

Characterization of SnO₂ Nanorods grown under oxidizing conditions

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Tin dioxide (SnO₂) is an n-type semiconductor with a wide bandgap of 3.6 eV. Its distinctive reactivity towards reducing gases is beneficial for gas detection of CO, H₂, CH₄ etc. [1]. A high surface to volume ratio is crucial for fast response and low detection limit of the sensor material, therefore proper control of the sensor material morphology is important. In this work we describe the structural characterisation of quasi one-dimensional SnO₂ nanorods produced via an autocatalytic vapor-liquid-solid (VLS) [2] mechanism with gold particles as a seed. Furthermore, the influence of oxygen and water vapor on the morphology is examined and determined.

The nanorods are grown via a chemical vapor deposition on fused silica covered with gold particles as catalyst. The particles are produced by magnetron sputtering and are 50 to 100 nm in size. By heating a source composed of either tin oxide (SnO) or tin and tin dioxide (Sn + SnO₂) in a two-zone furnace with argon as a carrier gas the required SnO vapor is formed. The substrate with the catalyst particles is heated to 600 °C. The vapor condenses on these particles, liquefies and forms the mono-crystalline SnO₂ nanorods.

The disproportionation of SnO to Sn and SnO₂ at the catalytic particle results in large tin droplets on top of the nanorods and increasing diameter of the SnO₂ nanorod (Fig. 1). The surplus of tin remains in the catalytic particle. Measurements of shape and size and calculations confirm this mechanism of SnO₂ nanostructure growth. The morphology of the structures resembles “tadpoles” [3]. The growth direction of the nanorod is along the [100] axis (Fig. 3 and 4). This axis corresponds to the corner-connected SnO₆ chains in the rutile structure of SnO₂. During the growth process a significant increase of the thickness along [010] of the nanorod and formation of a twin boundary is observed (Fig. 2). The observed growth direction is unusual, since the prevalent growth direction for SnO₂ is either <101> [4] or [001] [5] depending on the synthesis method.

Careful addition of oxygen or water to the carrier gas alters the morphology into thin nanorods with small Au-Sn alloy particles on top. Here the excess tin is oxidized to SnO₂. Hence, presence of oxygen or water hinders the increase of thickness and twinning of the rods (Fig. 5 and 6).

The growth morphology of the nanorods is determined by SEM and TEM imaging. Growth direction and chemical composition was determined by electron diffraction and EDS, respectively.

1. J. Watson, *Sens. Actuators* **5** (1984) p29-42.
2. R.S. Wagner, W.C. Ellis, *Appl. Phys. Lett.* **4** (1964) p89.
3. Liu, *Handbook of Nanostructured Materials and Nanotechnology* **5** (2000) p475-500.
4. Z. R. Dai, *J. Phys. Chem. B* **106** (2002) p1274-1279.
5. Y. Wang, *J. Phys. Chem. B* **108** (2004) p13589-13593.

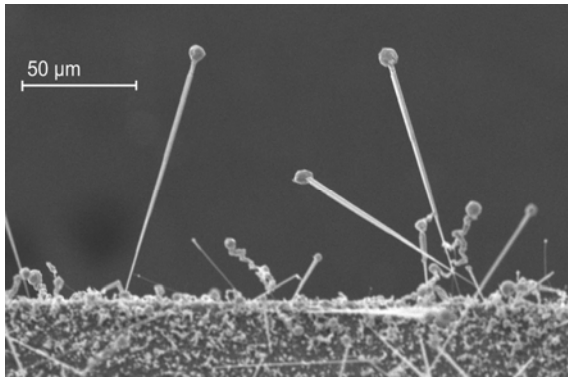


Figure 1. SEM image of “tadpole” SnO₂ nanorods synthesized in pure argon atmosphere.

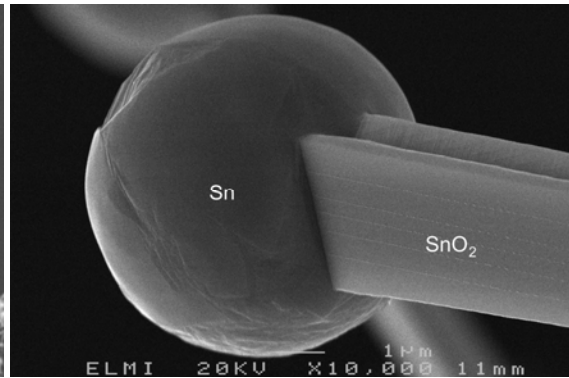


Figure 2. SEM image of twinned “tadpole” SnO₂ nanorod.

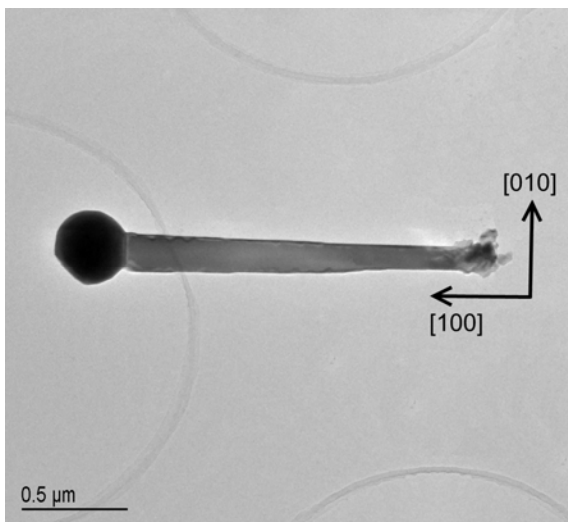


Figure 3. TEM bright field image of “tadpole” SnO₂ nanorod with growth direction in [100].

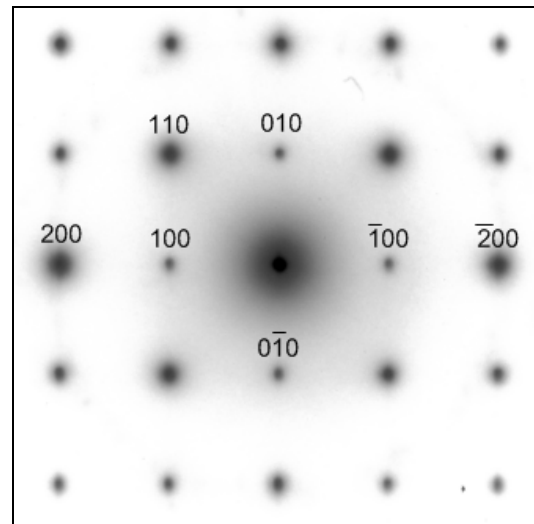


Figure 4. corresponding diffraction pattern in the [001] axis of tetragonal SnO₂.

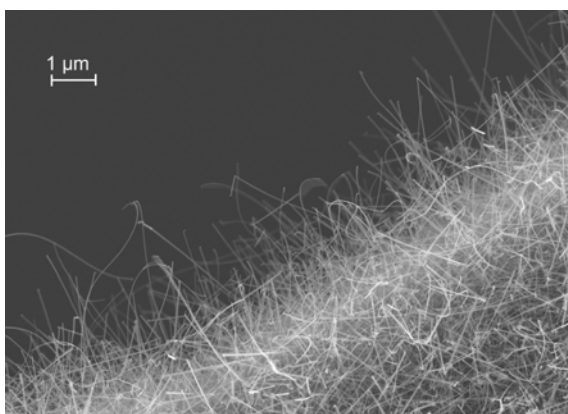


Figure 5. SEM image of SnO₂ nanorods grown with water vapor in argon.

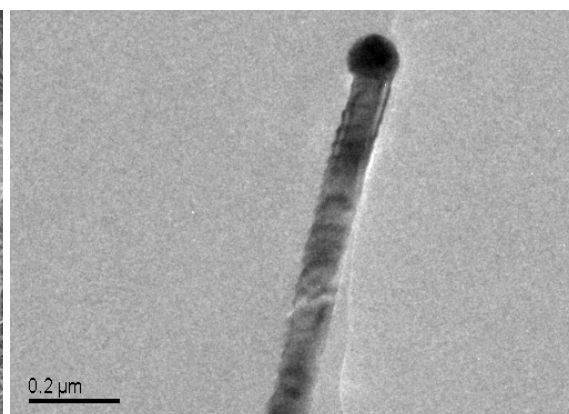


Figure 6. TEM bright field image of SnO₂ nanorod grown with water vapor in argon.