Synthesis and Characteristics of ZnO Nanowires

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Abstract:

Zinc Oxide (ZnO) nanowires hold a promising key to the world of nanotechnology. With its wide-band gap (3.37 eV), high breakdown strength, and large excitonic binding energy, ZnO possesses several advantages for use in electronic and photonic devices. Nanowires hold promise for future electronic devices and novel sensing devices. Pulsed laser deposition (PLD) has been used to deposit thin films, but its use in growing nanowires has been largely unexplored. This paper discusses the growth possibilities of ZnO nanowires using the PLD system.

In this work, ZnO materials obtained by pulsed laser deposition were studied to determine the potential for nanowire formation. ZnO was deposited (26 kV, 6 Hz, 350 mJ) on a variety of substrates including glass and sapphire. Depositions at 500 and 600°C were performed to examine the effects of temperature on growth. The effects of pressure were tested through depositions at 3.2 mTorr and 31.8 mTorr, at 500°C. The use of nanoscale metal clusters obtained by annealing thin films enabled us to study possible formations of nucleation sites for ZnO nanowires. Scanning electron microscopy (SEM) was used to gain knowledge of growth structure.

Introduction:

ZnO is a promising material for the realization and future of nanotechnology. With its wide band-gap (3.37 eV), high excitonic binding energy, and high breakdown strength, ZnO can be utilized for electronic and photonic devices, as well as for high-frequency applications. The availability of a native substrate and the potential for room-temperature operations opens the door to ZnO applications including chemical sensors and subscale electronic circuits.

Currently, pulsed laser deposition (PLD) is used to deposit thin films on a variety of substrates. PLD consists of a vacuum chamber containing a target material and substrate, mounted approximately 5 cm from the target. A KrF Excimer laser ($\lambda = 248$ nm) ablates the target material at high energy (350 mJ) and repetition (6 Hz) in the presence of ambient oxygen to form a plasma. The target material is then deposited on the substrate.

Stochiometric control with the pulsed laser deposition system allows for careful control over the ratio of atomic molecules deposited. The presence of ambient oxygen in the PLD chamber aids in depositing oxides. The focus of many PLD systems has been on the deposition of thin films. This experiment attempts to use the PLD system in a novel way: to grow ZnO nanowires. Nanowires are tiny components of nanotechnology (10^{-9} meter range) that

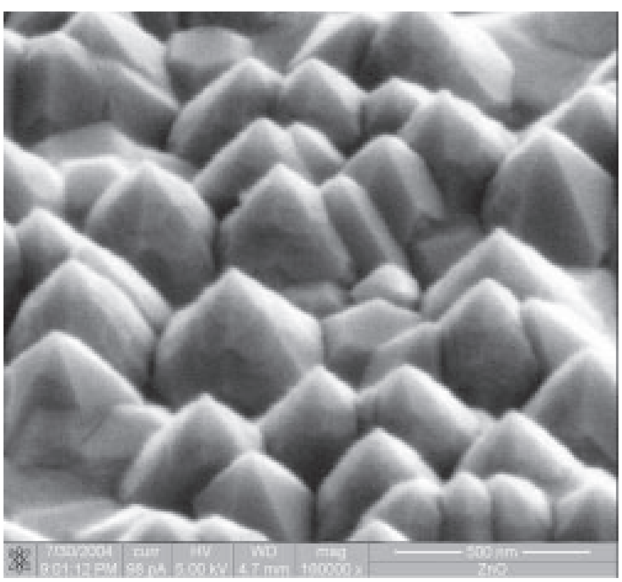

Figure 1: Low temperature and high pressure effects.

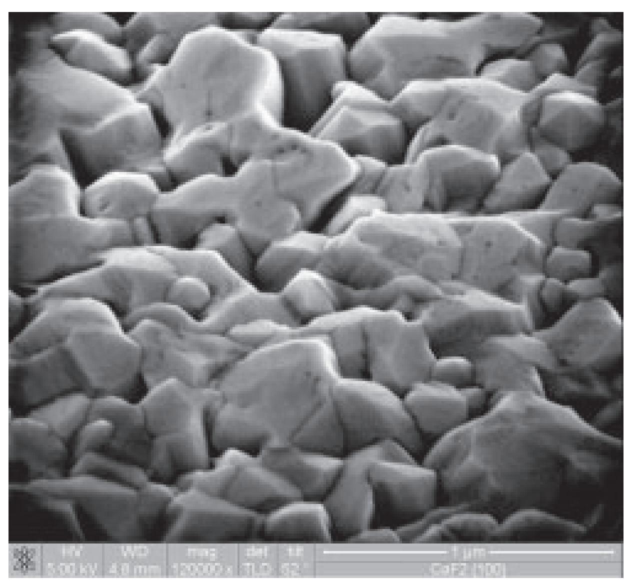

Figure 2: High temperature and high pressure effects.

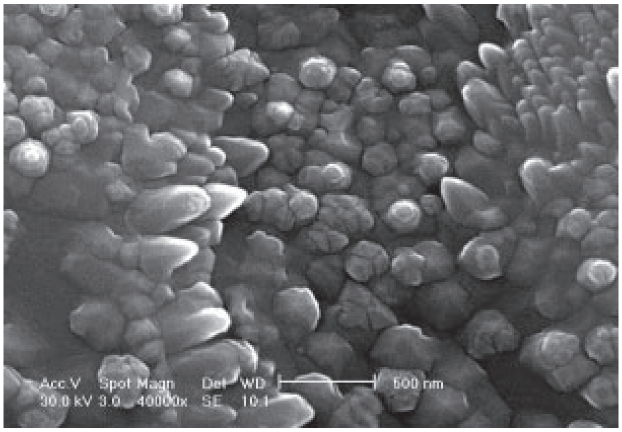

Figure 3: Low pressure and low temperature effects.

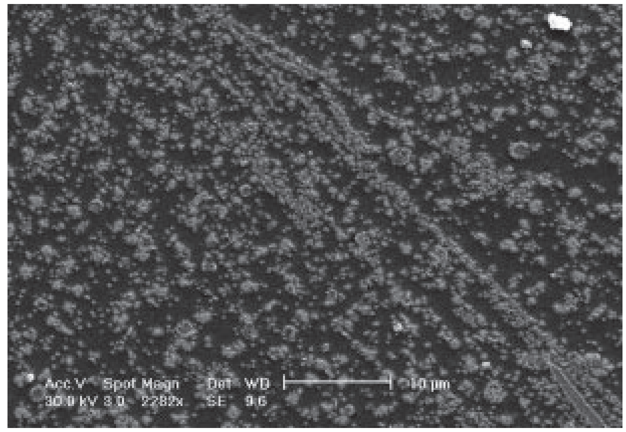

Figure 4: Clustering deposition over annealed thin film.

comprise the building blocks used to create electrical circuits. Attention is focused on developing methods of growth and control, leaving the future to develop applications of the nanowires.

ZnO holds promise for nanowire growth because of the chemistry of its growth method. ZnO grows preferentially along the C axis of a substrate, regardless of the specific composite of that substrate. This property of ZnO facilitates the construction of ZnO nanowires.

Procedure:

ZnO thin films were deposited with a pulsed laser deposition system using a KrF Excimer Laser (λ=248 nm) at a pulsed repetition rate of 6 Hz. [pulse width=20 ns]. ZnO targets were made from zinc oxide powder (purity 99.99%). The target to substrate distance was ~ 5 cm.

Three main experiments were performed involving the deposition of ZnO on sapphire (Al_2O_3), quartz glass, and gold (~ 80 Å) on glass (Au/Glass). The gold had been deposited previously using electron beam evaporation. The depositions were done in ambient oxygen at 500°C for 2 hours at a pressure of 31.0 mTorr, 500°C for 2 hours at 3.1 mTorr, and 600°C for 2 hours at 32.8 mTorr. In each experiment, the samples were held at deposition temperature for a thermal clean of 10 min.

The samples were examined using scanning electron microscopy.

Results and Discussion:

Comparisons at deposition temperatures of 500 and 600°C at 31.8 mTorr show that lower temperature results in consistent surface morphology. Structures are hexagonally faceted with pointed tips and are uniform in growth. At higher temperature, there is rough, non-uniform growth morphology (see Figure 1).

Comparisons at deposition pressures of 32.1 and 3.1 mTorr at 500°C show that low-pressure morphology is hilly and follows the contours of the underlying substrate. High pressure results in a flat underlying morphology on which the hexagonally faceted structures grow (see Figure 2).

Thin gold films (80 Å) were annealed upon which the ZnO was deposited and the results show the adhesion properties of gold did produce clusters of growth. Nucleation sites formed and the resulting structures are hexagonal and oriented in the c-axis (see Figure 3).

The results of the research indicate that low temperature and high pressure allow for better deposition of ZnO, and annealing gold thin films does affect the location of growth. However, it is not believed that nanowires were grown due to the pointed nature of the structures. Further analysis must be done.

Future Work:

A wider range of deposition conditions should be explored, in particular, growth at 400°C at 30.0 mTorr and 3.0 mTorr pressure. All experiments should be repeated as well to extract exact relationships between growth and deposition conditions. Optical reflectance measurements would be taken to characterize the ZnO growth further. The possibilities of glass substrates would be further examined.

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