Advances in Research
2(6): 332-337, 2014, Article no. AIR.2014.6.003

SCIENCEDOMAIN *international*
www.sciencedomain.org

Non-lithographic Fabrication of Ni-se Heterojunction Nanowires and their Electrical Characterization

Kanchan Kumari[1], Vijay Kumar[2*] and Karamjeet Singh[1]

[1]Department of Electronics and Communication Engineering, Punjab Technical University/ BBSBEC, Fatehgarh Sahib, Punjab, India.
[2]Department of Material Science and Engineering, Punjab Technical University/ PCET, Lalru Mandi, Punjab, India.

Authors' contributions

This work is carried out in collaboration between all authors. Authors KK and VK designed the study, literature searches and performed the experimental work. Author KS managed the characterization.

Original Research Article

Received 28th January 2014
Accepted 10th March 2014
Published 15th April 2014

ABSTRACT

In this paper, heterojunction nanowires of Ni-Se are fabricated via template-assisted electrodeposition process. Nanowires are characterized by scanning electron microscopy (SEM), Energy dispersive X-Ray Spectroscopy (EDS), X-ray diffractometry and electrical transport studies. SEM photographs reveal the uniform and dense growth of Ni-Se nanowires. X-ray diffraction pattern shows the crystalline nature of Ni-Se nanowires. EDS spectrum shows the much higher percentage of Ni as compared to Se. A collective current-voltage characteristic of heterojunction nanowires shows the resonant tunneling diodes (RTDs) like behavior with peak to valley current ratio 1.37 at room temperature.

Keywords: Electrodeposition; template; RTDs; SEM.

**Corresponding author: E-mail: nanovijay1@gmail.com; kannusharma1987@gmail.com;*

1. INTRODUCTION

The recent development in the technology of heterojunction has brought tremendous applications in our day to day life. The application of heterojunction based electronics devices include double heterostructure laser (DH) in telecommunication system, light emitting diodes (LEDs), high electron mobility transistor, satellite TV system, and resonant tunneling diodes (RTDs) [1-3 and references therein]. The double heterostructure laser (DH) found in virtually every home as part of compact disc (CD) player. In microelectronics industry, current manufacturing processes make use of lithographic techniques to imprint circuits on semiconductor materials, which is approaching to its physical limits. To continue the size reduction of semiconductors, new non-lithographic techniques that can manipulate objects at nano- or atomic scale should be developed. Materials at nanoscale find step toward miniaturization with a qualitatively new scale. Nanowires have been investigated for their intrinsic ability to make smaller devices by scientists and engineers. A variety of techniques have been used such as thermal evaporation, chemical vapor deposition (CVD), chemical self assembly, sol-gel process, and template synthesis for the fabrication of nanowires [5 and references therein]. Template synthesis is an elegant approach for the fabrication of 1D structure such as nanowires and nanotubes [4-8]. This technique makes use of porous membrane such as track-etch membrane, anodic alumina oxide (AAO), and mica etc. The desire material can be deposited into the pores of membrane via sol-gel, chemical vapor deposition (CVD), electrochemical deposition, chemical deposition, and electroless deposition. The size and shape of the Nanowires is true replica of pores geometry. In this paper we describe here the fabrication and characterization of metal-semiconductor heterojunction nanowires of Nickel-Selenium (Ni-Se) via template-assisted electrodeposition technique.

2. EXPERIMENTAL DETAIL

All chemicals purchased from Merck are of analytical grade with high purity. Anodic alumina oxide (AAO) templates of diameter 100nm, thickness 60 micron and pore density 10^9 pore/cm^2 are purchased from what man, USA. Ag/AgCl is used as Reference electrode and a Gamry Potentiostat Ref 600 is used as dc source for electrode position at room temperature (28 degree Celsius). Platinum (Pt) electrode is used as counter electrode (anode).

A thin film of gold is sputtered onto one side of AAO template using sputterer coater. This gold layer along with conductive adhesive copper tape acts as working electrode and provides a stable substrate (cathode) for the growth of Nanowires. The electrodeposition is carried out using bath conditions $NiSO_4.6H_2O$ (250 g/l), $NiCl_2.6H_2O$ (40 g/l) H_3BO_3 (40 g/l) for deposition of Nickel and Selenium dioxide {SeO_2 (8×10^{-4} M)} with 0.5 ml of 35% dilute H_2SO_4 for deposition of Selenium, the inter-electrode distance was kept 0.5 cm. The amount of metal deposited and time required to fill the pores is calculated using Faraday's Laws. The deposition of Ni and Se is done for the calculated time (i.e. 1300 sec for Ni and 200 sec for Se) in order to get heterojunction nanowires of Ni & Se. The quality of electrode position depends upon several parameters such as inter–electrode distance, pH value, agitation, current density, temperature etc. After the deposition was over, the membrane was washed with distilled water for several times and the sample was dried in room temperature.

3. RESULTS AND DISCUSSION

3.1 SEM Characterization

To study the morphology of nanowires, the nanowires are freed from template by dissolving it with 1M NaOH solution followed by rinsing with distilled water. The SEM photograph as shown in Fig. 1 reveals the good quality deposition with large scale and uniform formation of heterojunction nanowires. The elemental composition was confirmed by Energy dispersive X-ray spectroscopy (EDS) as shown in Fig. 2. EDS spectrum reveals the presence of Ni (Weight% 79.80) & Se (Weight%16.21) & O ((Weight% 3.99).The elemental composition of Se is less than Ni because of formation of hollow nanowires of selenium as observed in SEM.

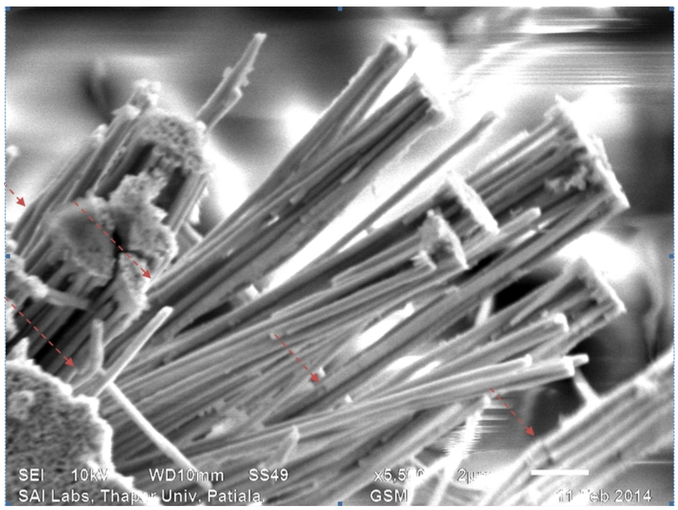

Fig. 1. SEM photograph of nanowires showing the presence of heterojunctions

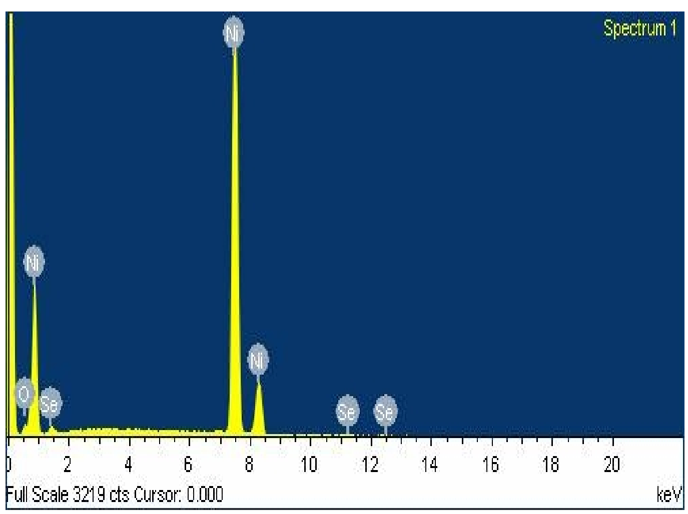

Fig. 2. EDS Spectrophotograph shows the presence of Ni and Se

3.2 XRD Characterization

XRD investigations show the peaks shown in Fig. 3 indexed to (111) crystal plane for NiO (JCPDS, 71-1179), (011), (200) crystal planes for Ni (JCPDS, 45-1027), and (102) crystal plane for Se (JCPDS, 06-0362). The peak corresponding to NiO is due to oxidation of Ni as the sample was dried in the presence of oxygen before the electrode position of Se in order to avoid the formation of alloy of Ni-Se. The average crystalline size (D) is determined using Debye-Scherrer formula and comes out to be 21 nm for Ni and 18 nm for Se. The Debye-Scherrer formula is given by:

D= Kλ/ (β cosθ)
λ= 1.54Å
K= 0.9, known as shape factor
Λ= X-ray wavelength,
B= Full Width Half Maxima (FWHM)

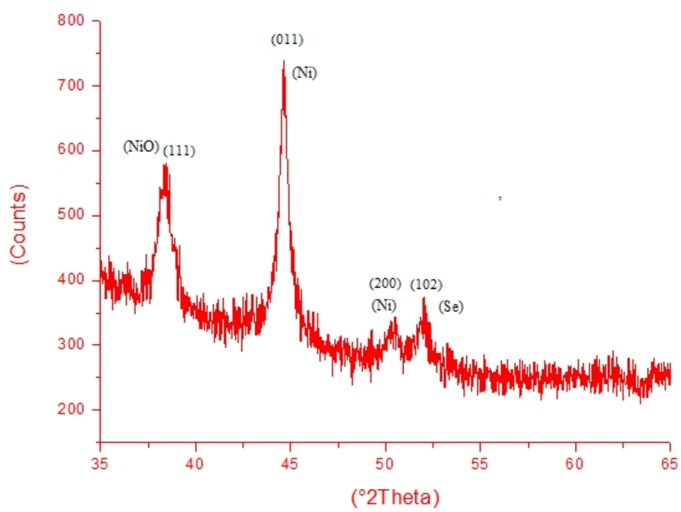

Fig. 3. In-situ XRD diffraction of Ni-Se heterojunctions

3.3 Electrical Characterization

Electrical characterization of Ni-Se heterojunction Nanowires embedded in AAO template is done at room temperature by using “Keithley Digital Source Meter” 2400. The collective Current-Voltage (I-V) measurement reveals the resonant tunneling diode like behavior at low sweep voltage 0 V to 1 V as shown in Fig. 4. I-V characteristics show RTD behavior with peak to valley current ratio (PVCR) 1.37. Lower value of PVCR may be due to non-homogeneous hetero-interface. Similar results have been reported in literature for Cu-Se RTDs by Biswas et al and Chaudhri et al. [9-10].

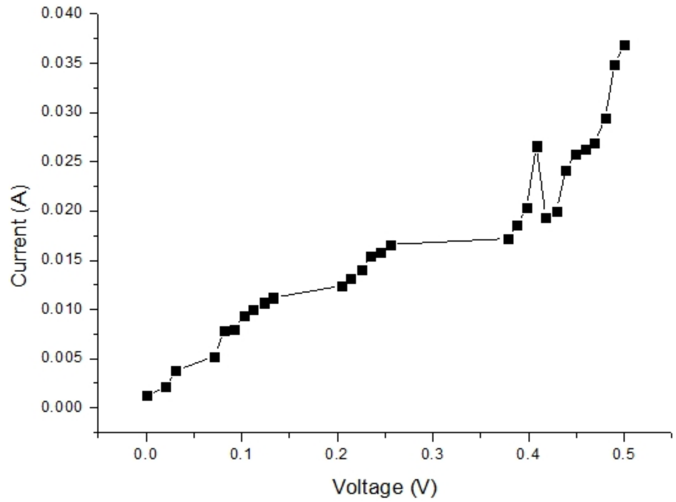

Fig. 4. Collective I-V behavior of Ni-Se heterojunction nanowires

4. CONCLUSION

Metal–semiconductor heterojunction nanowires of Ni-Se fabricated via Template synthesis shows the resonant tunneling diode (RTD) like behavior with peak to valley ratio 1.37 at room temperature. This method is suitable to synthesize mono dispersive nanowires of desired diameter and length. Peak current is observed at low voltage which is an important feature and offers the possibility of fabricating low-power dissipation electronic devices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lauhon LJ, Mark S. Gudiksen and Lieber Charles M. Semiconductor nanowire heterostructures. Phil. Trans. R. Soc. Lond. A. 2004;362:1247–1260.
2. Ling Johnny. Resonant tunneling diodes: Theory of Operation and Applications. University of Rochester, Rochester, NY 14627; 1999.
3. Akeyoshi T, Matsuzaki H, Itoh T, Waho T, Osaka J, Yamamoto M. NTT photonics laboratories; applications of Resonant-tunneling diodes to High-speed digital IC's. Indium Phosphide and Related Materials. 1999;11:405-410.
4. Khalaf MM, Ibrahimov HG, Ismailov EH. Nano structured Materials: Importance, Synthesis and Characterization. Chemistry Journal. 2012;2(3):118-125.
5. Martin CR. Nanomaterials: A Membrane-Based Synthetic Approach. Science. 1994;266(5193):1961-66.
6. Kumar Vijay, Kumar Sunil, Chakarvarti SK. Morphology and time resolved photoluminescence of electrochemically synthesized zinc oxide. J. Mater. Sci.: Mater Electron. 2010;21:1277-80.

7. Sanjeev Kumar. Synthesis and characterization of selenium nanowires using template synthesis. J. Experimental Nanoscience. 2009;4:341-346.
8. Huiyu Chen, Dong-Wook Shin, Jung-Gyu Nam, Kee-Won Kwon, Ji-Beom Yoo. Selenium nanowires and nanotubes synthesized via a facile Template-free solution method. Materials Research Bulletin. 2010;45:699–704.
9. Biswas A, Avasthi DK, Benoy K. Singh S, Lotha JP. Singh D, Fink BK, Yadav B, Bhattacharya, Bose SK. Resonant electron tunneling in single quantum well heterostructure junction of electrodeposited metal semiconductor nanostructures using nuclear track filters. Nuclear Instruments and Methods in Physics Research Section B. 1999;151(1-4):84-88.
10. Chaudhri Meeru, Vohra A, Chakarvarti SK. A model for Cu-Se resonant tunneling diodes fabricated by negative template assisted electrode position technique. Communication and Network. 2010;2:73-78.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=490&id=31&aid=4311