MgO covering of ZnO nanowires: structural and morphological characterization

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1. INTRODUCTION

One-dimensional (1D) ZnO nanostructures, such as nanowires (NWs) and nanorods are ideal systems for nanotechnology due to its unique electronic, optic and photoelectronic properties. However ZnO has intrinsic surface defects that can reduce the enhancement of optoelectronic devices. In this sense, MgO coating of ZnO NW has been proved to be isolating, thus reducing lasing thresholds and enhancing excitonic photoluminescence [1,2]. The usual techniques for the MgO covering require the use of spin coating or the use of pure magnesium as a source material. In this work, we present, as an alternative, a simple and easy process for the covering of ZnO NWs with MgO nanoparticles (NPs). An accurate morphological and structural characterization by SAED and HRTEM combined with local EDX analysis has been made.

2. RESULTS

2.1 Experimental conditions

Catalyst-free ZnO NWs were grown on amorphous quartz substrates by physical vapor transport (PVT). The coating of MgO nanoparticles on the so grown ZnO NWs was made by a two-step method. First, ZnO nanowires were covered by a solution of magnesium acetate (0.002 M) in methanol just by depositing a droplet of the solution. Next, an annealing at 400ºC for 10 min in open atmosphere was performed followed by a vacuum annealing at 700 ºC for 2 h. The morphology of ZnO NWs and MgO NPs was analyzed by SEM and TEM; crystalline structure was analyzed by High Resolution TEM, SAED and XRD. Crystalline defects were localized by High Resolution TEM. The composition was determined by EDX spectroscopy.

2.2 ZnO Nanowires with and without MgO covering

Fig. 1(a) presents a SEM top view of ZnO nanowires grown on amorphous quartz substrate. As can be seen, the sample consists of a large area with a high density ZnO NWs having a diameter ranging from 50 to 200 nm. ZnO NWs were generally single crystalline without significant defects, as shown in the HRTEM image of Fig. 1(b) and the corresponding electron diffraction pattern in Fig. 1(c). HRTEM analysis revealed the presence of some planar defects as stacking faults (SF) in a few ZnO NWs.

Figs. 1(d), 1(e) and 1(f) show SEM, TEM and HRTEM images of ZnO NWs covered by a quasi continuous layer of MgO nanoparticles with a mean diameter of 5 nm. The SAED pattern in the inset of Fig. 1(e), shows the presence of two sets of patterns: one consists of diffused and continued concentric rings that were attributed to non-oriented crystalline MgO NPs with a measured *a*-lattice parameter of about 0.4290±0.0005 nm.

The second pattern consists of intense spots in a periodic lattice and was attributed to the ZnO NWs. The measured lattice parameters were lower than those of ZnO NWs without MgO covering. In ZnO without visible MgO covering, EDX analysis indicated the presence of some Mg content (less than 5 at. %). The corresponding *a* and *c* lattice parameters of ZnO wurtzite structure were calculated from HRTEM images and were found to be a=0.3234±0.0005 nm c =0.5180±0.0005 nm. These values are slightly lower than those measured on a bare ZnO nanowire (a=0.3252±0.0005 nm c =0.5207±0.0005 nm). This suggests a Mg diffusion into the ZnO lattice and that the bigger Zn^{2+} ions (ionic radius 88 pm) are partially substituted by the lower Mg^{2+} ones (ionic radius 86 pm), resulting in a shortened lattice [3].

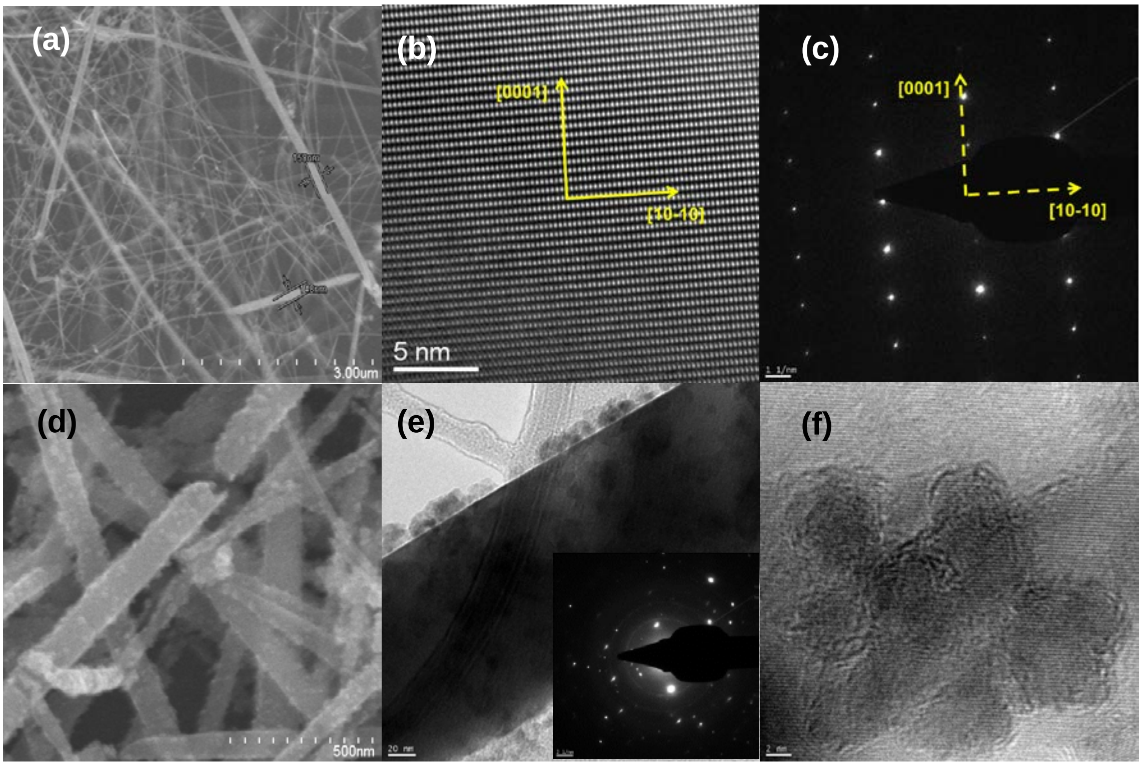

Figure 1. (a) Top view SEM image of the bare ZnO NWs. (b) HRTEM image of a ZnO nanowire and (c) its corresponding SAED pattern. The incident electron beam is along [0-10] direction in the real space. (d) SEM; (e) TEM and (f) HRTEM image of MgO covered ZnO nanowires. Inset of (e): SAED pattern.

Fig. 2 shows XRD patterns of ZnO NWs with and without covering of MgO NPs. The values of the *a* and *c* lattice parameters of the ZnO wurtzite structure calculated from the peak position follow the same trend. It is worth noticing that in spite of the MgO covering, the incorporation and/or diffusion of Mg atoms don´t generates significant changes in the morphological and structural properties of ZnO NWs. This MgO covering and Mg diffusion makes ZnO nanowires potentially attractive for creating photonic devices. In this case, Mg diffusion process should be taken into account, as it may lead to a slight modification of the optical behaviour of the ZnO NWs.

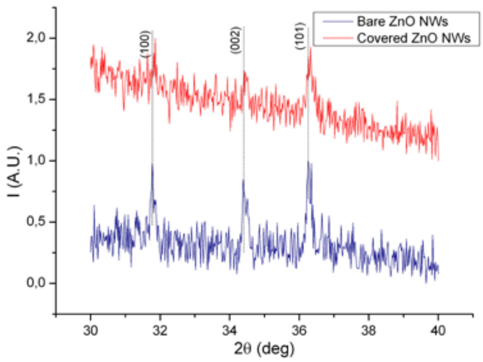

Figure 2: XRD patterns of bare and MgO covered ZnO NWs

3. CONCLUSION

ZnO nanowires were grown by the PVT method and a covering of MgO nanoparticles was added by a simple and easy two-step technique. ZnO nanowires were of good crystalline quality and the MgO covering consisted of MgO nanoparticles with a size of about 5 nm. HRTEM combined with localized EDX analysis revealed, in addition to the MgO covering, the presence of Mg diffusion (< 5 at %) in the ZnO lattice. This Mg diffusion resulted in a reduction of the *a* and *c* parameters of ZnO wurtzite structure, without significant changes in their crystalline quality.

4. REFERENCES

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