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Thesis Outline

Title: Galvanostatic Electrodeposition of ZnO Nanosheet as Photoanode in Dye Sensitized Solar Cell (DSSC)

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This thesis consists of 5 chapters. In chapter 1, the introduction of solar cell technology, dye-sensitized solar cell, and zinc oxide semiconductors are discussed. The purpose of this chapter is to give the background and state the objective of the study.

In chapter 2, the results for the galvanostatic electrodeposition of zinc oxide (ZnO) nanosheet are discussed in detail. Three different applied current densities were implemented: 1, 3, and 5 mA/cm^2, and the crystal growth mechanism was examined by observing the time by time growth of each applied current using Scanning Electron Microscopy (SEM), Field-Effect Scanning Electron Microscopy (FE-SEM), X-Ray Diffraction (XRD), and X-ray Photoelectron Spectroscopy (XPS). It was found that the general structure of the galvanostatic electrodeposition samples has a nanosheet morphology, which is grown perpendicularly against the conductive (In-doped Tin Oxide, ITO) substrate. And, after sufficient deposition time, a specific type of under-layer is grown beneath the nanosheet. The electrodeposition using 1 mA/cm^2 produces a dense-like type of under-layer. Meanwhile, the 3 and 5 mA/cm^2 deposition produces a particle-like under-layer, in which the particle size of the 5 mA/cm^2 seems to be smaller than the 3 mA/cm^2 deposition due to more nucleation that can be formed by the higher applied current. The dense-like under-layer produces excellent bonding to the ITO substrate, as opposed to those observed for the particle-like under-layer. The particle-like under-layer resulted in peeling off from the substrate after long enough deposition time (300 s for 5 mA/cm^2 and 1500 s for 3 mA/cm^2 deposition) while not so for the dense-like under-layer (up to 10800 s for 1 mA/cm^2 deposition). The nanosheet height was grown as the majority part of the total structure for most cases, except for those where the deposition time is too long (10800 s for 1 mA/cm^2 deposition). The nanosheet being grown contains zinc-acetate- and zinc-nitrate-complexes ($Zn_5(CH_3COO)_2(OH)_8.2H_2O$ or ZAH, $Zn_x(CH_3COO)_y(OH)_z.nH_2O$ or ZAHH, and

$Zn_5(OH)_8(NO_3)_2.2H_2O$ or ZNH) beside ZnO. Meanwhile, the under-layer part is very likely the product of the cathodic ZnO growth. The growth of the zinc-acetate-and zinc-nitrate-complexes was very likely faster than those of the ZnO one. Therefore, applying a small current (1 mA/cm^2) can well produce the dense-like structure of the under-layer with (002) preferred growth orientation. On the contrary, increasing the deposition current (3 and 5 mA/cm^2) increases the rate of the electrochemical reaction responsible for the ZnO growth which disturbs the preferred (002) growth, increases the pH locally at the substrate's vicinity that may cause nucleation, thus produces a particle-like structure as the under-layer. The annealing at 400 ^{o}C performed after electrodeposition completely transform ZAH, ZAHH, and ZNH into ZnO and producing a porous nanosheet structure as the result.

In chapter 3, the application of the unique structure obtained from the galvanostatic electrodeposition as photo-anode of the dye-sensitized solar cell (DSSC) is presented. The first comparison is made for electrodeposition with the same amount of charge (Q = 1500 mC/cm^2) for the three applied current density (1, 3, and 5 mA/cm^2). The electrodeposition is next performed for a prolonged time to obtain a taller nanosheet structure for the 1 and 3 mA/cm^2 deposition. The effect of the taller nanosheet as well as the specific under-layer on the performance of the DSSC is discussed in detail. The study is completed with the analysis using Electrochemical Impedance Spectroscopy (EIS).

In Chapter 4, the discussion about possible other applications are presented, hence for perovskite solar cell and photo-electrochemical water splitting (photolysis). For perovskite solar cells, the ZnO nanosheet structure can be utilized as a vessel where the perovskite crystal can grow inside. The concept is to be able to grow a single crystal in the vessel so that the grain boundary usually present was replaced by the ZnO nanosheet walls to improve the electron collection. For photolysis, the ZnO nanosheet has been used as the photoanode to split water upon UV light illumination. The abrupt current-response is observed during on-off light illumination indicating a good photo-response. The morphology of the nanosheet seems to influence the photolysis properties since taller nanosheet can produce larger photocurrent, especially at a large applied potential.

In chapter 5, a general conclusion of the study is addressed.