Growth mechanism of aligned ZnO nanorods by vapour phase process

M. Zha,[a] L. Zanotti,[b] D. Calestani,[c] A. Zappettini,[d] and C. Paorici[e]
[a] *IMEM-CNR, Parco Area delle Scienze 37/A, 43124 Parma (Italy), zha@imem.cnr.it*
[b] *IMEM-CNR, Parco Area delle Scienze 37/A, 43124 Parma (Italy), zanotti@imem.cnr.it*
[c] *IMEM-CNR, Parco Area delle Scienze 37/A, 43124 Parma (Italy), calle@imem.cnr.it*
[d] *IMEM-CNR, Parco Area delle Scienze 37/A, 43124 Parma (Italy), zapp@imem.cnr.it*
[e] *Parma University, Physics Dept., Via Usberti 7/A, 43124 Parma (Italy), carlo.paorici@unipr.it*

ZnO is an important and versatile functional semiconducting material. In recent years one-dimensional nanostructures (wires, tubes, tetrapods, etc.) have received increased attention not only for their specific properties but also for the fabrication of nanoscale devices. Among these structures the parallelly aligned, column-shaped nanorods, orthogonal to the growth substrate plane, are particularly interesting for many applications such as dye sensitized solar cells, transistors, nanogenerators, short-wavelength nanolasers, etc.

Many different techniques have been reported for the growth of ZnO nanostructures but thermal evaporation turns out to be one of the most convenient when considering the high quality and purity of the grown crystals, the simplicity of the growth apparatus and the easiness in the scaling-up of the process.

In this communication the authors report on a selective growth process as regards well-aligned ZnO nanorods arrays extended up to a few cm^2. The method, which is based on thermal evaporation and controlled oxidation, includes nucleation and growth kinetics control, adjustment of local growth temperature, selection of appropriate source materials and chemical composition of the substrate.

The optimized growth parameters allowed to obtain arrays of (0001)-oriented, vertically aligned single crystals with length and diameters within 1-3 microns and 20-10 nm respectively.

It is in particular pointed out: (a) the formation of sub-micrometric metal Zn clusters during the metal source evaporation; (b) their adhesion to a ZnO buffer layer (about 300 nm thick) previously deposited on the substrate (glass, Si, ...), which enables to keep an appropriate cluster distribution while avoiding larger clusters/drops formation thanks to suitable "surface wettability" conditions; (c) the subsequent growth of ZnO nanorods owing to the contemporary presence of Zn vapours, oxygen and Zn clusters on the substrate, these last ones acting as selective nucleation points.

On the ground of what above and consequent process re-adjustments, the here proposed method, with its elevated yields and reproducibility as well as low production costs, turns out to be especially well-suited for large-scale application requirements.