Nanowire diodes with semiconductor heterojunctions

Ionut Enculescu[1], Elena Matei[1], Monica Enculescu[1], Maria Eugenia Toimil Molares[2], Jean Philippe Ansermet[3]

[1]National Institute of Materials Physics, Atomistilor 103 bis, Magurele, Romania;[2]GSI Darmstadt, Germany; [3]EPFL, Lausanne
encu@infim.ro

During the last decade the main focus in the field of nanotechnology shifted from the pure knowledge driven research towards more complex, application focused work. Nanowires are quasi – 1 – dimensional nanoparticles with a huge potential of applications ranging from building blocks of tomorrow electronics to active components of ultrasensitive biological detectors. These nanostructures not only allow extreme miniaturization but, based on their unique morphology low dimensionality and high surface to volume ratio, offer new specific functionalities. The template method is one of the most convenient in order to fabricate nanowires or nanotubes [1].

By replicating a nanoporous membrane with cylindrical pores with controlled dimensions, such as polymer ion track membranes or anodic alumina, one is able to obtain nanowires with well controlled morphology and extremely high aspect ratio. Usually the replication of the nanoporous membranes is performed using electrochemical and chemical deposition due to the fact that is more difficult to fill such low diameter pores by employing physical methods. Using this approach metal and semiconductor nanowires were obtained. Further, complex structure nanowires such as multilayered magnetic nanowires with current perpendicular to plane giant magnetoresistance were prepared by a simple electrochemical pulsed deposition [2]. Semiconductor electrodeposition advanced steadily during the last two decades opening the possibility that by template replication to fabricate high quality nanowires. Moreover, the next logical step was to prepare more complex structures, either by pulsed deposition when the electrochemical properties of the system make it possible or in a more complicated manner namely by a sequential approach where the deposition bath is changed as a function of the desired result.

In this paper we present our results related to the fabrication of multisegment nanowires containing semiconductor heterojunctions, by electrochemical deposition in ion track membranes. Scanning electron microscopy, energy dispersive X-ray analysis and optical spectroscopy were employed to characterize the nanostructures.

The first step was to prepare the nanoporous membranes by swift heavy ion irradiation (performed at the UNILAC accelerator of GSI, with heavy ions such as Au or U with specific energy of 11.4 MeV/nucleon) of the polycarbonate foils 30 micrometer thick. The total fluence of irradiation will represent the pore density, taking into account that each ion passing through the sample leaves a defect track. This defect track is further etched with a mixture of an aqueous solution of sodium hydroxide (5M) and 10% methanol at a temperature of 50°C. In these conditions the etching is extremely selective, cylindrical, parallel pores being obtained. The diameter of the pores is controlled by the etching time, a 2 micrometer diameter corresponding to one hour of etching.

The next step of the algorithm was to deposit the working electrode. Thus, a thin layer of gold was deposited onto one face of the membrane and further thickened by electrodeposition of copper. After the metal electrode was prepared, the pores were completely closed on that face of the membrane.

We deposited multisegment nanowires, containing a metal i.e. nickel and a semiconductor heterojunction zinc oxide/cadmium telluride. Nickel electrodeposition was performed using a typical Watts bath containing nickel sulphate and chloride as source of metal ions and boric acid as pH buffer. CdTe was deposited from a solution containing cadmium sulphate, tellurium dioxide as sources of cadmium and tellurium ions. The pH of the solution was approximately 2. Zinc oxide was deposited from a nitrate bath which contains zinc nitrate as the source of zinc ions (see figure).

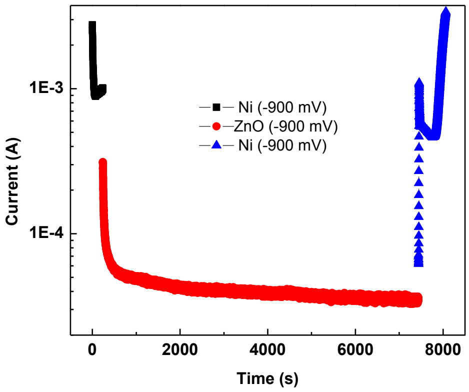
The structures where characterised from the point of view of composition, morphology, optical and electrical properties.

By this approach we succeeded in fabricating nanowires with high morphological and structural quality. These can be employed in a wide field of applications, most interesting being the biological molecule (DNA, cancer markers, proteins and so on) detectors. Such nanostructures with controlled properties may also be used in optoelectronics, as photodetectors. By further refining the method and improving the quality of the deposited nanowires one can develop ultra miniaturised light emitting diodes or even laser diodes.

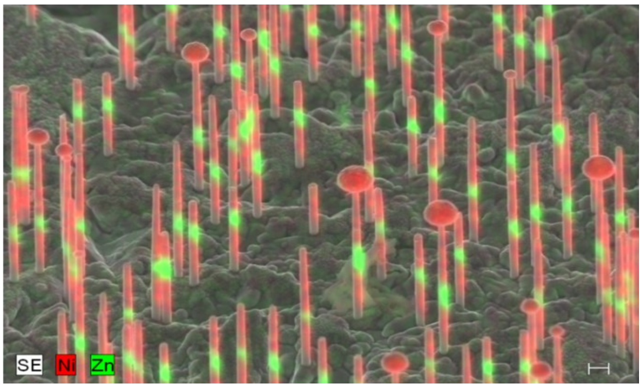
References

[1] Martin C. R., Science, , 266, (1994) 1961-1966.
[2] Enculescu I.; Toimil-Molares M.E.; Zet C.; Daub M.; Westerberg L.; Neumann R.; Spohr R. Appl. Phys. A, (2007), **86**, 43 – 47.
[3] I. Enculescu, M. Sima, M. Enculescu, M. Enache, V. Vasile and R. Neumann, Optical Materials, **30**, (2007), 72-75
c

Figure



(a)



(b)

Figure caption (a) deposition current for a Ni – ZnO – Ni multisegment array of wires and (b) EDX mapping of an array of multisegment wires.