# SELECTIVE GROWTH OF ZnSe NANOWIRES BY MOLECULAR BEAM EPITAXY

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One-dimensional semiconducting nanostructures have attracted increasing interest in recent years both for fundamental physics and for their potential applications in electronic and optoelectronic devices [1]. Several methods have been proposed for the synthesis of single-crystal nanowires (NW), such as laser ablation, high-temperature thermal evaporation and plasma-enhanced chemical vapor deposition [2,3]. In most cases, a metallic catalyst allows the growth of one-dimensional structures.

Molecular beam epitaxy (MBE) is a very effective method to grow heterostructures with very sharp interfaces. Alloy composition and doping concentration can be accurately controlled by using multiple effusion cells. Single electron transistors and resonant tunneling devices have been demonstrated with III-V semiconductor NWs using this technique [4,5].

NWs based on II-VI compounds are suitable candidates for applications in nano-optics [6]. ZnSe has been extensively studied as a material for blue-light emitting devices [7,8], but only few reports are found in literature on the synthesis of ZnSe NWs [9,10]. MBE growth of ZnSe NWs on GaP(111) substrates has been reported by Chan et al. [9]. They proposed 530ºC as the lower limit for gold-catalyzed nucleation. Zhang et al. [10] achieved a growth temperature of 450ºC using metal-organic chemical vapor deposition and Ag as catalyst, but the absence of any silver particle at the NW tips suggests a more complicated growth mechanism than standard vapor liquid solid growth [10].

Here we present the selective growth of ZnSe NWs by MBE, using solid sources for Zn and Se, and gold as the catalyst. The growth selectivity is demonstrated by the absence of ZnSe where no catalyst is present, see Fig 1. The structural and optical properties of the ZnSe nanostructures are investigated by field-emission scanning electron microscopy (SEM), high-resolution transmission electron microscopy (HRTEM), Raman spectroscopy, and photoluminescence (PL).

The growth conditions must be carefully optimized in order to maximize NW growth and to suppress secondary nucleation events. Contrary to chemical vapor deposition methods, in MBE there is no etching mechanism to remove any undesired ZnSe deposited on the uncoated surface. Thus, in order to achieve selective growth, the substrate temperature is critical. It has to be optimized in order to provide enough thermal energy to allow material diffusion and desorption. We deposited NWs in the 300-550ºC substrate temperature range. At the highest temperature only few NWs grow. When the temperature is lowered to 400-450ºC their density dramatically increases. Large quantities of NWs, up to several microns in length, arise from the gold-coated zones and extend to the surrounding areas (Fig. 1). High crystalline quality is achieved, as shown by HRTEM in Fig. 2. At 300ºC shorter and tapered NWs do nucleate.

This indicates that the lower temperature does not allow the excess material to desorb from the NW sides.

Photoluminescence in the blue region is observed from samples with a high density of NWs (grown at 300-450ºC). Fig. 3 shows a PL spectrum from a sample grown at 450ºC. No PL from the uncoated substrate is found. This confirms the selective growth at this temperature.

**References:**


[1] X. Duan, Y. Huang, R. Agarwal, and C. M. Lieber, *Nature* **421** (2003) 241.
[2] R.Q. Zhang, Y. Lifshitz, and S.T. Lee, *Adv. Mater.* **15** (2003) 635.
[3] S. Hofmann, et al., *J. Appl. Phys.* **94** (2003) 6005.
[4] C. Thelander, et al., *Appl. Phys. Lett.* **83** (2003) 2052.
[5] M. T. Bjork, et al., *Appl. Phys. Lett* . **81** (2002) 4458.
[6] M. H. Huang, et al., *Science* **292** (2001) 1897.
[7] N. Nakayama, et al., *Electron. Lett.* **29** (1993) 1488.
[8] A. Colli, et al., *Appl. Phys. Lett.* **83** (2003) 81.
[9] Y.F. Chan, et al., *Appl. Phys. Lett.* **83** (2003) 2665.
[10] X.T. Zhang, et al., *Appl. Phys. Lett.* **83** (2003) 5533.


**Figures:**

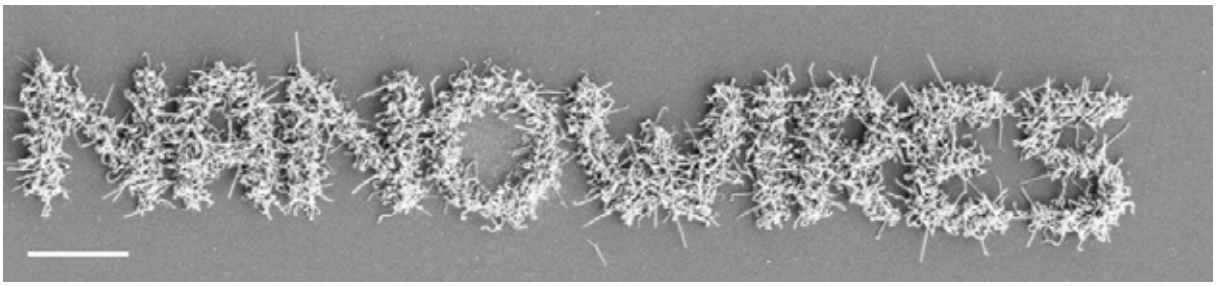

Fig. 1: SEM micrograph showing the selective growth of ZnSe NWs at 450ºC. Scalebar is 2µm.

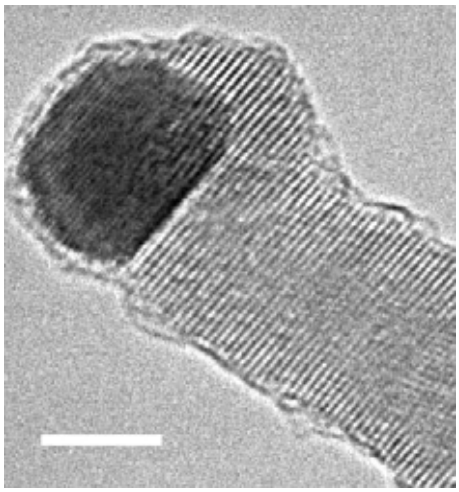

Fig. 2: HRTEM micrograph of a ZnSe NW. Scalebar is 5 nm.

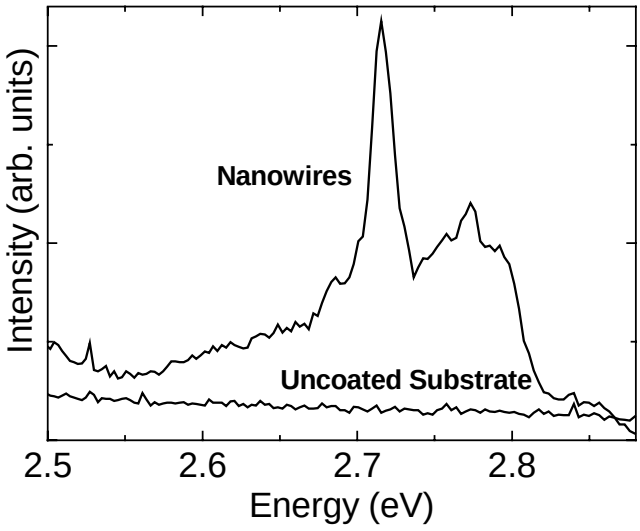


Fig. 3: PL spectrum of ZnSe NWs grown at 450ºC. No emission is seen from the uncoated substrate.