Synthesis of ZnO nanowires using gold colloids and optical spectroscopy

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ZnO is a direct wide band-gap (3.37 eV) semiconductor material with a large exciton binding energy of 60 meV, and is a good candidate to create promising devices due to its unique properties [1]. In particular, ZnO nanowires (NWs) offers novel properties, such as a surface to volume ratio almost infinite that gives an increased sensitivity and a band-gap dependence as a function of the NW diameter. Usually ZnO NWs are grown by the vapour-liquid-solid (VLS) method using Au as catalyst [2].

In this work, we reported the synthesis of ZnO NWs using Au colloids as catalyst by the VLS growth process on SiO_2/Si, alumina and quartz substrates. The Au colloidal solution was deposited over the substrate using three different methods: drop casting, immersion and spin-coating. We chose the drop-casting method as the standard deposition process, as we obtained the most homogeneous distribution and the best quality ZnO NWs. Then, several test involving different solvents (toluene, hexane and water) and different colloidal concentrations (1:1, 1:10 and 1:50) were performed. The morphology and the crystallinity of the ZnO NWs have been characterised using field-emission scanning electron microscopy (FESEM) and high-resolution transmission electron microscopy (HRTEM). Using toluene as a solvent for 5 nm Au colloids over SiO_2/Si substrates we obtained ZnO NWs with diameters and lengths ranging from 30 nm to 360 nm and 0.3 µm to 9.3 µm, respectively. Over alumina substrates and with a 1:1 colloidal concentration we obtained ZnO NWs with a more uniformal distribution of the dimensional parameters with average values of 60 nm in diameter and 1.4 µm in length. The same procedure was done for 5 nm Au colloids dissolved into hexane over SiO_2/Si substrates, obtaining ZnO NWs with diameters and lengths ranging from 40 nm to 400 nm and 0.4 µm to 11 µm, respectively. In the case of alumina we obtained ZnO NWs with average values of 80 nm in diameter and 1.7 µm in length. Finally, in the case of water as a solvent, a drop with a 1:1 concentration was deposited over SiO_2/Si obtaining ZnO NWs with diameters and lengths ranging from 40 nm to 270 nm and 0.5 µm to 6.8 µm, respectively; and using the alumina substrate we obtained ZnO NWs with average values of 60 nm in diameter and 0.8 µm in length. Different morphologies of the ZnO NWs were obtained, as shown in figure 1. HRTEM analysis reveals the high crystal quality of the ZnO NWs, see figure 2.

Raman spectra corroborate the well known ZnO phonon characteristics [3], see figure 3 and table 1. Photoluminescence spectra shows two emission peaks: one around 380 nm, associated to an exciton and a broader peak, from 450 nm to 720 nm, associated to the defects such as oxygen vacancies [4], see figure 4. The relative emission intensity of both peaks changes depending on the solvent used for the Au colloids.

References:

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[3] R. Cuscó, E. Alarcón-Lladó, J. Ibáñez, L.Artús, J. Jiménez, B. Wang, M. J. Callahan, Physical Reviews B, **75** (2007) 165202.
[4] F. Güell, J. O. Ossó, A. R. Goñi, A. Cornet, J. R. Morante. Superlattices and Microstructures, **45** (2009) 271.

Figures:

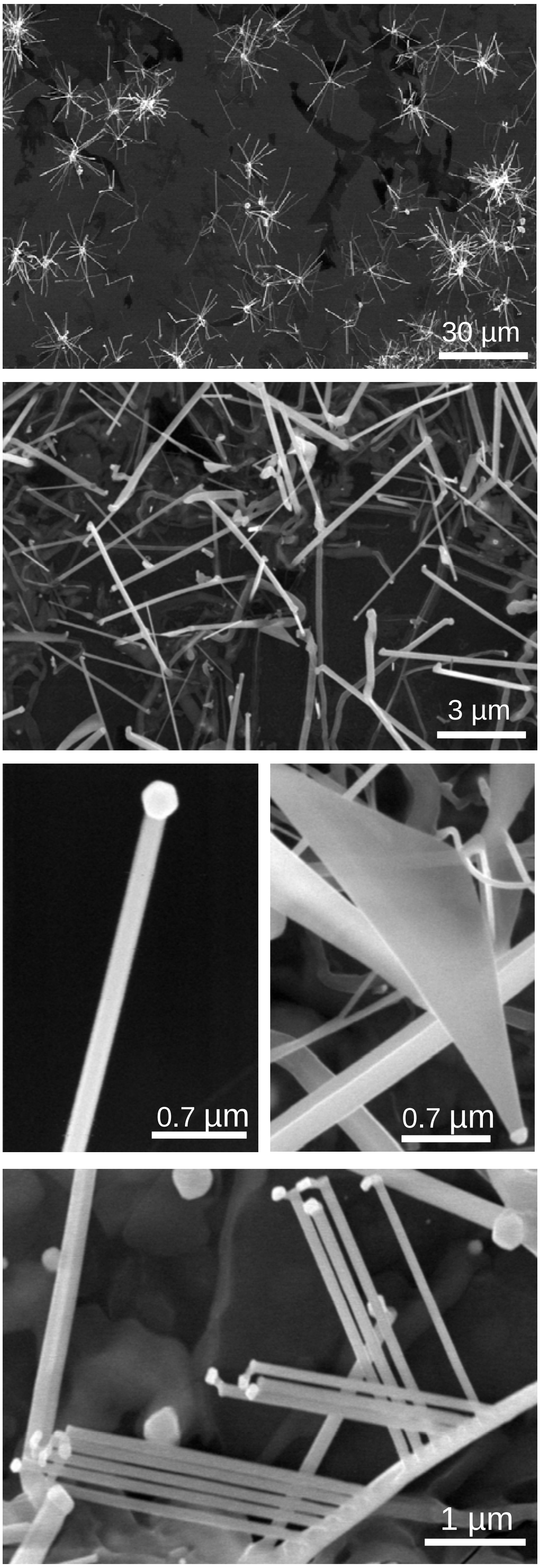

Figure 1. FESEM images of ZnO NWs with different morphologies obtained grown by the VLS process.

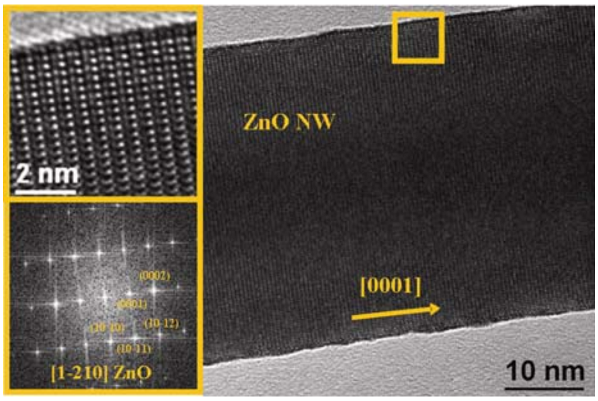

Figure 2. HRTEM images of a single crystal ZnO NW.

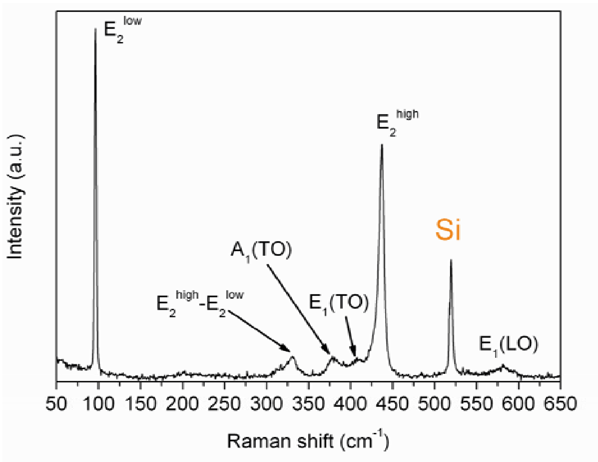

Figure 3. Raman scattering spectrum of the ZnO NWs.

	E_2^{low}	E_2^{high} -E_2^{low}	A_1(TO)	E_1(TO)	E_2^{high}	E_1(LO)
Our data	97	332	380	407	437	582
Bulk [3]	99	333	378	410	438	590

Table 1. Raman-active phonon-mode frequencies (in cm^{-1}) for ZnO.

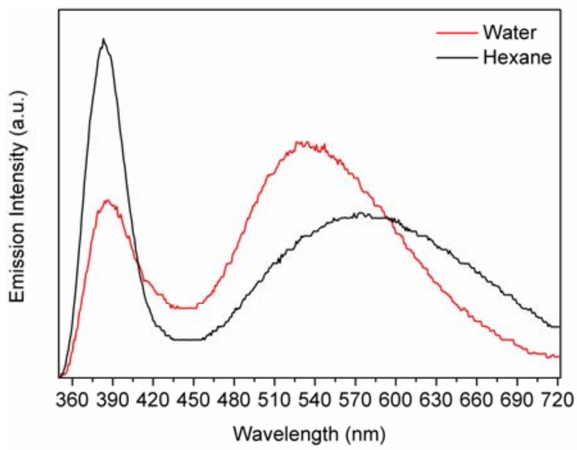

Figure 4. Room-temperature emission spectra of the ZnO NWs with UV excitation at 325 nm.