Fabrication of copper nanowires by electrodeposion method

Ahatesham Ahmed Khan, A.A. Koser

Department of Nanotechnology, Medicaps Institute of Science & Technology

Abstract:

The present work focuses on the synthesis of copper nanowires. Copper is one of the most important metals in modern electronic technology. We are trying to synthesize copper nanowires from the aqueous solution of copper (II) sulphate on glass filter paper. Electro chemical deposition technique based on the principle of electroplating was adopted for copper nanowire synthesis.Diameter and length of wire depends on the supply voltage, temperature, time for deposition. The studies have revealed the formation of fine, uniform arrays of mono and poly crystalline copper nanowires which show potential applications in nanodevices, chemical and biological sensors, optical and electronic devices because of their unique electrical, magnetic, optical as well as their mechanical properties.

Keywords: Nanomaterial, Metallic nanowires, Templates, Electrodeposition.

Introduction

Nanotechnology is technology which has applications in the real world at Nano scale. Size of particle 1-100nm is called nanoparticle. Nanotechnology, often abbreviated to "nanotech," is the study of the control of matter on an atomic and molecular scale. In nanotechnology, at least one dimension of particle structures of size under 100nm. (1)

Nanomaterial can be fabricated by two approaches in nanotechnology. First is "bottom-up" approach, in this materials are fabricated by atom-by-atom from molecular constituents, which accumulate themselves chemically by principles of molecular recognition. Second is "top-down" in this approach, nanomaterial are made from bulk objects, Means bulk materials reduce into nanomaterial without atomic-level control. (2)

Nanowires are among the most exciting one-dimensional nanomaterial because of their unique properties, which result primarily from their chemical composition and large surface area to volume ratio. These properties make them ideal building blocks for the development of next generation electronics, optoelectronics, and sensor systems.(3)

In nanowireis one dimension structure that can be efficiently transport of electrical charge carriers.(4) During the past decade, nanowires have attracted a vast interest due to a large variety of promising applications in areas such as nanoelectronics, biotechnology, magnetism, thermoelectric, solar cells etc.(5)
Nanowires have many interesting properties that are different from bulk. This is because electrons in nanowires are quantum confined laterally and thus occupy energy levels that are different from the traditional bands found in bulk materials. (6)
Copper is an important material for the microelectronic industry due to its low resistivity and its low vulnerability to electro migration. Copper nanowires are synthesized for applications in solar cells, flat panel displays, and sensors. (7)
The most common approaches to synthesize copper nanowires include electrodeposition, chemical vapor deposition, electroless deposition, and solution growth. Among them, electrochemical deposition is most suitable for fabrication of nanowires of small dimensions and high aspect ratios. (8)

Based on the above-described template technique, poly- and single-crystalline Cu nanowires with high aspect ratios were synthesized by electrodeposition. Copper is one of the most important metals in modern electronic technology. Many methods have been developed for the fabrication of copper nanowires but template synthesis is considered to be most suitable and useful for growth of nanowires. (9)

Material and method

We used electrodeposition method for fabrication of copper nanowires, because it is simple and low cost method. In this work, anode (platinum strip) will be used in a solution of copper sulphate. Copper is plated out onto the pores of a filter at the cathode. Here we have used copper tape which is insulted from back side as a cathode.

- Cathode

  $CuSO_4 \rightarrow Cu^{2+} + SO_4^{2-}$

  $Cu^{2+} + 2e^- \rightarrow Cu$

- Anode

  $Cu \rightarrow Cu^{2+} + 2e^-$

- $Cu^{2+} + SO_4^{2-} \rightarrow CuSO_4$

Electrodeposition is performed for 14 min at constant 9V. During this process average current flow is 49.2 mA. In beginning current start decreasing, afterward it becomes constant then it start increasing and finally it is constant. In the beginning, the current density increases which show that all the pores were empty. After complete deposition we kept our sample in 20 ml ethanol for 2 hours. To observe and measure the nanowires, we will release the nanowires from the filter and examine the wires under an optical microscope, or scanning electron microscope.

To remove nanowires from filter paper, we place filter in ethanol this allows the wires to settle under gravity, now pipette up a few drops from the bottom of the suspension for analysis. To observe and measure the nanowires, we will release the nanowires from the filter and examine the wires under an optical microscope, or scanning electron microscope.

Result and discussion

In fabrication of copper nanowire by using electrodeposition method, Length of wires depends upon the thickness of template which is used for deposition. Diameter depends on the concentration of electrolyte, temperature of deposition amount of charge flow, time of deposition.

- Number of coulombs C = Amperes (A) seconds (s)
- We ran the current for 13 minutes (840 seconds), then the calculation would be
- 49.2mA for 840s = 41.3 coulomb
- This can be converted to electronic charges as follows:
- Number of electron charge = $41.3/ 1.67X10^{-19} = 24.7X10^{19}$

A convenient unit in electrochemistry is the Faraday (or mole electron), defined as the amount of charge (in coulombs) represented by one mole of electrons. This can be calculated by the following:

- $1.67X10^{-19}$ col X $6.022X10^{23}$ per mole = 96,472 col =1 faraday
- 41.3 col/ 96472 for 1 mole of copper =$2.14X10^{-4}$

This tells us how many moles of copper charge will react. Two moles of electrons are required to react with one mole of Cu^{2+}, since the copper ion is doubly positive charged. In this process 41.3 coulombs of charge will react with $2.14*10^{-4}$ moles of copper during the electro-plating process. This amount of copper will be electro-deposited at the cathode and into the pores of the filter that we are using as a deposition template. The filter pores are cylindrical, so the deposited copper nanowires will be too. We know the diameter of the pores (and resulting wires) from the filter manufacturer, but nanowire length will depend on how much copper we deposit. Using the molecular weight for Cu (63.5 g/mole) and the mass density (89.6g/cm3) we can calculate the mass and the volume of the deposited copper.

$2.14X10^{-4}$ mole of copper X 63.5gm/ mole = 13.5mg of copper

Total 13.5mg of copper is deposited at cathode.

References

1. Luisa Filloppani and Duncan Sutherland “Fundamental concept of Nanoscience and nanotechnology

2. J. C. Tarafdar, Shikha Sharma and Ramesh Raliya “Nanotechnology: Interdisciplinary science of applications” African Journal of Biotechnology

3. Younan Xia, peidongYang, Yugang Sun, Yiying Wu, Byron Gates, Franklin Kim and Haoquan yan “One Dimensional Nanostructure Synthesis, characterization and Applications” Advanced Materials

4. JJ. Pascual, J.Gomez-Herrero, J. Mendez and A.M. Baro “The Conductivity of a Nanowire: Quantum and Localization Regimes”

5. Neil P. Dasgupta, Jianwei Sun, Chong Liu, Sarah Brittman, Sean C. Andrews, Jongwoo Lim, Hanwei Gao, Ruoxue Yan and Peidong Yang “Semiconductor Nanowires Synthesis, Characterization and Applications” Advanced Materials

6. L. C. Lew Yan Voon, Yong Zhang B. Lassen, M. Willatzen, Qihua Xiong and P. C. Eklund “Electronic Properties of Semiconductor Nanowires” Journal of Nanoscience and Nanotechnology

7. Vu Binh Nam and Daeho Lee “Copper Nanowires and Their Applications for Flexible, Transparent Conducting Films” MDPI.

8. Hardev Singh Virk “Fabrication and Characterization of Copper Nanowires” Nanowires Implementations and Applications InTech

9. M. I. Irshad, F. Ahmad, N. M. Mohamed, M. Z. Abdullah “Preparation and Structural Characterization of Template Assisted Electrodeposited Copper Nanowires” International Journal of Electrochemical Science.