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Synthesis and characterisation of selenium nanowires using template synthesis

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Selenium (Se) nanowires were grown in the pores of anodic alumina membrane as template. Facile electrodeposition technique was used for the synthesis of Se nanowires. Scanning electron microscopy was used for the morphological study of the nanowires. X-ray diffraction and Energy dispersive X-ray fluorescence were utilised for the structural characterisation. The optical properties of Se nanowires were investigated using optical absorption spectroscopy.

Keywords: nanowires; template synthesis; electrodeposition; scanning electron microscopy

1. Introduction

Selenium (Se) with direct band gap (1.7 eV) is an important semiconductor with interesting properties like high photoconductivity, high photosensitivity and non-linear optical responses. Se has been used as a key material for xerography, rectifiers, etc. [1,2]. It is also one of the required elements of the human body. Se can pick up the activity of the gluthione peroxidase and seleno-enzyme and can avert free radicals from destroying cells and tissues [3].

Se mainly exists in the forms of trigonal selenium (t-Se), consisting of helical chains, monoclinic selenium (m-Se), composed of Se_8 rings, and amorphous selenium (a-Se), consisting of mixtures of chaotic chains [4]. Presently a large number of technologically important materials, such as CdSe and ZnSe, are fabricated by reacting Se with Cd^{2+} or Zn^{2+} precursor to obtain II–VI semiconductor material [5]. These II–VI semiconductor materials are important for different applications in bio-sensors, hybrid solar cells and nanodevices. In the recent years, investigation of Se nanoparticles has become of major importance because some properties of Se nanoparticles that are different from those of the bulk [6] have increased the number of applications [7–14]. Different techniques have been used to synthesise and characterise these nanoparticles.

Different methods have also been adopted to synthesise selenium nanowires like sono-chemical synthesis [15], silver-induced growth in aqueous solution [16],

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hydrothermal method [17], electrodeposition [18,19], physical adsorption through vapour phase diffusion [11], reverse micelles [20], etc. In this article we report the growth of selenium nanowires using electrodeposition in the pores of anodic alumina membrane as template.

2. Experimental details

Template synthesis technique was used to synthesise selenium nanowires. Anodic alumina membrane having pore size 100 nm (commercially available Whatman) was used as template for the synthesis of selenium nanowires. All chemical reagents were of analytical grade and used as received without further purification. An aqueous solution of $80\,g\,L^{-1}$ SeO_2 and $40\,g\,L^{-1}$ H_3BO_3 was used as electrolyte. The pH value of the electrolyte used was 2.5. The electrodeposition was carried out at constant potential (1.5 V) for 30 min at room temperature ($30 \pm 1^{\circ}C$). The colour of the sample was blackish orange just after the electrodeposition, and turned to black with metallic shine after 20 hours.

The crystallography of the template-synthesised nanowires was studied using a Panalytical X'pert X-ray diffractometer equipped with Cu-Kα radiation. A small part of the deposited sample was dissolved in 1M NaOH for 1 h and then washed several times with distilled water and ethanol prior to study the morphology of Se nanowires under a JEOL-6100 scanning electron microscope (SEM). An energy dispersive X-ray fluorescence (EDXRF) spectrometer was used to analyse the elemental composition of nanowires. The optical properties of the nanowires were investigated using a Shimadzu UV–Vis spectrophotometer in the wavelength range 300–700 nm.

3. Results and discussion

The SEM micrograph (Figure 1) presents the surface morphology of the template-synthesised Se nanowires. It is clearly depicted in the micrograph that the diameter of the

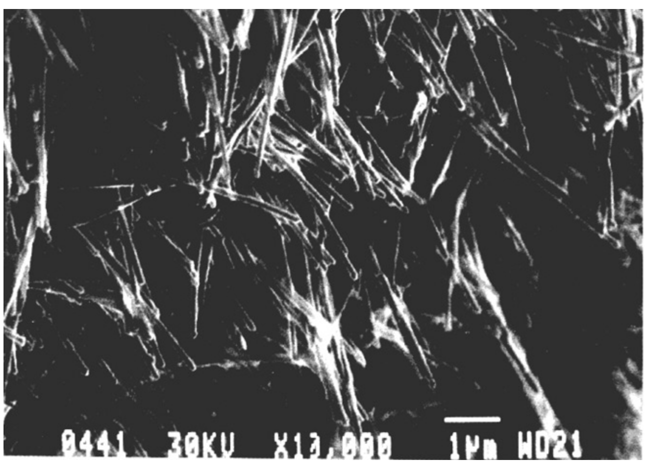

Figure 1. SEM micrograph of electrodeposited selenium nanowires having diameter 100 nm.

homogeneous cylindrical wires is similar to the pore size (100 nm) of the anodic alumina template. The length of the nanowires observed is 6 µm. It confirms that the nanowires' morphology can be controlled by the nanochannels used as templates.

It is clearly depicted in the X-ray diffractogram (Figure 2) that the electrodeposited Se nanowires show strong texture along (111) direction. In our case Se shows trigonal structure, but not as strong as reported by some other groups [15,17–19]. Zhang et al. [18,19] reported that room temperature electrodeposited samples were annealed at 180°C for 1 h to obtain single trigonal structure. Se shows metallic and semiconductor properties and dissimilar Se phases with very analogous internal atomic structures frequently coexist [19].

The EDXRF graph (Figure 3) shows that the template-synthesised nanowires mainly consist of Selenium with a very small amount of impurities like calcium and iron. The large peaks due to copper are also seen in the EDXRF plot. These peaks are due to the copper used as target material. The presence of calcium may be due to the handling of sample with naked hands during EDXRF characterisation. However the exact reason for the small amount of iron is not found.

The absorption spectrum (Figure 4) of template-synthesised nanowires is composed of three peaks at 575, 460 and 275 nm corresponding to 2.16, 2.7 and 3.3 eV, respectively. The lower energy peak corresponding to 2.16 eV may be due to indirect transition between intermolecular chains of Se [21]. The higher energy transitions may take place from covalent bonds within the selenium chain. The absorption peaks corresponding to 2.7 and 3.3 eV may be credited to direct transitions [22].

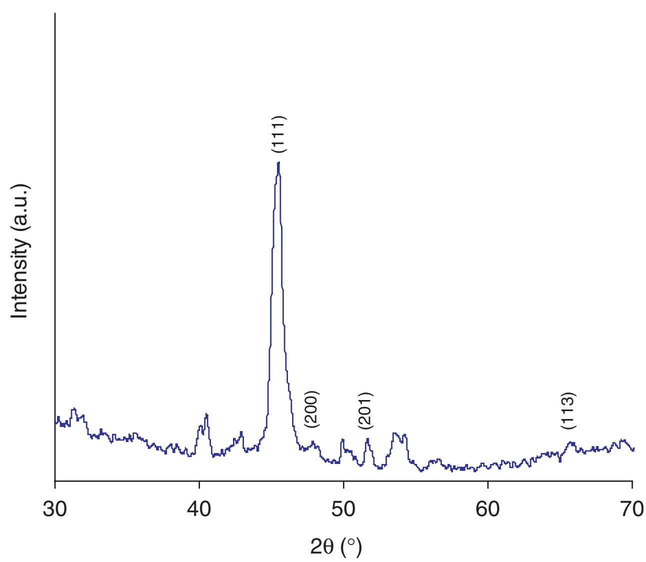

Figure 2. X-Ray diffractogram of Se nanowires.

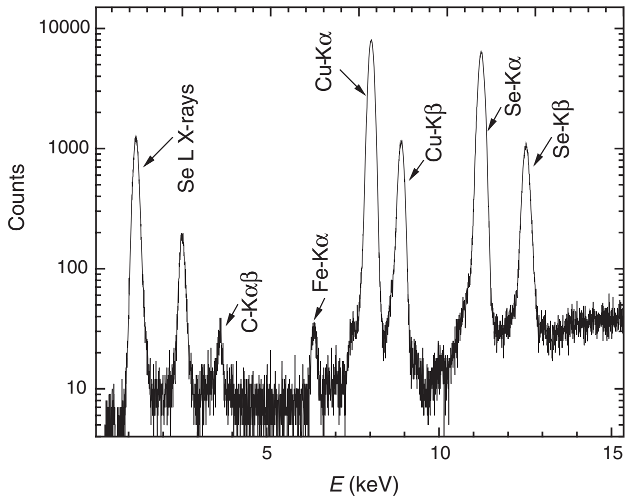

Figure 3. EDXRF graph for Se nanowires.

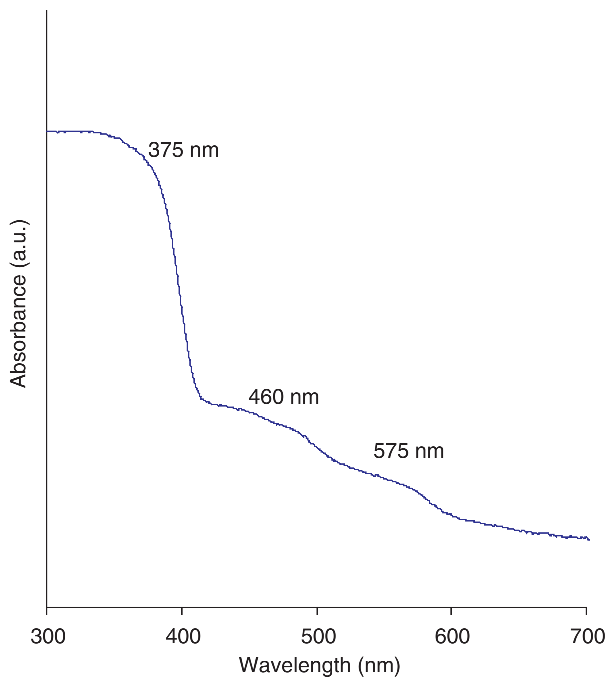

Figure 4. Absorption spectrum of Se nanowires.

4. Conclusions

In conclusion, ordered arrays of Se nanowires with uniform diameters about 100 nm have been fabricated by electrodeposition using template synthesis technique. One major advantage of the Se nanowires fabricated using template synthesis technique is that the nanowires' morphology can be controlled by the nanopores used as templates. The template-synthesised Se nanowires are found to be not single crystalline but they have growth direction along the [111] direction.

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