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Method Article

Ruthenium nanoparticles stabilized by mercaptan and acetylene derivatives with supercapacitor application

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A B S T R A C T

Ruthenium nanoparticles (RuHT, RuPET and RuPA) were prepared by hydrazine hydrate reduction of RuCl_3 and stabilized by the self-assembly of organic molecules (hexanethiol, phenylethanethiol and phenylacetylene). The sizes of these Ru nanoparticles were carried out by transmission electron microscopic measurement, with the average core sizes of 2.84 ± 0.55 nm, 3.06 ± 1.22 nm, and 3.10 ± 1.08 nm, respectively. The structures and properties of these Ru nanoparticles were further examined and verified by UV–vis, FTIR, ^1H NMR, XPS and fluorescent measurements. The performance of the supercapacitor was characterized by cyclic voltammetry and constant-current charge-discharge analysis. Ru nanoparticles exhibited enhanced supercapacitor behaviors as compared with blank electrodes. The Ru nanoparticles for supercapacitors in the H_2SO_4 electrolyte exhibited areal capacitances of 347.8, 304.9 and 229.1 mF cm^{-2} for RuPET, RuPA and RuHT at a scan rate of 10 mV s^{-1} , and specific capacitances for 344.4, 249.3, 230.0 F g^{-1} for RuPET, RuPA and RuHT at a current density of 0.5 A g^{-1} , respectively. The interfacial bonding between ruthenium and the outlayer organic ligands and varied ratio of ruthenium in high valence might be the reasonable explanation for the capacitance difference.

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A R T I C L E I N F O

Method name: Hydrazine hydrate reduction

Keywords: Ruthenium nanoparticles, Organic ligand, Supercapacitor, Cyclic voltammetry, Charge-discharge analysis

Article history: Received 6 April 2018; Accepted 4 July 2018; Available online 7 July 2018

- Ru nanoparticles were protected by organic ligands via a simple reduction method.
- These Ru nano-compounds were almost the same core size by this method.
- The properties of Ru nanoparticles could be easily controlled.

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Specifications Table

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More specific subject area	Analytical Chemistry
Method name	hydrazine hydrate reduction
Name and reference of original method	<ol style="list-style-type: none"> 1 X. Kang, N. B. Zuckerman, J. P. Konopelski, S. Chen, Alkyne-functionalized ruthenium nanoparticles: ruthenium-vinylidene bonds at the metal-ligand interface, <i>J. Am. Chem. Soc.</i> 134 (2012) 1412. 2 Y. Guo, L. Chen, Y. Song, P. Hu, S. Chen, Ruthenium nanoparticles stabilized by the self-assembly of acetylene, carboxylate, and thiol derivatives, <i>Adv. Mater.</i> 6 (2014) 1060.
Resource availability	<ol style="list-style-type: none"> 1 http://pubs.acs.org/doi/pdfplus/10.1021/ja209568v 2 http://www.ingentaconnect.com/content/asp/sam/2014/00000006/00000005/art00024

Method details

The Ru nanoparticles were prepared by hydrazine hydrate reduction method, similar procedure that has been used previously in our work [1,2]. In a typical reaction, for example, approximate 20.8 mg RuCl_3 (0.1 mmol) was dissolved in about 1 mL ethanol. Then, the dark wine solution was transferred to 10 ml toluene solution. Then, 32 μL phenylacetylene (or 40 μL 2-phenylethanethiol or 42 μL 1-hexanethiol) was added, and let these ligands contact with Ru ions completely for 30 min. 8 mg hydrazine hydrate (about 2 fold excess equivalents) was used and added drop by drop with a dropping pipet. After the addition of hydrazine hydrate, the reaction was allowed to stir for 24 h to prepare organic-capped Ru nanoparticles. After the reaction, organic solvent was then removed by rotary evaporator. The resulting sample was then washed several times with acetonitrile and ethanol, successively to remove excess ligands. Finally, the purified Ru nanoparticles were dissolved and kept in dichloromethane (DCM), and the solution presents dark brown or black color.

References

- [1] X. Kang, N.B. Zuckerman, J.P. Konopelski, S. Chen, Alkyne-functionalized ruthenium nanoparticles: ruthenium-vinylidene bonds at the metal-ligand interface, *J. Am. Chem. Soc.* 134 (2012) 1412.
- [2] Y. Guo, L. Chen, Y. Song, P. Hu, S. Chen, Ruthenium nanoparticles stabilized by the self-assembly of acetylene, carboxylate, and thiol derivatives, *Sci. Adv. Mater.* 6 (2014) 1060.