Zinc Oxide Nanostructures – Current Status

Lupan O., Sontea V., Cretu V., Railean S., Trofin V.
Department of Microelectronics and Semiconductor Devices, Technical University of Moldova, Republic of Moldova
sontea@mail.utm.md

Abstract – Development of ZnO nanostructures is of great importance for industrial applications. We analyze synthesis and properties control of zinc oxide, which are important in understanding the growth mechanism and further developing ZnO-based nanodevices. Also, we briefly review research activities and progress in developing improved control of technological processes for ZnO as nanomaterial. Recent reported applications of ZnO low-dimensional structures will be discussed.

Keywords – nanomaterial; ZnO; nanostructures; synthesis.

I. INTRODUCTION

Semiconducting oxides nanostructures are of potentially wide fundamental and technological interests in science ranging from the quantum physics to nanooptoelectronics [1,2]. Bulk materials are of importance for making substrates of high quality and for enhanced devices with extended lifetime. However, size reduction to the nanometer scale causes quantization of density of states, which alters the intrinsic properties of crystalline materials. Research interest for investigation of the behavior of matter at nano-scale has accelerated the elaboration of a number of new advanced multifunctional materials with defined structure, morphologies and properties. These electronic, magnetic, piezoelectric or optical properties of the materials, ranging from micro to nano-scale, along with multifunctionality due to small size effect, have contributed extensively to different fields of device applications, especially for optoelectronics, medical diagnostics, and gas sensors. ZnO is one of technologically important materials, which presents significant practical and scientific importance for different areas including nanodevices for electronic and biomedical applications [1-4].

For example, ZnO exhibits various applications in gas sensors, electrodes for dye-sensitized solar cells DSSCs, light-emitting devices, luminescent materials, and thin-film transistors [1-12]. To present potential utilities of ZnO nanomaterial, we point out on some typical applications of ZnO low-dimensional structures in Table I (here we present our results only).

By correct understanding technological aspects, it is possible to solve difficulties in synthesis of stable doped zinc oxide due to low-doping efficiency, etc.

II. ZINC OXIDE NANOSTRUCTURES

A. Problems and Solutions

For stable device applications, a big problem is the lack of reproducible and reliable n- and p-type conductivity with shallow donor and acceptor states in zinc oxide, respectively.

It is expected that doping nanocrystals would lead to new physics and chemistry [13]. Similar to their bulk counterpart, doping of semiconductor nanocrystals by impurity atoms permits tailoring their behavior, which can enable their new application in nano-electronics and nano-optoelectronics [14]. However, multiple recent reports indicated that doping could be difficult for nanocrystals [14]. As it was mentioned earlier, simple addition of a transition metal compounds to the growth solution does not result in incorporation of dopants. Such problems could be due to the fact that the surface-bound dopants may have different geometries, and exchange coupling interactions with the semiconductor band electrons than substitutionally incorporated dopants have, and the target physical properties of the material may therefore be compromised. Enormous efforts have been directed to this area of research by different research groups worldwide. Therefore, it is important to perform more comprehensive study of the technical procedures over the synthesis technique in order to allow exact control over the defects, the type of conduction and the emission properties with the possibility to elaborate and fabricate nano-ZnO – based electrical, magnetic and optical nanodevices.

B. Growth of Zinc Oxide

Zinc oxide material possess several types of the fastest growth directions [1]. Due to different growth rates, the controlled synthesis of preferred nanoarchitecture for specific applications can be realized by a well control of the synthesis process [15]. The growth techniques for zinc oxide nanostructures can broadly be classified as:

a) solution phase synthesis and
b) gas phase synthesis.

In the solution growth procedures, the synthesis of the material is carried out in a liquid. In most of reports they are in aqueous solutions and the process is referred to as hydrothermal synthesis. As heterogeneous nuclea-
tion takes place at a low level of supersaturation of the complex solution, it different zinc oxide nanostructures can be grown by controlling the reactant concentration, process temperature, and pH value [15]. This technique can be represented by: template assisted growth; spray pyrolysis for growth of thin films; electrophoresis; electrodeposition; sol-gel route; hydrothermal [1,15]. Figure 1 represents a SEM image of the Mn-doped ZnO nanorods synthesized in a hydrothermal process at 97 °C aqueous solutions.

Figure 1. SEM image of the Mn-doped ZnO nanorods synthesized in a hydrothermal process at 97 °C aqueous solutions

In the gas phase growth techniques: gas phase synthesis is realized in the gaseous environment in a closed chamber. In most of the reports such kind of growth is carried out at temperatures from 450 °C to 1450 °C. The following gas phase methods have been reported:

- physical vapor deposition;
- vapor phase transport, which includes vapor solid (VS) and vapor liquid solid (VLS) growth;
- chemical vapor deposition;
- metal organic chemical vapor deposition (MOCVD);
- thermal oxidation of pure Zn and condensation;
- field assisted thermal decomposition [1].

In our previous works - some morphological and structural properties of the ZnO nanostructures have been shown. Detailed technological description for these low-dimensional structures and their characteristics has been reported in our works [5-12].

III. CONCLUSION

Zinc oxide nano-structures are attractive nanobuilding-blocks for applications in nano-devices like sensors, photodetectors, energy generators, solar cells, light-emitting devices. Within the next decade, zinc oxide nanostructures will move into industrial applications, if its growth and performances can be controlled. Also, synthesized nanostructures will be integrated in devices by using different approaches, e.g. focused ion beam nanolithography [5-9], self-assembly, electric-field assisted assembly, etc.

REFERENCES