Chapter 1

Introduction

1.1 Introduction

Zinc oxide (ZnO) is one of the most important II–VI semiconductors with a wide and direct band gap of 3.37 eV and a large exciton binding energy of 60 meV at room temperature [1]. Direct wide band gap of ZnO is suitable for the fabrication of short wavelength devices, operating in the blue and ultra-violet regions of the electromagnetic spectrum, such as light emitting diodes, laser diodes and UV detectors [2]. Also, a large exciton binding energy of ZnO enhances the luminescence efficiency of light emission [3]. The synthesis of ZnO nanostructures has been of growing interest owing to their promising physical and chemical properties and the potential applications in nanoscale devices. Therefore, a variety of ZnO nanostructures have been reported, such as nanowires [1], nanotubes [4], nanorods [5], nanoribbons [6], nanobelts [7], nanocombs[8] and nanobridges [9]. Different synthesis routes such as thermal evaporation [10], pulse laser deposition (PLD) [11], metal organic chemical vapor deposition (MOCVD) [12], sol–gel [13], oxidation of metallic zinc [14], electrochemical deposition [15] and chemical vapor deposition [16] have been employed. It is well known that the novel properties of ZnO nanostructures are dependent on their shape and size [17]. In addition, the effects of the growth parameters on the mechanism growth of ZnO nanostructures are not well-understood. So far, very little attention has been focused on understanding the relationship between the effect of synthesis parameters and the growth mechanism of ZnO nanostructures of such systems prepared by carbothermal methods at atmospheric pressure.

To further understand the growth mechanism and to control the size and the shape of ZnO nanostructure, more detailed investigations are needed.

Moreover, one of the other key issues that has really limited the use of ZnO in some practical device applications, is the difficulty in consistently creating *p*-type ZnO. Therefore, the formation of *p*-type ZnO has been a topic of intense investigation for several years. Many efforts have been made to fabricate *p*-type ZnO by doping with group-V (N, P, As, Sb) elements while, most efforts on *p*-type doping of ZnO have focused on nitrogen-doping, whereas a few reports had concentrated on phosphorus-doping.

In this study, parametric studies on the synthesis of ZnO nanostructures on bare and Au coated Si substrates have been conducted using carbothermal reaction at atmospheric pressure. The growth conditions of the ZnO nanostructures formed were studied as a function of substrate location, furnace temperature, Ar gas flow rate, deposition time and ZnO powder to carbon powder mass ratio. In addition, P-doped ZnO nanostructures have been synthesized by the same method on bare silicon substrate using phosphorus pentoxide (P_2O_5) as the dopant source. The advantages of carbothermal route over other methods are simplicity of the system, low cost and good quality products.

1.2 Objectives of the thesis

In this thesis, there are three main targets. (i) To study the effects of different growth conditions on the growth mechanism of ZnO nanostructures grown on bare and gold-coated silicon substrates using carbothermal reaction at atmospheric pressure. (ii) To compare the growth mechanism of ZnO nanostructures without catalyst and the growth mechanism with catalyst. (iii) To synthesize and characterize p-type P-doped ZnO nanostructures by carbothermal reaction at atmospheric pressure using phosphorus pentoxide (P_2O_5) as a dopant source.

1.3 Organization of the thesis

Following this introductory chapter, a background of ZnO nanostructures will be reviewed in chapter 2, along with ZnO properties, discussions on previous studies on the effects of different growth parameters on ZnO nanostructures growth process, a review on growth mechanisms and modules that attempt to explain the formation of ZnO nanostructures and a brief discussion in theoretical background of the formation of nanocrystal followed by explanations of the different techniques that had been used in ZnO nanostructures characterization. Chapter 3 describes the experimental steps including; samples preparation, growth process and examples of the different measurements that had been used in ZnO nanostructure characterizations. In addition, chapter 4 presents the results and discussions of the effects of different growth parameters on the ZnO nanostructures growth process grown on bare and gold-coated silicon substrates followed by the study of the effect of doping process on the morphology, structural and the optical properties of ZnO nanostructures. Finally, chapter 5 provides the conclusion of all of the investigations.