

# Morphological characterization of electrochemically synthesized cobalt nanowires using ion track membranes

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15  $\mu\text{m}$  thick polycarbonate films were irradiated to  $^{58}\text{Ni}$  (sp. energy 11.4 MeV per nucleon) having fluence of the order of  $10^7$  ions/ $\text{cm}^2$ . Irradiated foils were etched chemically in 6N NaOH solution at 50 °C for 12 minutes to obtain the diameter of 100 nm. Aligned cobalt nanowire bunches have been prepared by dc electrodeposition in porous polycarbonate templates from cobalt sulphate solution containing boric acid at 45 °C. These nanowires have uniform diameters of about 100 nm, which corresponds to the pore sizes of the templates used and lengths are up to 6  $\mu\text{m}$ .

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## 1. Introduction

In the current era of technology there is continuously nonstop advancement in miniaturization of electronics components. But, the laws of quantum mechanics, the restrictions of production method, and the rising expenses of the production facilities may rapidly avert us from the more scaling down of conventional silicon technology. The hunt for substitute technologies has motivated a surge of curiosity in nanometer-scale materials and devices in current years [1-4]. For the reason that of their exceptional characteristic metal nanowires is one of the majorities striking materials that may escort to a variety of potential applications [5-10]. Examples comprise interconnects for nanoelectronics, magnetic devices, chemical and biological sensors, etc [1,2,6,11].

The most important intensifying demands for high performance data storage media and sensing devices, enormous effort is currently put into the perfection and studies of new magnetic resources. For the most part magnetic devices endorse at the present time still make use of bulk or thin film materials. Nanofabrication techniques present the technical competence to create magnetic objects with nanometric level precision having excellent magnetic properties, which may be tailored by control the size, the shape, or the composition of the nanostructures [12-13]. When the dimensions of the magnetic nanowires become analogous to exchange length or the domain wall thickness, the magnetization arrangement may undeniably be strongly affected [12].

To generate regular periodic arrays of magnetic nanowires, nanodots and nanopillars advanced lithographic techniques are presently engaged. As a substitute, to create regular arrays of ferromagnetic nanowires, electrochemical deposition of ferromagnetic metals into porous templates is executable [14-16]. For the

most part frequently used templates are ion track membranes and anodic alumina membranes [17-22]. This technique has the striking features of extreme simplicity in operation and high cost-effectiveness but using this technique nanowires cannot be developed at pre-specified sites in such templates, which is the essential requirement or need for magnetic storage applications [12-13].

Henry et al. [12] revealed that shape and crystal magnetic anisotropies either contend with each other or add to each other depending on whether the diameter of the Co wires is larger or smaller than a decisive diameter of 50 nm. Darques and his group [13] reported that the pH of the electrolytic solution plays an vital role in controlling both the structure and the effective anisotropy of electrodeposited Co nanowires. A topical investigation on the electrochemical deposition of cobalt nanowires has revealed that the electrolyte bath acidity, or pH, leads to considerable modifications in the structure of the electrodeposited Co nanowires [13]. Recently Almasi Kashi and his group [23] fabricated Co nanowires by ac electrodeposition of cobalt ions into anodic alumina membranes as templates, using diverse waveforms and frequencies. They had also investigated the magnetic properties and microstructures of nanowires as a function of waveform and frequency of deposition potential.

A systematic study for modelling the synthesis process of cobalt nanowires using nanodes array as a template was reported by S. Valizadeh et al. [15]. They also found an analytical expression for diffusion-controlled limiting current for an array of nanodes, and talk about the electrochemical kinetics of mass transport and steady-state behaviour of these nanoelectrodes, which are altering as time passes throughout the nanoprocessing growth.

Vila et al. [16] presented the magnetotransport measurements on single cobalt nanowires generated by

electrodeposition into nanoporous membranes and contacted by an electron beam lithography method. They also show that Electron-beam lithography proves to be an elegant technique to make nanosized multiprobe connections on isolated wires and perform measurements on parts of the nanowire as small as 500 nm. They also found that measurements of different sections of a single 60 nm Co nanowire show the inhomogeneity of magnetization reversal processes along the identical wire. Again Vila et al. [17] described the synthesis and field emission properties of perpendicularly aligned cobalt nanowire arrays generated by electrodeposition into nanopores of track etched polymer layers deposited on silicon substrates. They also reported the expected metallic behavior and good emission homogeneity and reproducibility of cobalt nanowire arrays.

In the present work aligned cobalt nanowire bunches have been prepared by dc electrodeposition in porous polycarbonate templates from cobalt sulphate solution containing boric acid at 45 °C. These nanowires have uniform diameters of about 100 nm, which corresponds to the pore sizes of the templates used and lengths are up to 6 µm.

## 2. Experimental details

15µm thick foils of polycarbonate were irradiated with heavy ions  $^{58}\text{Ni}$  (sp. energy 11.4MeV per nucleon) at normal incidence utilizing the UNILAC facility at GSI, Darmstadt, Germany. The fluence was of the order of  $10^7$  ions/cm<sup>2</sup>. Using these conditions, the penetration range of the ions in polycarbonate was larger than the thickness of the foils and the dE/dx of the ions was well above the threshold required for homogeneous etching. The irradiated polycarbonate foils were etched chemically at 50 °C in a 6N NaOH solution containing 10% methanol for 12 minutes. The resulting pores are cylindrical, their diameters increase linearly with time of etching. In the present work we created the pores with average diameter 100 nm.

In general an appropriate cell design is required and the lay-out design of such electrodeposition cell along with other significant details, of the technique has been conferred earlier [24]. Two-electrode electrochemical cell was used for cobalt deposition in the pores of polycarbonate membrane. The electrodeposition was carried out at a stable potential in the range 1.20-1.25 V at 50°C. The aqueous electrolyte used was the mixture of cobalt sulphate salt ( $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ ) (40g/l) in a boric acid solution ( $\text{H}_3\text{BO}_3$ ) (40g/l). Boric acid was used as a buffer. All analytical grade chemicals were used. Time dependence of electrical current was recorded during the electrodeposition process as shown in Fig. 1.

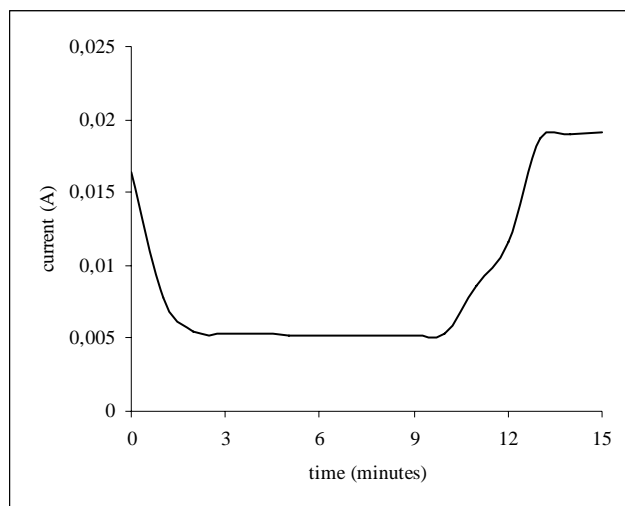


Fig.1. Variation of electrical current as a function of time during electrochemical deposition process.

After the electrodeposition was over, the electrolyte was drained out and the cathode flushed with 3%  $\text{H}_2\text{SO}_4$ , followed by Milli Q water rinsing and air-drying. For polycarbonate ion track membranes, dichloromethane was used as solvent followed by rinsing with water and ethanol [24]. After drying, the specimen was geared up for SEM scanning. Flushing of dichloromethane causes the nanowire bunches formation.

## 3. Results and discussion

For the morphological characterization of the cobalt nanowires by means of SEM, cobalt nanowires, self-supporting on the copper tape, were observed by dissolving the host polycarbonate matrix in dichloromethane. The dirt free and dehydrated samples were mounted on the specifically planned aluminum stubs with the help of double adhesive tape, coated with a layer of gold palladium alloy in “JEOL, FINE SPUTTER JFC 1100” sputter, coated and viewed under “JEOL, JSM 6100 SCANNING MICROSCOPE” at an accelerating voltage of 30 KV. Images were recorded on the photographic film in the form of negatives at diverse magnifications. Fig. 2 shows scanning electron microscopy (SEM) images of a sample in which all the nanowires are misaligned perpendicularly to the copper tape plane. Bunches of cobalt nanowires are formed because they got affected due to the hydrostatic pressure during the dissolution of the host polycarbonate membrane.

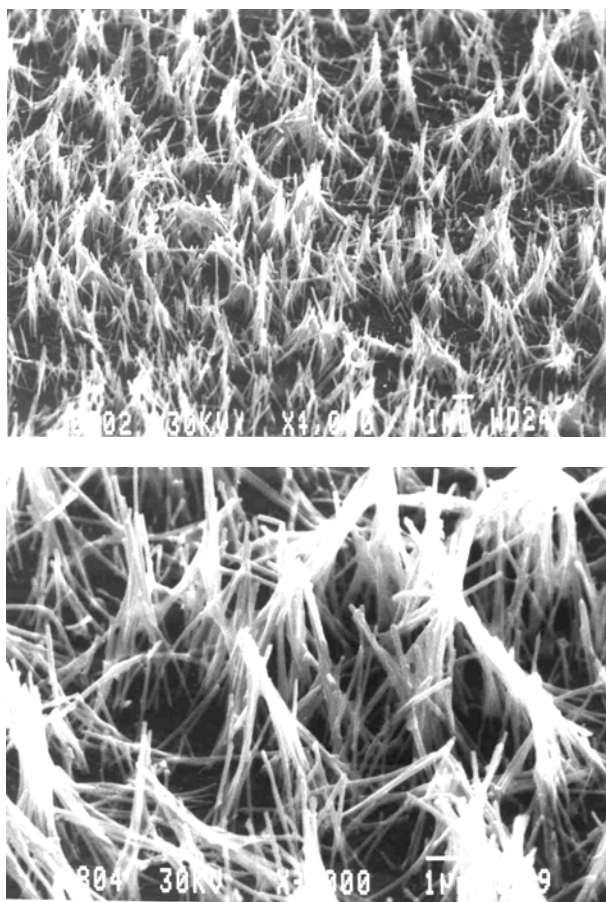


Fig. 2. SEM micrographs of electrodeposited copper nanowires after the dissolution of host ion-crafted polycarbonate membrane.

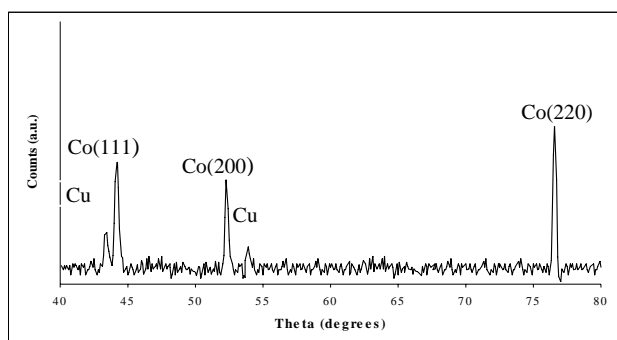


Fig. 3. X-Ray diffractogram of electrodeposited cobalt nanowires.

X-ray diffraction measurements were carried out using a Philips PW1710 diffractometer with Cu-K $\alpha$  radiation in 2 $\theta$  mode. As specified in the X-ray diffractogram (Fig. 3), the material (cobalt) deposited is effectively in the fcc structure instead of the hexagonal one. SEM images revealed that the length and average diameter of the cobalt nanowires produced was 6  $\mu$ m and 100 nm respectively.

#### 4. Conclusion

In conclusion we have fabricated and characterized arrays of electrodeposited cobalt nanowires. Template synthesis is an extremely simple and cost effective technique to fabricate magnetic nanowires. Polycarbonate ion track membranes act as ideal templates for the generation of nanowires. Electrochemically synthesized cobalt nanowires can be used as nanomagnets, field ion emitters etc.

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