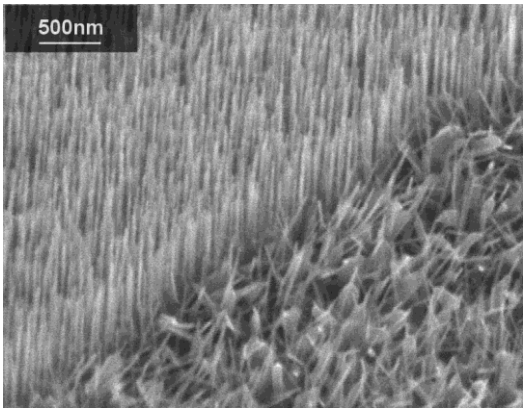
The study of growth mechanism as a key for large-scale vapor-phase synthesis of ZnO nanostructures

Davide Calestani, Mingzheng Zha, Andrea Zappettini, Marco Villani, Lucio Zanotti
IMEM-CNR Institute – Parma (ITALY)

The growth of zinc oxide (ZnO) nanostructures is one of the main topics in today's Material Science. These nanostructures have several proved or potential application in many fields, such as optoelectronics, photovoltaics, transparent electronics, gas-sensing, "piezo-tronics", etc.
For real-world technological application of these nanostructures, large-scale and low-cost synthesis processes are strongly required.
Many different growth processes have been presented in literature for ZnO nanostructures, "wet" chemical syntheses probably represent the easiest way to obtain them with high yields and low cost.
However, ZnO nanostructures with a large variety of morphologies can be obtained also by vapor-phase growth processes, with high crystal perfection grade. If no catalyst is used in the growth process, a very low dopant/impurity content is also obtained (a fundamental request for some applications), but reproducibility and yield are generally much lower than those of chemical syntheses.
In this presentation a deep-study of the vapor-phase nucleation and growth mechanisms of selected ZnO nanostructures (nanorods, nanotetrapods, nanowires and nanobelts) is presented. By mean of the obtained results, it has been possible to enhance the growth procedures and strongly improve the synthesis yields.
Since the higher purity is generally one of the main advantages of vapor-phase growth process, only zinc and oxygen have been used as reagents, avoiding any catalyst or precursor. Metallic Zn has been preferred to ZnO as starting material to keep growth temperature as low as possible (generally <500°C).
Large amounts of ZnO tetrapods have been obtained by a continuous streaming reaction, directly in the vapor phase. On the other side, thin aligned ZnO nanorods rods have been grown over some square centimeters areas, by mean of a ZnO layer. Then, also randomly oriented long nanowires have been obtained on several substrates, with homogeneous distribution.
The role of Zn/O ratio, supersaturation and seeding-substrates is discussed in the different cases and results are compared, together with structural and optical characterizations.
Moreover, some examples of functionalization of the obtained nanostructures and feasible applications are described.



SEM image of the cross region between two different seeding-layer (tilted view). Different nucleation on them gave rise to thin aligned ZnO nanorods only over the proper ZnO layer.