Photoswitch of a bundle of bis(8-hydroxyquinoline) nickel nanoribbons

XIUHUA WANG*, LI LIU, MINGWANG SHAO[a]
Anhui Key Laboratory of Functional Molecular Solids, College of Chemistry and Materials Science, Anhui Normal University, Wuhu 241000, China
[a]*Functional Nano and Soft Materials Laboratory (FUNSOM), Soochow University, Suzhou 215123, China*

Bis(8-hydroxyquinoline) nickel nanoribbons with average width of 100 nm and thickness of 20 nm and length up to tens of micrometers have been synthesized via a facile solvothermal method. A photoswitch was fabricated based on bis(8-hydroxyquinoline) nickel nanoribbons and the nanoribbons were found to be sensitive to light. As the light source was switched on and off, the currents could be reversibly switched between high and low value at the voltage of 0.01 V. The photocurrent enhanced by ca. 8.7 times under irradiation of an incandescence lamp compared to in the dark. This conclusion was interesting and might be found potential application in light-controlled devices in the future.

(Received December 13, 2010; accepted June 9, 2011)

Keywords: Bis(8-hydroxyquinoline) nickel, Nanoribbons, Photoswitch

1. Introduction

Since Tang firstly reported the efficient low-voltage-driven organic light-emitting diodes based on tri(8-hydroxyquinoline)aluminum in 1987 [1], 8-hydroxyquinoline and its derivatives metal complexes are intensively investigated, due to their excellent electronic and optical properties [2]. In recent years, one-dimensional (1D) organic metal complexes nanomaterials have attracted a great deal of excitement owing to their superior properties, such as variety, flexibility, multifunctionality, designability, and tailorability, which have allowed them to be widespreadly used for cheap and novel optoelectronic nanodevices [3-6].

Up to now, a few successful preparations of 1D nanostructure materials based on 8-hydroxyquinoline metal complexes have been reported, such as solid-state reaction [7], templates [8], vapor deposition techniques [9], solvothermal method [10], and microemulsion solution method [11, 12]. All these methods are important. Among these, solvothermal method is simple and inexpensive compared to physical vapor deposition.

Herein, we prepared bis(8-hydroxyquinoline) nickel (NiQ_2) nanoribbons through a facile solvothermal method without surfactants or templates. The photoconductivity property of NiQ_2 nanoribbons was studied. As the light source was switched on and off, the photocurrents could be reversibly switched between high and low value at the voltage of 0.01 V, which might be useful in the fabrication of photosensor and photoswitch microdevices or nanodevices in the future.

2. Experimental

2.1 Preparation of NiQ_2 nanoribbons

All of the chemical regents used were analytical grade and without further purification. In a typical synthesis, 0.5 mmol $NiCl_2$ and 1 mmol 8-hydroxyquinoline were dissolved into 40 mL methanol under stirring, which was transferred into a Teflon-lined autoclave of 60 mL capacity and heated to 150 °C for 8 h and cooled to room temperature naturally. Then ultrapure water was dropwise added into the resulting solution under violently stirring. The resulting suspension was separated centrifugally, washed with ultrapure water for several times, and then dried under vacuum at 60 °C for 12 h.

2.2 Characterization

The powder X-ray diffraction (XRD) pattern was recorded on a Shimadzu XRD-6000 X-ray diffractometer equipped with Cu Kα radiation (λ = 0.15406 nm); a scanning rate of 0.05 ^{o} s^{-1} was applied to record the pattern in the 2θ range of 5-50 ^{o}. The morphology and size of the products were studied by a Hitachi S-4800 scanning electron microscope (SEM). Fourier transform infrared (FTIR) spectrum was obtained with KBr pellets for solids on a Shimadzu FTIR-8400S spectrometer. The low magnification image was taken from an Olympus optical microscope. The photoconductivity measurements were tracked with a CHI 620B electrochemical workstation.

3. Results and discussion

The XRD pattern of the as-prepared product is shown in Fig. 1. The peaks at 2θ = 6.73, 16.5, 18.3, 18.8, 23.2, 24.7, 29.3 ^{o} are strong and in agreement with those reported in literature [13], which reveal that the as-prepared products are NiQ_2.

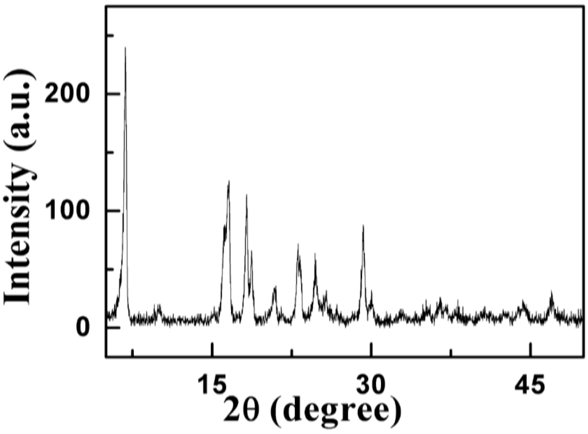

Fig. 1. XRD pattern of NiQ_2.

The FTIR spectrum is recorded to reveal the composition of the products as shown in Fig. 2. The vibrations at 1604, 1577, 1373, and 1327 cm^{-1} are assigned to the quinoline group of NiQ_2. The bands at 1500 and 1470 cm^{-1} should correspond to the vibrations of the pyridyl and phenyl groups in NiQ_2. The band at 1111 cm^{-1} is attributed to a C-O stretching vibration. The peaks at 822, 787, 744, and 644 cm^{-1} are associated with C-H deformation vibrations, and the peaks at 505 cm^{-1} are associated with the Ni-O and Ni-N stretching vibration, which further support that the as-prepared products are NiQ_2 [14, 15].

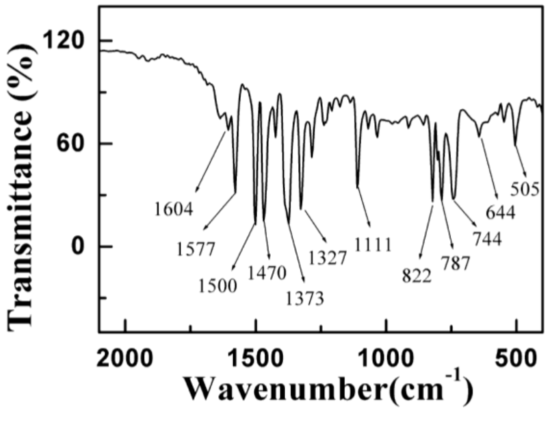

Fig. 2. FTIR spectrum of NiQ_2.

Fig. 3a displays a panoramic SEM image of the as-prepared products, which shows they are large-scale ribbon-like morphology with lengths up to tens of micrometers. The high magnification SEM image shown in Fig. 3b further reveals that the as-synthesized products are ribbon-like morphology with average width of 100 nm and thickness of 20 nm.

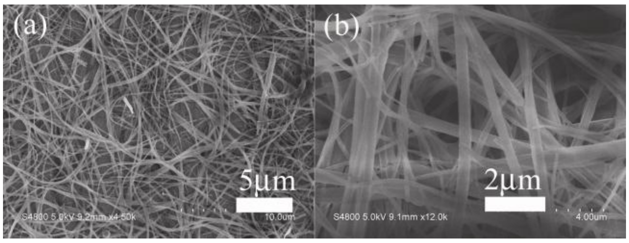

Fig. 3. SEM images of NiQ_2 with ribbon-like morphology: (a) at low magnification, (b) at high magnification.

In order to measure the current signals through NiQ_2, indium tin oxide (ITO) coated glass with the electrode gap of 25 μm was employed as the substrate. A bundle of NiQ_2 was dispersed and bridged over the electrodes with effective length of about 40 μm, as shown in the inset of Fig. 4. Gold gap electrodes were fabricated on the substrate by thermal evaporation with a micrometer-sized Au wire as the mask; by slightly moving the Au-wire mask, Au–Au gap electrodes were deposited [16].

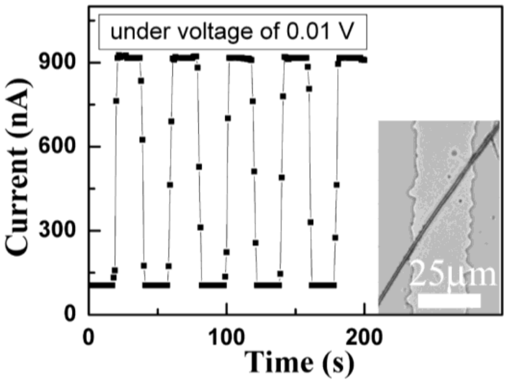

Fig. 4. Photoswitch characteristics of a bundle of NiQ_2 ribbons during light switching on/off, and the image of a bundle of the products between two Au electrodes from an optical microscope (inset).

The reversible photoswitch characteristic of NiQ_2 during light switching on/off was shown in Fig. 4. A voltage of 0.01 V was applied across the two electrodes and the current recorded during the light was alternatively on and off at 20 s intervals. Obviously, the current through the NiQ_2 promptly increases (on) or decreases (off) according to the illumination on/off. In these cases, the energy from the light excites the electrons in the semiconductor NiQ_2 from the valence band into the conduction band, increasing the charge carrier concentration via direct electron-hole pair creation and thus enhancing the conductivity of the nanoribbons. It is observed that the current of NiQ_2 nanoribbons under illuminated is enormously increased by ca. 8.7 times compared with the current in dark. The experimental results provide a foundation for the development of organic chelates nano-devices.

4. Conclusions

In summary, Large-scale NiQ_2 nanoribbons were successfully synthesized via a facile solvothermal approach, without any template or surfactant. The photocurrent of a bundle of NiQ_2 exhibited the unique photoswitching response, which was fast and reversible under on/off light exposure conditions. And the results suggested the possible application in photosensitive devices in the future.

Acknowledgements

This work was supported by the National Natural Foundation of China (20571001), College Natural Science Foundation of Anhui Province (KJ2009B003Z), and the Doctoral Fund of Anhui Normal University.

References

[1] C. W. Tang, S. A. VanSlyke, Appl. Phys. Lett. **51** 913 (1987).
[2] R. Pohl, P. Anzenbacher, Org. Lett. **5**, 2769 (2003).
[3] X. J. Zhang, J. S. Jie, W. F. Zhang, C. Y. Zhang, L. B. Luo, Z. B. He, X. H. Zhang, W. J. Zhang, C. S. Lee, S. T. Lee, Adv. Mater. **20**, 2427 (2008).
[4] Y. S. Zhao, H. B. Fu, A. D. Peng, Y. Ma, D. B. Xiao, J. N. Yao, Adv. Mater. **20**, 2859 (2008).
[8] D. K. Ma, J. H. Zhang, X. K. Hu, H. Y. Zhou, Y. T. Qian, Chem. Lett. **36**, 630 (2007).
[5] J. J. Chiu, C. C. Kei, T. P. Perng, W. S. Wang, Adv. Mater. **15**, 1361 (2003).
[6] C. J. Leea, J. I. Hana, D. K. Choi, D. G. Moon, Mater. Sci. Eng. B **165** 148 (2009).
[7] B. L. Dubey, N. Tiwari, Bull. Chem. Soc. Jpn. **65**, 495 (1992).
[9] C. P. Cho, C. A. Wu, T. P. Perng, Adv. Funct. Mater. **16**, 819 (2006).
[10] X. H. Wang, M. W. Shao, L. Liu, Synth. Met. **160**, 718 (2010).
[11] W. Chen, Q. Peng, Y. D. Li, Crys. Growth Des. **8**, 564 (2008).
[12] H. C. Pan, F. P. Liang, C. J. Mao, J. J. Zhu, H. Y. Chen, J. Phys. Chem. B **111**, 5767 (2007).
[13] L. Land, W. Li, J. Dianzeng, J. Coord. Chem. **61**, 1019 (2008).
[14] T. Gavrilko, R. Fedorovich, G. Dovbeshko, A. Marchenko, A. Naumovets, V. Nechytaylo, G. Puchkovska, L. Viduta, J. Baran, H. Ratajczak, J. Mol. Struct. **704**, 163 (2004).
[15] J. E. Tackett, D. T. Sawyer, Inorg. Chem. **3**, 692 (1964).
[16] Q. X. Tang, H. X. Li, Y. L. Liu, W. P. Hu, J. Am. Chem. Soc. **128**, 14634 (2006).

---

*Corresponding author: xhwang@mail.ahnu.edu.cn