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Research Article

Template Synthesis and Characterization of Ni Nanostructures

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Abstract. Nanostructures of a typical ferromagnetic material, nickel are fabricated by electrodeposition (in a DC mode) within the pores of polycarbonate track etched membranes. The cylindrical pores with pore diameter 100 nm have been used for present study. Negative template method via two electrode potentiostatic arrangement in electrochemical cell has been used to synthesize the ordered array of one-dimensional Ni nanostructures. Deposition has been carried out at 41 ± 2 degree, 1.6 V and so formed one dimensional nanostructure has been obtained at a Copper substrate. The elegant approach of template synthesis has advantage that shape and diameter of one-dimensional nanostructure can be varied as per the requirement, by using the templates of different pore shapes and diameters. Crystalline nature of one-dimensional Ni nanostructures is confirmed by X-ray spectroscopy using Rigaku X-ray diffractometer. I-V characteristics have also been drawn using Keithley source meter, in order to check out the variation in electrical conductivity from bulk to nanoscale.

Keywords. Nanostructures, Template synthesis, XRD, Electrical conductivity

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1. Introduction

Shape controlled synthesis of low dimensional nanostructures gain a rapid momentum in the present research scenario; for their interesting chemical and physical properties [1, 12, 16, 17]. Nanometer scale provides a pathway to realize these interesting properties. Objective behind the synthesis of low dimensional nanomaterials is to understand the material properties and to utilize these, integrate the material in the form of a device. That's why perhaps the synthesis part is most vital in the functioning of nanodevice.

One-dimensional nanostructures are perfect building blocks for functional nanodevices [3, 14] Electrical conductivity is one of the most important aspect in the material selection for a nanodevice. It is not only the nano-scale but the cross-section as well, that has an effect on the electrical resistivity/conductivity of a nanowires [5]. It indicates that conductivity of nanowires can be manipulated through bottom up approach, as it focus on building nanoscopic structures starting from molecular level [9, 13, 15]. The conductivity of nanowires is also very sensitive to the contact geometry and poor electrical contacts may result in a non-linear current-voltage characteristics [8]. Despite the difficulties of growth on substrate and electrical contacts, the demand of electronic industry to go for further small is a natural driving force of enthusiasm for the synthesis and characterization of materials of low dimensions.

Measurement of electrical conductivity/resistivity was also found to be done for Ag [6, 11], Pd [7] nanowires, Au, Pd nanostructures [10], and gold nanowires [5]. Electrical conductivity can also be measured by atomic force microscope (AFM) [2]. In most of the cases, a decreasing trend is found in conductivity of nanoscale materials as compared to their bulk counterparts. However, degree of variation is different for different materials.

2. Experimental Details

2.1 Synthesis of Ni Nanowires

Ni nanowires are synthesized via template-based technique [2]. In this technique; polycarbonate Track Etched Membrane (Whatman filters) of cylindrical nanopores with diameter 100 nm is used. Utilizing the process of electrodeposition, 10 micron long Ni nanowires vertically aligned on Cu substrate are obtained, which acts as cathode during electrodeposition. The electrolyte for Ni nanowires contains $NiSO_4$ @ 6 gm/100 ml and boric acid @ 3 gm/100 ml. De-ionized (DI) water was used to prepare the electrolyte. Pure Ni is used as anode and Cu substrate acts as cathode. pH of electrolyte was adjusted around 3 using conc. H_2SO_4. The experiment was performed at 41 ± 2 degree temperature in Physics Research Lab, NIT, Kurukshetra, India.

2.2 Characterization

Free standing array of Ni nanowires were characterized by Rigaku X-ray diffractometer, and the current-Voltage Characteristics are studied by Keithley 2400 source meter. To draw I-V graph two probe system is used, Cu substrate acts as one electrode and another is sharp tip of steel as another electrode directly placed on other end of nanowires. Silver paste is used in order to avoid the problem of poor electrical contacts. The experimental arrangement for I-V measurement is shown as a block diagram in Figure 1.

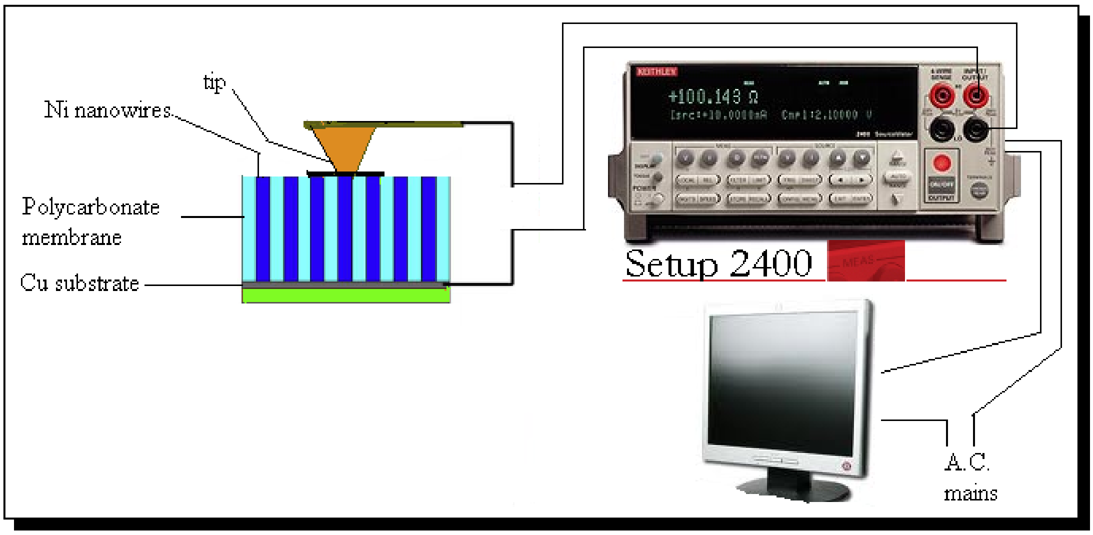


Figure 1. Block diagram of the arrangement for I-V measurement

3. Results and Discussion

3.1 X-ray Diffraction Study

Electrochemically synthesized Ni nanowires on Cu substrate were characterized by their XRD spectra as shown in Figure 2, and it was found that so formed nanowires are polycrystalline and their average grain size found to be approximately 30 nm. In XRD study, presence of both phases is evident in Ni nanowires, i.e., hexagonal and cubic. The XRD pattern is observed from 40 to 144.5 degree (2 theta) with a scan speed @ 3 degree/min in addition to the hexagonal and cubic phases, 3 additional peaks are observed and these correspond to Cu substrate.

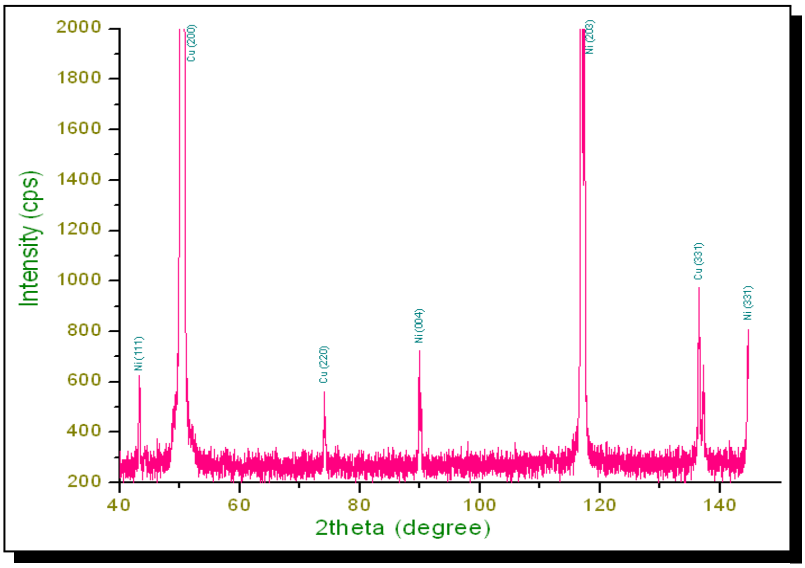


Figure 2. XRD spectra of Ni nanowires on Cu substrate

The intensities, interplanar spacing and grain size corresponds to different planes are shown in Table 1. The XRD pattern is re-drawn up to 2000 cps on Y-axis in order to observe the peaks of low intensity. Observed spectra are then compared with standard JCPDS card: 45-1027 (hexagonal) and 04-0850 (cubic).

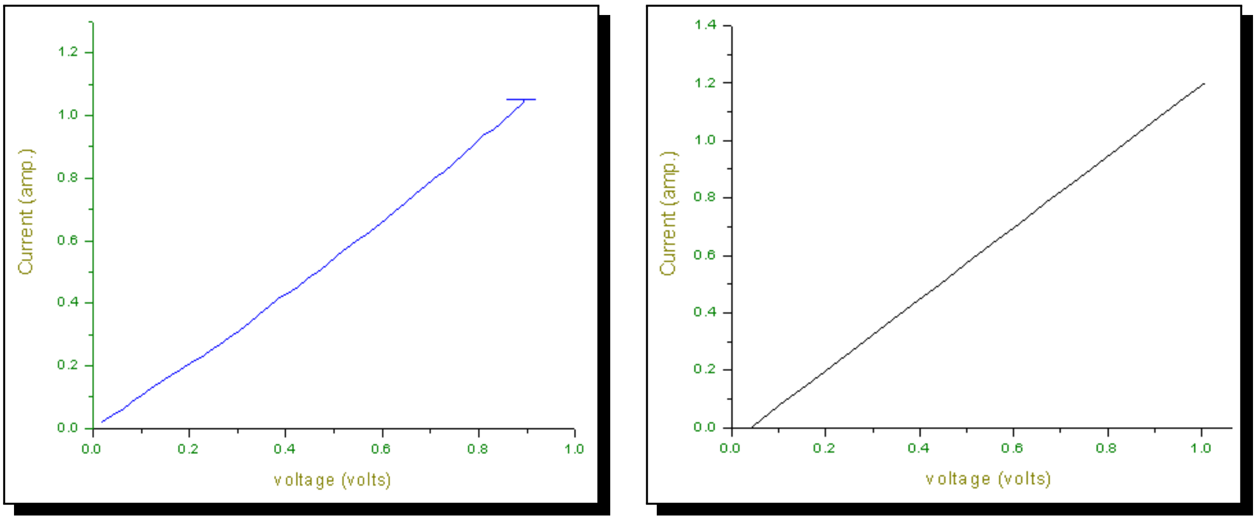
Table 1. Grain size and interplanar spacing of polycrystalline Ni nanowires

S. No.	2theta (degree)	FWHM (deg.)	Max. Int. (cps)	d-value	App. grain size (nm)
1	43.299	0.614	593	2.088	14
2	89.938	0.583	726	1.090	19
3	116.930	0.263	4987	0.904	58

3.2 I-V Measurement and Electrical Conductivity of Ni Nanowires

Two probe arrangements via 2400 Keithley source-meter was used to draw the current v/s voltage measurement of Ni nanowires. Cu substrate was used as one electrode and tungsten tip of around 100 micron is another electrode.

At a time, tip covers around 300 cylindrical pores containing Ni nanowires. Current v/s voltage graph as shown in Figure 3 is not exactly a straight line but almost a straight line. The deviation from straight line is on the account of discrepancy in electrical contacts. The source meter used has an upper limit of 1.05 Ampere on current measurement.



(a) (b)

Figure 3. I-V graph of Ni nanowires (a) as observed, (b) linear fit

Resistance was measured from slope of the linear fit data and is 1.07 ohm. This is the resistance of approximately 300 nanowires (parallel arrangement) that are in contact with tip. The resistance of one wire is 280 ohms. Then conductivity of one nanowire of Ni, 100 nm diameter and 10 micron long is approximately 0.046×10^6/cm ohm as compared with that of bulk Ni material 0.144×10^6/cm ohm. It shows a decrease of around 3.1 times in the conductivity of Ni as we approach from bulk to nanoregime.

Flow of current between two electrodes signifies the presence of conducting material inside the pores of polycarbonate membrane and XRD spectra confirms the material as Ni. So, on the basis of these two characterizations it is evident that one dimensional nanostructures of Ni are confined inside the 100 nm (diameter) pores of polycarbonate membranes and as the deposition starts from bottom i.e. surface of substrate, so formed one-dimensional nanostructures obviously nanowires rather than nanotubes.

4. Conclusion

Array of 10 micron long polycrystalline Ni nanowires of 100 nm diameter has been obtained on Cu substrate via electrodeposition in polycarbonate TEMs. Validity of ohm's law and a decrease in electrical conductivity at nanoscale is evident from I-V characteristics. Around 3.1 times decrease in the electrical conductivity of Ni is observed as we approach from bulk scale to 1D nanowires of 100 nm.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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