Research Article

QUANTUM DOTS AND NANOWIRES: FABRICATION AND CHARACTERIZATION

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ABSTRACT
Quantum Dots and Nanowires have emerged as backbone of 21st century industry based on nanotechnology. A variety of nanofabrication techniques have emerged during the last two decades like atomic deposition, chemical methods, chemical self assembly, cluster methods and lithographic techniques. However, the electrochemical method involving the electro-deposition of metals/semiconductors into etched pores of Ion Track filters/membranes is a simple and convenient technique. Template synthesis of Quantum Dots and Nanowires has been achieved by using anodic alumina membranes and polymer membranes of pore diameter varying from 20-200 nm. The copper nanowire micrographs show non-uniformities in growth. Using Reverse Micelle technique, nanorods of Barium carbonate and Barium oxalate were synthesized along with nanocrystals of Iron oxalate. Cadmium sulphide nanocrystals and needles have been grown using micro-emulsion technique with different co-surfactants. Characterization of grown nanostructures has been done by using SEM, TEM and XRD.

KEYWORDS Quantum dots, Nanowires, Electrodeposition, Template, Reverse micelles.

INTRODUCTION

In recent years, one of the most active areas of research has been nanotechnology (1). Quantum dots (0D), also known as nanocrystals, are a special class of materials known as semiconductors, which are crystals composed of periodic groups of II-VI, III-V, or IV-VI materials. Quantum dots are unique class of semiconductors because they are so small, ranging from 2-10 nanometers (10-50 atoms) in diameter. At these small sizes materials behave differently, giving quantum dots unprecedented tunability and enabling never before seen applications to science and technology.

Nanowires/nanorods (1D) have attracted considerable attention in recent years (2, 3) because of their novel physical properties and potential applications as interconnects in nanometre-scale electronics. The progress in this field has been accelerated by advances in both synthetic methods of preparing the nanoporous templates, and development of techniques capable of filling the pores of such membranes. Examples of long aspect ratio nanoporous membranes include nanochannel glass membranes, anodized aluminium substrates, and various polymeric membranes. Filling of the pores of such membranes with long aspect ratio nanowires/nanorods has been accomplished by electro-deposition, high- pressure metal melt injection, and photochemical methods.

Many methods have been developed for the fabrication of copper nanowires but template synthesis (4) is considered to be most suitable and useful for growth of nanowires. Electrochemical deposition route is easy, low-cost as well as less cumbersome compared to other fabrication techniques. Electrochemical cell used in electrodeposition of copper into pores of anodic alumina template was fabricated in our laboratory.

Nanocrystalline semiconductor materials such as PbS, CdS and ZnS have attracted considerable attention due to their unique properties which are missing in bulk materials. CdS, in particular, has been extensively studied due to its potential applications in field effect transistors (FETS), light emitting diodes (LEDs), photocatalysis and biological sensors (5-7). This study is undertaken to develop fabrication techniques for quantum dots and naowires to exploit their application in nanodevices.

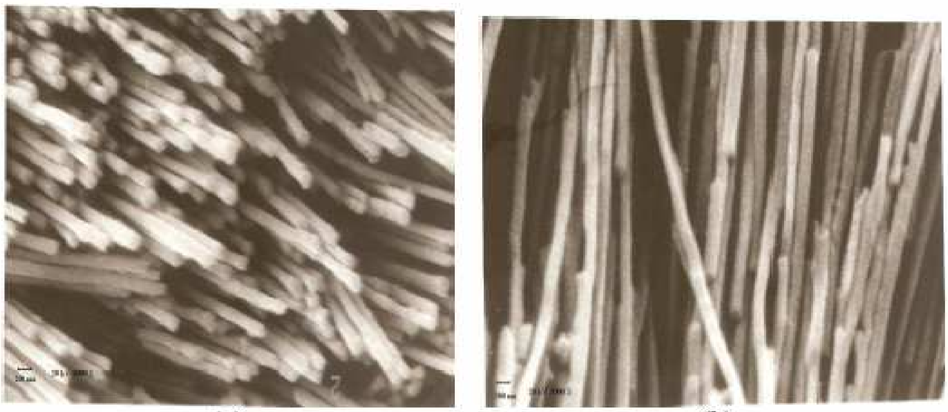
MATERIALS AND METHODS

Anodic Alumina Membrane (AAM) manufactured by Whatman Company has been used to grow quantum dots and nanowires by electrodeposition technique. The pore size selected varies from 20 nm to 200 nm. The electrochemical cell fabricated in our laboratory was used to grow copper nanowires of 200 nm using an electrolyte with a composition of 20gm/100 ml $CuSO_4.5H_2O$ + 25% of dilute H_2SO_4 at room temperature. Electrodeposition of copper nanowires depends on many factors, namely, inter-electrode spacing, electrolyte composition and pH value, current density and time of deposition. To achieve uniform deposition of nanowires, templates were cleaned in the ultrasonic bath for 10 minutes. After cleaning, the templates were fixed to the adhesive copper tape to make it a perfect cathode. The copper nanowires were liberated from their host AAM matrix by dissolving it in 1M NaOH at room temperature (22^0C) for 2 hours. The copper nanowires grown on copper foils were dried in an oven at 50^0C for 30 minutes. The cleaned and dried nanowires were mounted on aluminium stubs with the help of double adhesive tape, coated with a layer of gold palladium alloy in Jeol Sputter JFC 1100 and viewed under Scanning Electron Microscope (Jeol, JSM-6100) at an accelerating voltage of 20 kV. Fig.1 (a, b) shows SEM micrographs of electrodeposited copper nanowires of 200 nm diameter and length of a few microns.

We also followed chemical route to nanotechnology using Reverse Micelle technique (8, 9) of microemulsions to grow nanorods and nanodots/quantum dots of some metals. The mechanism for the formation of nanocrystalline material using reverse micelles may be understood qualitatively by considering the synthesis of a simple compound like metal oxalate and carbonate. Microemulsion. A should be metal ion and B should be oxalate in case of metal oxalate and in case of metal carbonate B should be carbonate. These two microemulsions are mixed by constant stirring and the droplets continuously collide, which results in the interchange of reactants. During this process, the reaction takes place inside the nanoreactor. In microemulsion system, the reverse micelles of metal and oxalate/carbonate forms the fused dimer which finally breaks down into two stable smaller droplets because surface tension becomes high due to large surface area and dimmer is unable to sustain its geometry.

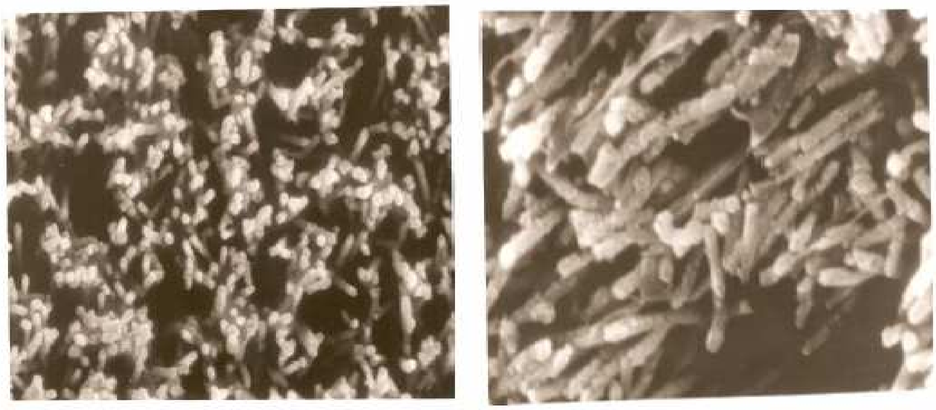
RESULTS AND DISCUSSION

Copper nanowires were examined under SEM under different magnifications. Fig. 1(a) shows a typical cross-sectional view of copper nanowires grown in alumina template. Fig. 1(b) represents the lateral view of nanowires. Obviously, the diameter of copper nanowires is identical to the diameter of pores (200 nm) of anodisc. Nanowires are quite uniform but they are not perfect cylinders. It has been reported (10) that pore diameters of commercially available templates vary over a large range. The aspect ratio, that is, the ratio of length to diameter, is on the order of 300.



(a) (b)

Fig. 1(a,b) SEM images of Copper nanowires (cross-sectional & lateral views)



(a) (b)

Fig. 2(a,b) SEM images of Copper nanowires (cross-sectional & lateral views)

Electrodeposition of copper nanowires was achieved in polycarbonate template under identical conditions. The polymer template was dissolved in dichloromethane at room temperature. SEM micrographs of grown copper nanowires are shown in Fig. 2(a,b). The cross-sectional and lateral views are somewhat distorted and not as smooth as in case of anodisc alumina templates. The diameter of copper nanowires matches with the pore diameter (100 nm) of polycarbonate template. We also performed electrodepostion in 20 nm pore diameter alumina template. Due to over deposition of copper into nanopores, we failed to grow copper nanowires. Instead, what we achieved was a pattern resembling some botanical plant species depicting nature's self assembly (Fig.3).

It is reported (11) that over deposition of copper may also lead to metallic micro-rose having petals in nanometer dimensions

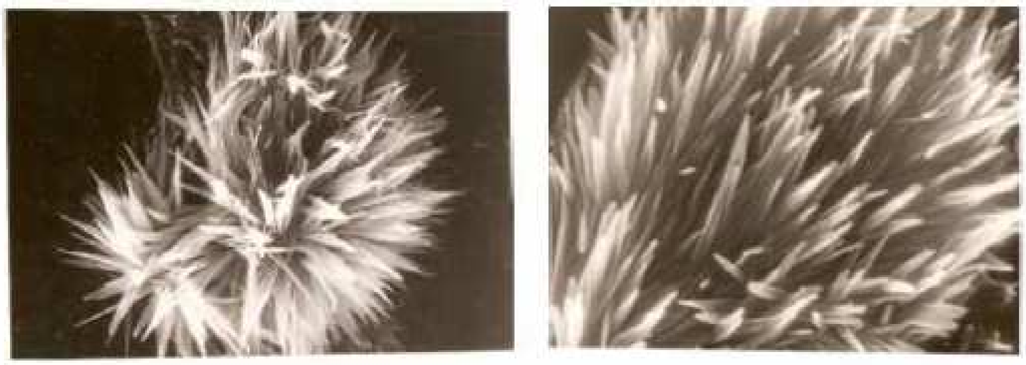
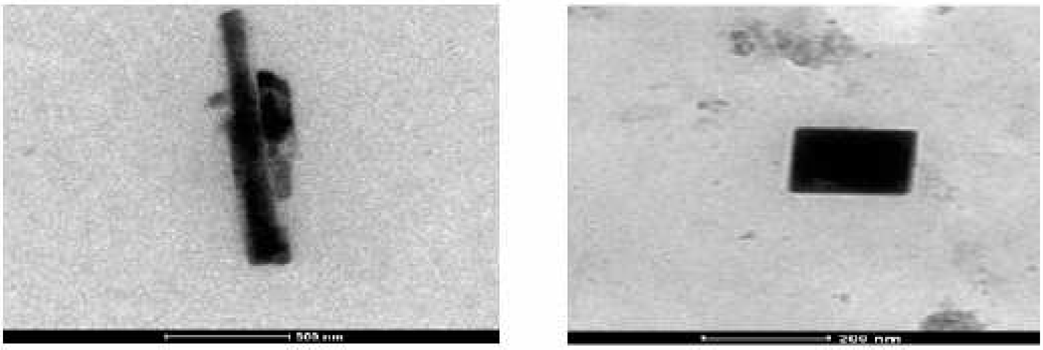
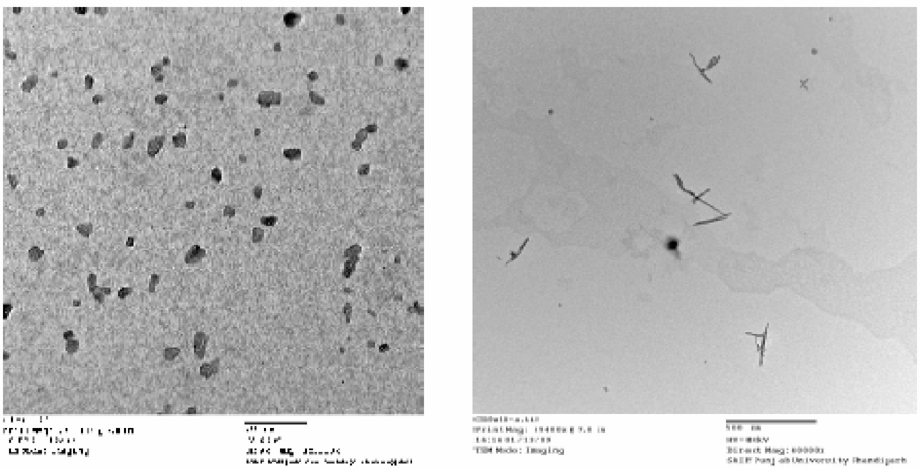


Fig.3. SEM micrographs showing over deposition and nature's self assembly.



(a) (b)

Fig.4. TEM micrographs: (a) Nanorod of Barium Oxalate (b) Nanocrystal of Iron Oxalate



(a) (b)

Fig. 5. TEM micrographs: (a) Cadmium Sulphide Nanocrystals, (b) CdS Nano-needles

Our second line of attack has been the chemical route of Reverse Micelle technique (12). Transmission Electron Microscope (200 kV FEI, Amsterdam) micrographs of nanorods of Barium carbonate and naocrystals of Iron oxalate prepared in our laboratory are shown in Fig. 4(a,b). Cadmium sulphide nanocrystals and nano-needles have also been fabricated using chemical route as shown by TEM micrographs in Fig. 5(a,b).

CONCLUSIONS

Our preliminary investigations confirm that electrodeposition of copper nanowires in anodic alumina and polycarbonate templates are the simplest route to nanotechnology. The diameter of copper nanowires matches with the pore diameter of templates. Structure and morphology of copper nanowires reveals its polycrystalline nature. Nanorods/needles and nanodots/crystals fabricated by reverse micelle technique are going to be tested for future applications in nanodevices.

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REFERENCES

1. Ratner M and Ratner D, “Nanotechnology: A gentle introduction to the next big idea”, Pearson Education Publication, London, 2003; G Z Cao, ‘Nanostructures and Nanomaterials”, London:Imperial College Press, 2004.
2. Sarkar J, Khan G G and Basumallick A, Bull. Mater. Sci., 30(3), 271 (2007).
3. Sun Shin H, Song J Y and Yu J, Materials Letters, 63, 397 (2009).
4. Virk H S, Kishore K and Baloria V, J. Nano Res., 10, 63 (2010).
5. Alivisatos A P, Science, 271, 933 (1996).
6. Kolvin V L, et al., Nature, 370, 354 (1994).
7. Klein D L, et al, Nature, 389, 699 (1997).
8. Ganguli A K and Ahmad T, J. Nanoscience and Nanotechnology, 7, 2029 (2007).
9. Ahmed J, Vaidya S, Ahmed T, Sujatha Devi P, Das D and Ganguli A, Mater. Res. Bull., 43, 264 (2008).
10. Schonenberger C, Van der Zande B M I, Fokkink L G J, Henry M, Schmid C, Kniger M, Bachtold A, Huher R, Birk H and Stairfer V, J. Phys. Chem. B, 101, 5497 (1997).
11. Kumar S, Kumar V, Sharma M L and Chakarvarti, S K, Superlattices and Microstructures, 43, 324(2008).
12. Ahmad T and Ganguli A K, J. Am. Ceram. Soc., 89, 1326 (2006).