# Structure and morphology of the $Zn_xMg_{1-x}O$ nanowires studied using shape memory composite nano-tweezers

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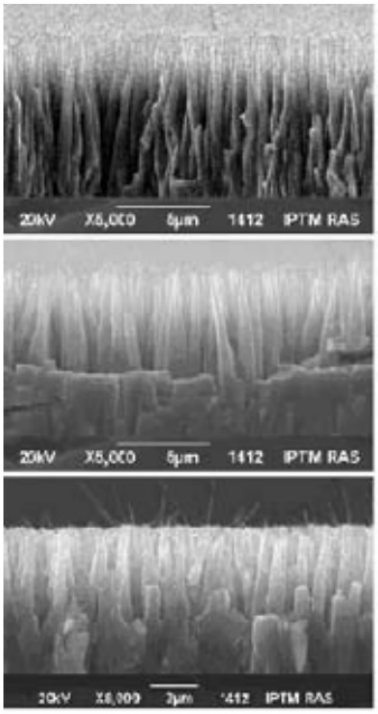
## Introduction

In the past 20 years, one-dimensional (1D) carbon nanotubes and semiconducting inorganic nanowires (NWs) have been extensively studied as potential building blocks for nanoscale electronics, photonic devices, optoelectronics, sensors, and energy producing devices due to their unique physical and functional properties [1-6]. Among nano-structures, nanowires (NWs) [7-9] are an important class of material that exhibit one-dimensional (1D) electrical properties and attractive optical properties with great potential for applied and fundamental basic research. NWs are usually single-crystalline, highly anisotropic with different functional properties, particularly promising in electronics, sensorics, photonics and solar energy.

As it was manifested in [10] NWs with flat end facets can be exploited as optical resonance cavities to generate coherent light on the nanoscale. Room temperature UV lasing has been demonstrated for the ZnO and GaN nanowire systems with epitaxial arrays [11], combs [12], and single nanowires [13, 14]. ZnO is wide bandgap semiconductors (3.37, 3.42 eV) suitable for UV-blue optoelectronic applications. The large binding energy for excitons in ZnO (~60 meV) permits lasing via exciton-exciton recombination at low excitation conditions. Well-faceted nanowires with diameters from 100 to 500 nm support predominantly axial Fabry-Perot waveguide modes (separated by $\lambda = \lambda 2/[2Ln(\lambda)]$, where L is the cavity length and $n(\lambda)$ is the group index of refraction owing to the large diffraction losses suffered by transverse trajectories [10].

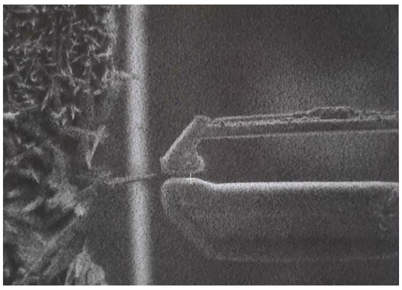
In the present work we study the doping of ZnO with magnesium which allows controlled increasing of the width of the forbidden zone from 3.37 eV (for ZnO) to 7.8 eV (for MgO) by increasing the concentration of Mg. The purpose of the present study is to demonstrated a simple method of producing arrays ("forest") of nanowires $Zn_xMg_{1-x}O$ with a high concentration of Mg by annealing ZnO vapor Mg. Another purpose of our work is to improve the technology of 3D manipulation of submicron objects based on composite shape memory nanotweezers controlled by external heating in vacuum chamber of FIB device and to perform selection of NWs from the forest, harvesting, transportation into TEM vacuum chamber and detailed study of their morphology, crystallographic structure and composition.

## Material

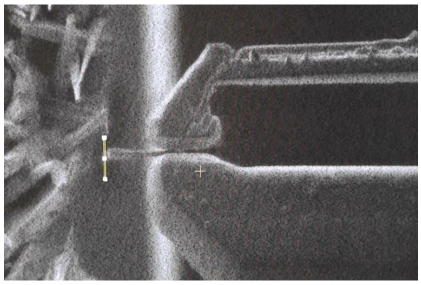



SEM image of the forest of ZnxMg1-xO nanowires.

## Results

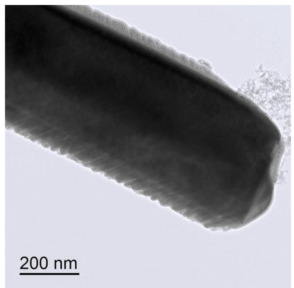


The selection of the individual NW from the forest. The controlled gap of the nanotweezers is about 0.8 μm



The harwesting of the slected individual object and its separation from the invironment by cutting of the part of the NW by ion beam.

The operation of ZnxMg1-xO NW attaching by Pt layer using FIB CVD to copper grid for further TEM study.




The end facet of the $Zn_xMg_{1-x}O$ NW stuied by TEM. The thickness of the NW near end facet is about 400 nm.

## Conclusions

We can conclude that in the present work we have performed the experimental study of the doping of ZnO with magnesium which allows controlled increasing of the width of the forbidden zone from 3.37 eV (for ZnO) to 7.8 eV (for MgO) by increasing the concentration of Mg. It was demonstrated that producing of the arrays of ZnxMg1-xO MWs with a high concentration of Mg by annealing ZnO vapor Mg allows to grow forest of regular NWs with relatively perfect structure and shape. Using the improved technology of 3D manipulation of submicron objects based on composite shape memory nanotweezers controlled by external heating in vacuum chamber of FIB device there were perform selection NWs from the forest, harvesting, transportation to TEM vacuum chamber and detailed study of their morphology, crystallographic structure and composition. The most of the samples studied demonstrated single crystalline structure sometimes accompanied by the regular defect arrays and twins. 3D manipulation system based on shape memory composite nanotweezers in vacuum chamber of FIB device have proved its flexibility and reliability. The selection of individual NWs, transportation and attaching to copper grid of TEM is accomplished routinely. The continuation of the applied study of the possibilities of creating of UV nano lasers in wide range of wavelengths using $Zn_xMg_{1-x}O$ NWs is on the way. Further improvement of the 3D manipulation system can lead to the creation of production technology of UV nano lasers on the principle of top-bottom for the next generation optoelectronic and photonic devices.

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