Preparation of CdS Semiconductor Nanowire by a Convenient Ultraviolet Irradiation Technique

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Cadmium sulfide (CdS) nanowire was synthesized by a convenient ultraviolet irradiation method using hydroxyethyl cellulose as a soft template at room temperature.

The preparation and characterizations of nanowires or nanorods of various materials have received considerable attention and the potential wide-ranging application of these kinds of nanomaterials have been predicted.[1–5] The template method has been demonstrated to be very effective for the fabrication of nanowires or nanorods of desired materials, examples include the carbon nanotubes[1,2] and the nanochannels in nuclears track polycarbonate membranes[3] or porous alumina[4,5] which act as hard templates with which the desired materials are synthesized. In addition, soft template methods[6] may be applied although soft templates cannot always regulate the size and morphology of the products, for example, the polyacrylamide has been used as template for the preparation of long CdS nanowires.[7] It will be interesting to explore the possibility of the use of solution-based synthesis of nanowires without the presence of preformed templates.

In this communication, we report a convenient ultraviolet radiation technique to synthesize CdS nanowire with hydroxyethyl cellulose (HEC) as template at room temperature.

The $CdSO_4 \cdot 8/3H_2O$ (5 mmol), $Na_2S_2O_3 \cdot 5\ H_2O$ (10 mmol), hydroxyethyl cellulose (HEC, 1 g) and isopropyl alcohol (2 mL) were dissolved in 100 mL deionized water and stirred to form a transparent solution. The transparent solution was kept for 24 h at room temperature. Then the solution was irradiated for 48 h in the field of ultraviolet irradiation. Two 20-W column-like low-pressure mercury lamps (λ = 253.7 nm) were used as the ultraviolet irradiation source. After irradiation, the yellow product was collected and washed with ethanol. Finally the product was dried in a vacuum at room temperature.

The X-ray diffraction (XRD) pattern for the obtained product was recorded by a Philips PW1710 X-ray diffractometer with Cu Kα irradiation (λ = 0.15418 nm). Transmission electron microscopy (TEM) image was taken with a JEM-200CX TEM, using an accelerating voltage of 120 kV. The X-ray energy dispersion spectrum was recorded by a Philips 9100/6 X-ray energy dispersion analysis equipment.

Figure 1 shows the XRD pattern of CdS crystal produced by the ultraviolet irradiation method. It indicates that the as-obtained product is indentified as β-CdS and belongs to the cubic crystal system comparing with the reported data (JCPDS 10-0454). The three peaks with 2θ values of 26.5°, 43.9°, 52.0° are corresponding with the three crystal planes of 111, 220, 311 of the β-CdS, respectively.

The product was also characterized by transmission electron microscopy (TEM). Figure 2 shows the typical TEM image revealing that the as-obtained product has wire-like morphology The diameters of CdS nanowires are about 40 nm although some small CdS nanoparticles are attached to the CdS nanowires. Their length of CdS nanowires varies from a few to tens micrometers.

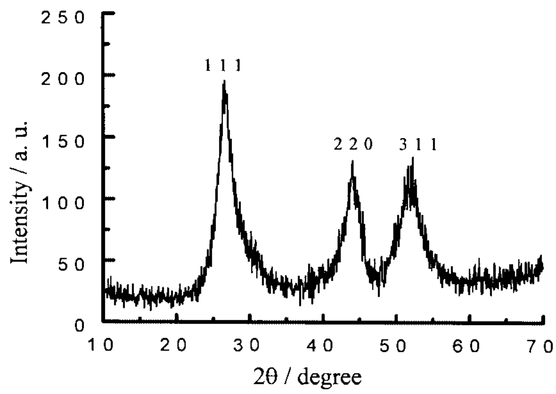

Figure 1. X-Ray diffraction pattern of the as-obtained CdS.

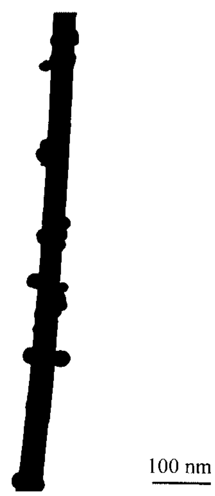

Figure 2. The TEM image of a typical CdS nanowire.

The chemical composition of the product was determined using X-ray energy dispersion analysis. The X-ray energy dispersion spectrum (Figure 3) reveals that the nanowires are composed of Cd and S. And the quantitative analysis indicates that the atomic ratio of Cd to S is approximate 1:1.

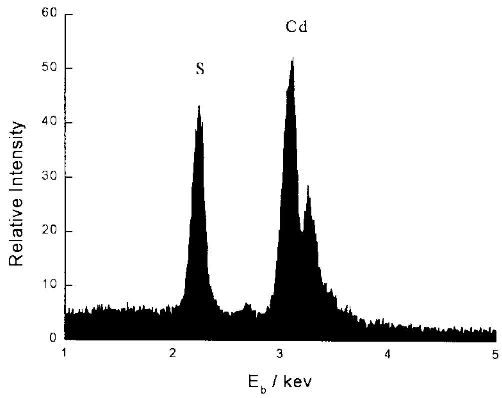

Figure 3. The X-ray energy dispersion spectrum of the as-obtained CdS nanowire.

In the ultraviolet irradiation process, some probable reaction may be going on under the ultraviolet irradiation. S^{2-} ions may be formed as a result of reduction of $S_2O_3^{2-}$ ions with hydrated electrons:

$$H_2O \xrightarrow{irradiation} e^-_{aq}$$

$$S_2O_3^{2-} + 2\,e^-_{aq} \longrightarrow S^{2-} + SO_3^{2-}$$

In this experiment, the hydroxyethyl cellulose (HEC) is a long-chain macromolecule with many hydroxy groups and the average molecular weight of HEC is approximate 123000. When HEC is dissolved in water, the HEC is unfolded and the long chain can be easily formed by HEC molecules through hydrogen bonds. The long chains can act as soft templates. When Cd^{2+} ion meets with S^{2-} ion, CdS can grow along these long chains and the CdS nanowire may be formed. S^{2-} ions are from the decomposition of sodium thiosulfate ($Na_2S_2O_3$) by ultraviolet irradiation. HEC in solution is used as a soft template.

In summary, CdS nanowires were successfully prepared by ultraviolet irradiation method using hydroxyethyl cellulose as a soft template at room temperature. The method gives a novel mild chemical route to fabrication of semiconductor nanowire, which may be applied in many fields.

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