Catalytic growth of ZnO nanowires by rf magnetron sputtering

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Single crystalline zinc oxide (ZnO) nanowires are usually grown by a vapor-liquid-solid (VLS) process at temperatures in the range 850-950 ° [1,2]. Also, Si and GaAs nanowires are grown by using gold nanoparticle catalysts. Notably III–V nano-whiskers have been grown on III–V substrates in a metalorganic chemical vapor deposition MOCVD [3,4] This approach relies on annealing a thin Au film to form the seed particles. In this way, a homogeneous whisker width distribution is obtained, the mean size of which could be controlled by the thickness of the Au layer and the way this layer transforms to nanoparticles. We have followed a similar approach but using rf magnetron sputtering in UHV conditions as a first step towards size- shape- and position-controlled nanowires, similarly to what Samuelson et al started in GaAs in 2001 [5] Our approach aims at obtaining ZnO nanowires with a low level of impurities, to try to understand and correlate electronic transport and photonic and luminescence properties. Low temperature (400ºC) metalorganic vapor-phase epitaxial growth of vertically well-aligned ZnO nanorods has been also reported in [6]

Gold thin films have been grown by resistive thermal evaporation in a UHV chamber on both Si (100) and Sapphire single crystalline substrates. The morphology and the crystallography were measured by Atomic Force Microscopy and X-Ray diffraction. Selected gold thicknesses were deposited: 2, 4 and 10 nm. The gold deposited on top of the Si and sapphire was patterned by optical lithography. In this way the substrate has gold coated and uncoated areas that allow a direct comparison of different ZnO growth morphologies on Au/Sapphire patterns and on Sapphire, by scanning electron microscopy imaging.

The gold on sapphire annealing experiments were performed inside an UHV oven/sample holder to characterize the temperature range in which the gold thin films break into droplets or nanodisks due to atomic thermal diffusion, ~400-600ºC. In the same range of temperatures the ZnO deposition was carried out by rf magnetron sputtering from a ZnO target in Argon atmosphere at 100 W rf power.

Figure 1 a, b, & c shows selected SEM images, where the morphology of the ZnO is shown on top of the substrate directly (right images) and on annealed gold (left images) for the three different gold nominal thicknesses: 2, 4 and 10 nm, respectively. The ZnO structure on Gold and on the substrate is markedly different for 4nm gold, which shows that the gold annealed nanostructures of this size range act successfully as catalysts for the ZnO growth. On the other hand, for 2 nm, and for 10 nm (practically a continuous film) the ZnO growth is quite similar, that shows that this size range does not promote the vertical growth of ZnO nanowires.

References

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Figures

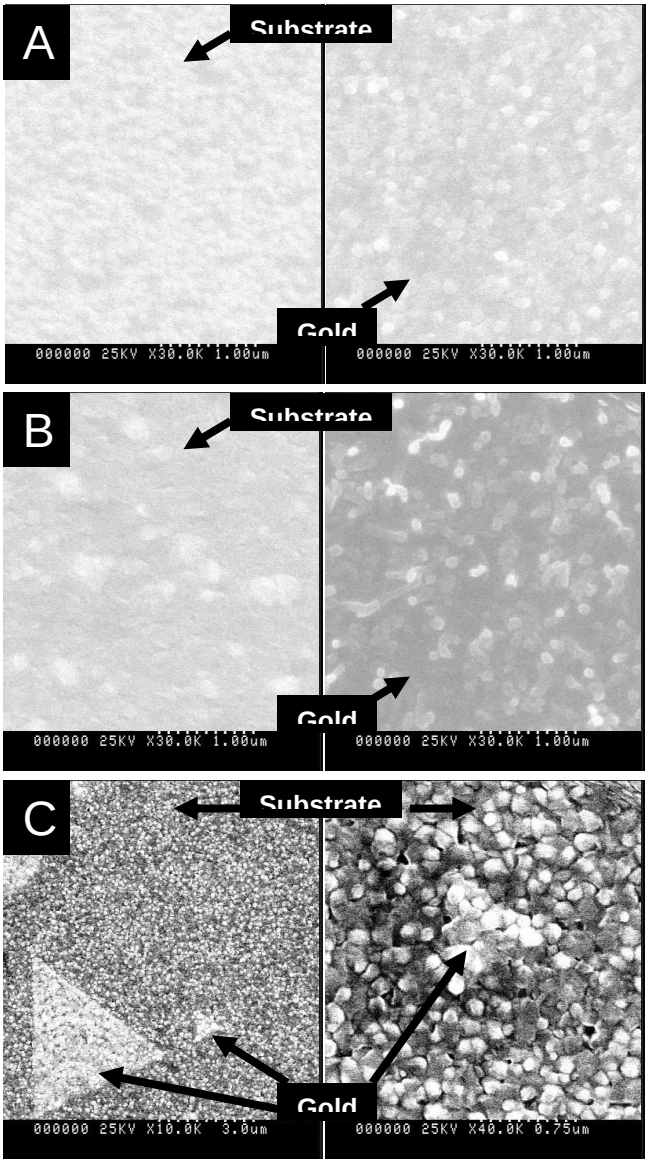

Figure 1: ZnO growth at elevated temperatures on gold patterned surfaces for different nominal gold thicknesses: a) 2nm, b) 4nm, and c) 10nm.