O ₄ | Nanofibers | Electrospinning | 0.01 – 3.0 / 445 mA g ⁻¹ | 1336 / - | 604 / 40th | [6] |
| Co ₃ O ₄ /C | Hollow spheres | Spray pyrolysis | 0.02 – 3.0 / 30 mA g ⁻¹ | 800 / - | 800 / 50th | [29] |
| C@Co ₃ O ₄ | Carbon coated spheres | Hydrothermal process | 0.5 – 3.0 / 440 mA g ⁻¹ | 818 / - | 567 / 107th | [30] |
| CoO | Nanoparticles | Urea-assisted auto-combustion synthesis | 0.005 – 3.0 / 0.1 mA cm ⁻² | 1159 / - | 565 / 23th | [53] |
| CoO | Octahedral nanocages | Coordination-mediated etching route | 0.05 – 3.0 / 143 mA g ⁻¹ | 1338 / - | 807 / 50th | [18] |
| CoO/CNF | Platelike CoO /carbon nanofibers | Thermal decomposition and recrystallization | 0.01 – 3.0 / 200 mA g ⁻¹ | 841 / - | 725 / 100th | [36] |
| Co ₃ O ₄ /CoO/graphene | Nanosheets | Urea-assisted auto-combustion synthesis | 0.005 – 3.0 / 21 mA g ⁻¹ | 1158 / 890 | 801 / 30th | [56] |