CHAPTER 1

Introduction

1.1 Historical Background

In the world trend of developing green energy, solar cells are the first choice. Among types of the solar cells, dye-sensitized solar cells (DSSC) [1] developed in last twenty years are considered to be the third generation solar cells because of their lower cost and higher efficiency compared with other traditional solid-state-semiconductor solar cells as shown in Figure 1.1. A DSSC basically consists of six components, i.e. transparent conducting glass (TCO), compact film, sensitizing dye-attached porous TiO_2 thin film, electrolyte and a metal coated TCO as a counter electrode as shown in Figure 1.2.

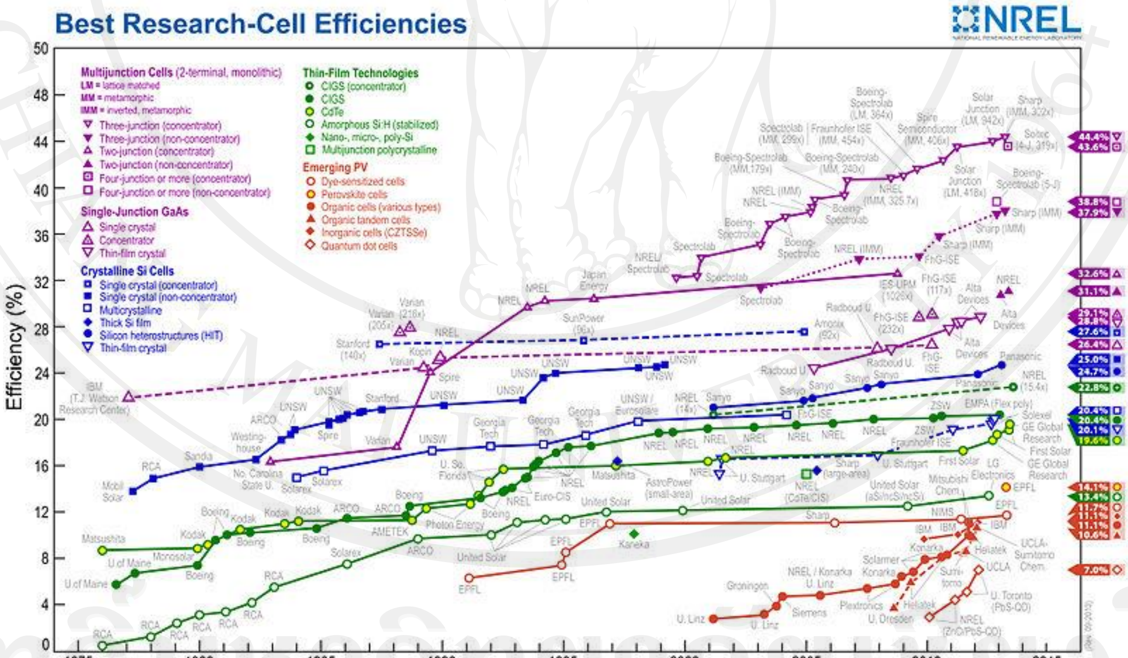
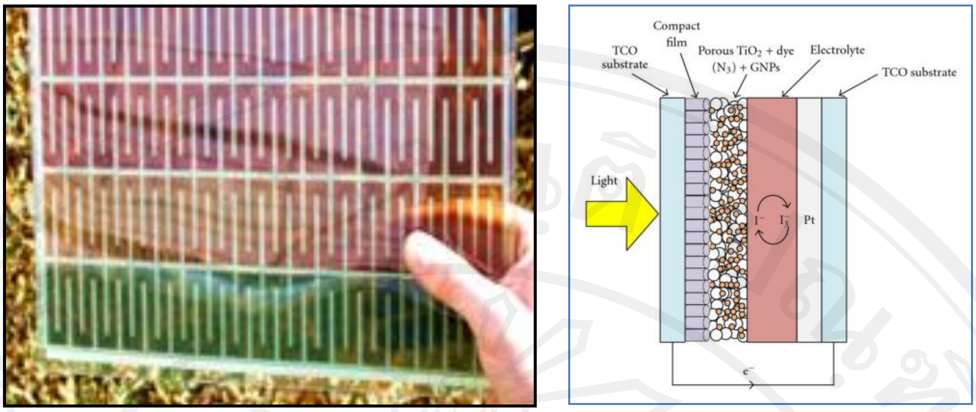


Figure 1.1 Reported timeline of solar cell energy conversion efficiencies (from National Renewable Energy Laboratory (USA))[1].



(a) (b)

Figure 1.2 Dye-sensitized solar cell (a) A commercial Dye-sensitized solar cell [2] (b) the schematic of a DSSC which is consisted of 6 components[3].

The semiconductor material popularly used is titanium dioxide (TiO_2) in anatase [4] which also has several critical factors to increase the performance efficiency of DSSC, include its porosity and the electron transportation property of the TiO_2. Highly nanostructured TiO_2 can highly increase the material porosity so that the material surface area can be greatly increased to let more electrons be injected. Metal or nonmetal-doped TiO_2 can further improve the material electron transportation property. DSSCs are currently very attractive to the market owing to the high ratio between efficiency and cost, good workability under weak sunlight conditions and higher temperatures, and strong mechanical structures.

Filtered cathodic vacuum arc deposition (FCVAD) [5] is a simple and effective technique to make metallic thin films. Owing to many advantages, such as a very high deposition rate, a good control of the deposition parameters, and an excellent quality and good adhesion of the coating, FCVAD has been utilized to TiO_2-film coating for many applications, including optics, photocatalysis, photo energy conversion and biocompatibility. In additions, the in-house developed FCVAD system in Figure 1.3 is taking a major role in this study.

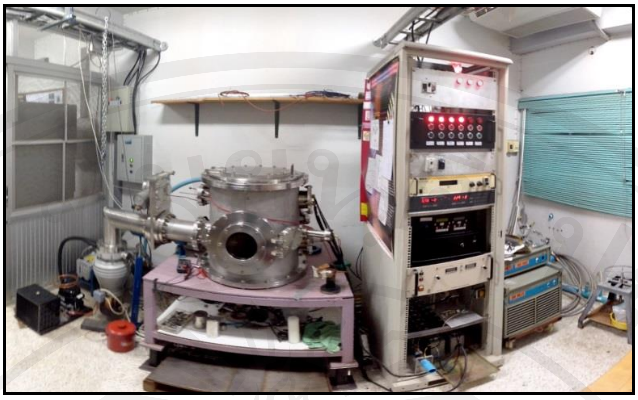


Figure 1.3 The Photograph of the in-house developed FCVAD system at Chiang Mai University.

Titanium oxide has three major crystalline phases: rutile, anatase and brookite, but only the anatase is good for photo energy conversion. Moreover, nanostructure of TiO_2 greatly affects the photo energy conversion. Formations of TiO_2 (anatase) and its nanostructure by using FCVAD depend on the deposition conditions, including oxygen (O_2) partial working pressure, substrate temperature, substrate bias, deposition time, arc current, and pulse parameters (the pulse width and frequency), etc. Therefore, using FCVAD to form TiO_2 (anatase) is still a complex issue because of so many conditions or parameters involved. In physics principle, elevated substrate temperature and bias increase the ion energy so as to increase activation of the phase transformation. O_2-pressure controls the TiO_2 phase stability and it cooperates with the arc current and the pulse parameters to control the amounts of two elements deposited and thus the phase formation. The present research was aimed a systematic investigation on the effect on microstructure of the TiO_2 films from FCVAD.

Not only TiO_2 is interesting, the diamond-like carbon (DLC) layer is also interesting in a plenty of research laboratories these days. The DLC plays an important role as a protection layer against corrosion and wear. According to the almost never ending of size reduction, the few tenth-nm thickness layer formation is challenging. In addition, tetrahedral amorphous carbon is an ideal material which is suitable to use as a protection layer due to its hardness, smoothness and all others properties are independent to film thickness as shown in Figure 1.4. Therefore the film with thickness between 1 nm to 100 nm is possible. In addition, the Filtered Cathodic Vacuum Arc (FCVA) is a capable technique to synthesize DLC thin film.

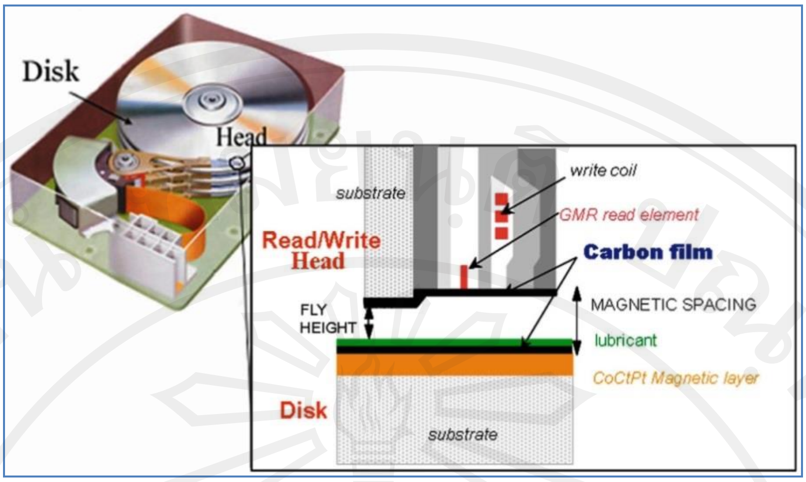


Figure 1.4 Hard disk architecture [6].

Although the DLC is composed of a pure carbon element, The doping of reactive gas is also necessary to increase their toughness and adhesion [7]. Therefore, it is interesting to study the different deposition conditions of DLC.

1.2 Objectives

- To investigate the properties of TiO_2 thin nanofilm which contains the highest amount of anatase structure by FCVAD.
- To investigate the properties of a few nanometers DLC film which contains the highest ratio of sp^3/sp^2 structure by FCVAD.
- To upgrade the in-house FCVAD system in order to measure the plasma's current and to develop the deposition's temperature controller.

1.3 Scope of Study

- Depositing TiO_2 films on Si and glass substrate TiO_2 (anatase) films with nano-pores of a few hundred nanometers thickness
- Studying the effect from varying the FCVAD conditions including the bias voltage, doping partial pressure of O_2, deposition time and annealing temperature on TiO_2 film and arc voltage, bias voltage as well as doping partial pressure of N_2 for DLC film.
- Analyzing the film's structure, composition and properties by various analysis techniques.

1.4 Educational Application Advantages

- Anatase TiO_2 nano-films can be used in the dye-sensitized solar cells (DSSC) to increase the solar cell performance efficiency for green energy and can be used as a photocatalytic material to depollute water for environment protection.
- DLC films can be used as a hard coating for protection of microelectronic components and devices to prolong their use life and eventually reduce the costs and protect the environment.