PROPERTIES OF SINGLE-CRYSTALLINE ZnO NANODOTS AND HIGHLY-TEXTURED ZNO FILMS GROWN BY ELECTROCHEMISTRY

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ZnO is a n-type semiconductor with a large band gap in the UV range, and has attractive electronic, mechanical, thermal and acoustical properties. Thin films have been used as piezoelectric transducers, short wavelength optical devices, UV light emitters, and photovoltaic cells [1-6]. Single crystal nanowire arrays can be easily obtained developing a new generation of devices in optoelectronic, photovoltaic cells, gas sensor, field emission and piezoelectrics [7-11]. Most of the films and nanowire arrays are grown by vapor phase techniques, requiring high temperature and vacuum.

In this work self assembled ZnO nanodots and films are grown by one step electrodeposition without further thermal treatment on a large area on Au/Si substrates. This process works at low temperatures (<100ºC), ambient pressure, and is easily implemented in large scale. The basic ZnO formation reaction is the generation of hydroxide ions at the electrode surface (cathode) by a reduction of an oxygen precursor. The results presented in this work have used hydrogen peroxide and nitride ions according to the following reaction:

$NO_3^- + H_2O + 2e^- \rightarrow NO_2^- + 2OH^-$

$H_2O_2 + 2e^- \rightarrow 2OH^-$

Zn^{2+} reacts with OH^- for temperatures above 50ºC following:

$Zn^{2+} + 2OH^- \rightarrow ZnO + H_2O$

The nanodots obtained have an hexagonal shape with a diameter between 150 and 400nm and a height between 50 and 200nm, as determined by SEM and AFM measurements. Characterization by SEM and X-ray diffraction of the nanoparticles showed a single crystal structure oriented with the c-axis perpendicular to the substrate (see figure 1 and 2). Their spatial and size distributions, crystallinity and photoluminescence behavior depends on the deposition parameters such as substrate type, electrochemical potential and intensity, oxygen source, deposition time, bath temperature and composition.

A comparison with highly-textured ZnO films also obtained by electrodeposition will be shown. These have been grown at a constant potential, and at different electrochemical conditions and baths. Figure 3 shows SEM images that demonstrate that the film forms by the coalescence of vertical hexagonal grains. The films have a (002) preferred orientation (XRD in figure 4), suggesting that the nanodots are nucleation points for the film growth

References:

[1] S. Peulon, D. Lincot, Adv. Mater, **8**, (1996) 168.
[2] D. Gal , G. Hodes, D. Lincot, HW. Schock , Thin Solid Films, **79**, (2000) 361.
[3] M. Izaki, T. Omi, Appl. Phys. Lett., **68**, (1996) 2439.
[4] Th Pauporte, D. Lincot, Appl. Phys. Lett, **75**, (1999) 3817.
[5] L. Stott, J. Hedström, M. Rückh, J. Kessler, KO. Velthaus, HW. Schock, Appl. Phys. Lett, **62**, (1993) 597.

[6] Th. Pauporte, T. Yoshida, R. Cortes, M Froment, D. Lincot, J. Phys. Chem. B, **107**, (2003) 10077.
[7] W.I. Park, G.C. Yi, Adv. Mater., **16**, (2004) 87.
[8] C. Levy-Clement, R. Tena-Zaera, M.A. Ryan, A. Katty, G. Hodes, Adv. Mater., **17**, (2005) 1512.
[9] L.C. Tien, P.W. Sadik, D.P. Norton, L.F. Voss, S.J. Pearton, H.T. Wang, B.S. Kang, F. Ren, J. Jun, J. Lin, Appl. Phys. Lett., **87**, (2005) 222106.
[10] Y.K. Tseng, C.J. Huang, H.M. Cheng, I.N. Lin, K.S. Liu, I.C. Chen, Adv. Funct. Mater. **13**, (2003) 811.
[11] Z.L. Wang, J. Song, Science, **312**, (2006) 242.

Figures:

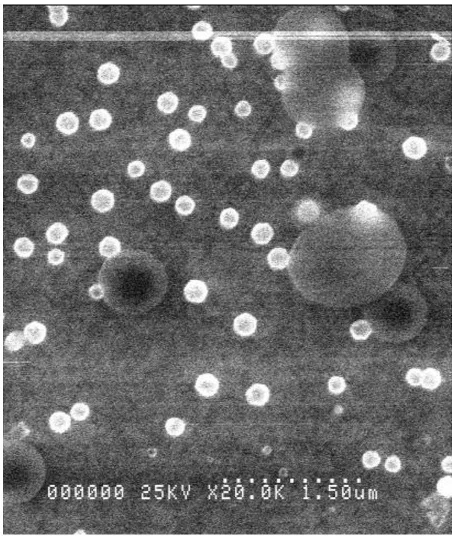

Figure 1. SEM top view of ZnO nanodots grown by a low scan voltammetry from -1,5V to +0,9V at 80ºC

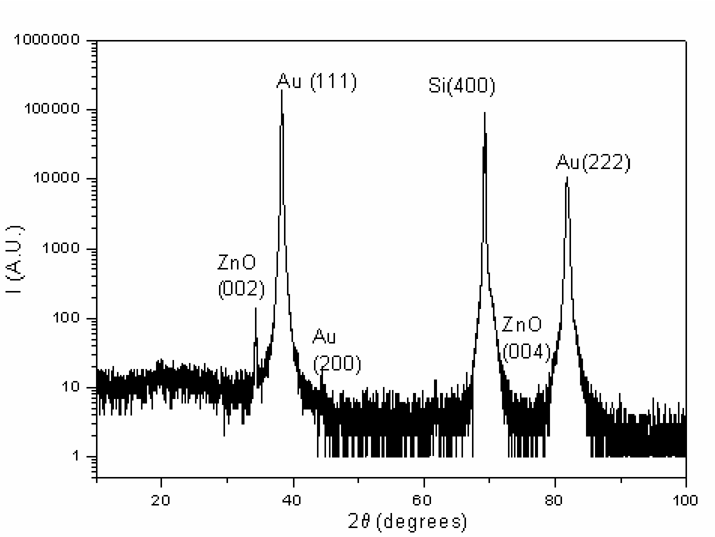

Figure 2. XRD diagram of ZnO nanodots grown by a low voltammetry scan from -1,5V to +0,9V at 80ºC.

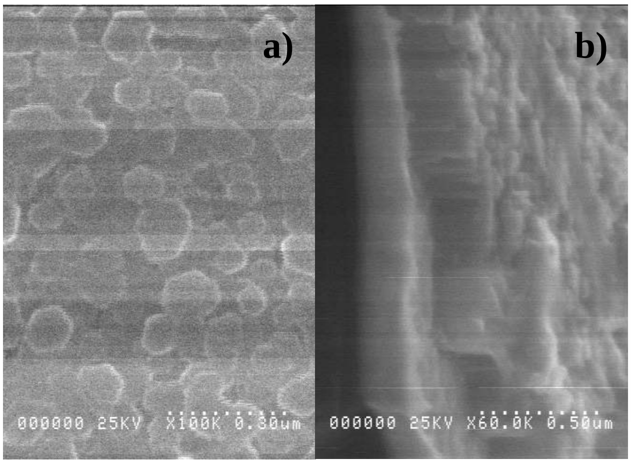

Figure 3. a) SEM top and b) cross sectional view of ZnO film grown at a constant potential of -0,9V for 1h at 80ºC

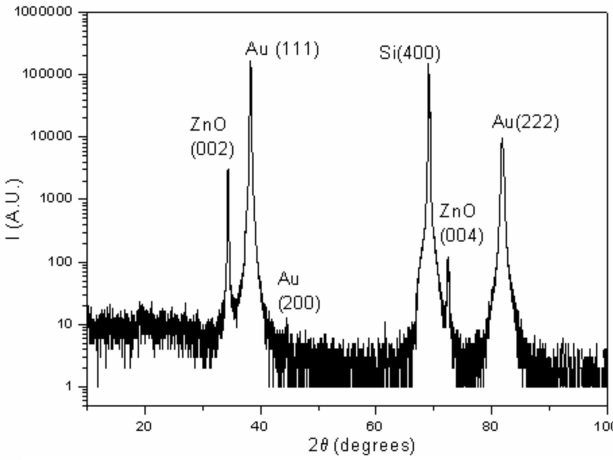

Figure 4. XRD diagram of a ZnO film grown at a constant potential of -0,9V for 1h at 80ºC