# CHAPTER I
# INTRODUCTION

## 1.1 Background and Motivation

Recently, low-coherence interferometry (LCI) is one of the most popular optical techniques for determining the microscopic properties of material, such as thickness, roughness, and surface profile. One of the most famous methods, using this LCI technique, is optical coherence tomography (OCT). It is a non-invasive and non-contact method for constructing the surface profile and cross-section image of both living tissue and non-living substance sample.

Duncan et al. [1] applied OCT to study a defection of single-crystal silicon carbine (SiC) and a flaw in Teflon-coated layers on a copper wire. The intensity of backscattered light from non-defection area was stronger than the one from deflection area.

Jonathan [2] also studied a shape profile of silicon V-grooves with OCT. In his research, a depth profile of 1 mm glass slide and a circular-shaped of solid washer were first extracted for testing OCT. Then, parameters, such as depth, width and bottom width of silicon V-groove and double silicon V-grooves profile were determined. These parameters, observed in this research, approached to the ones measured by a stylus contact method and Nikon microscope.

The main part, that let OCT to determine the micro- or even nano- scale parameters such as roughness of material surface and spacing between each layer of multi-layer samples, is a halogen lamp or a superluminescent diode (SLD) This is caused by a few micrometers of coherence length of this kind of light source.

With a SLD and OCT, Onodera et al. [3] determined an envelope of intensity signals by using a modulus of the complex degree of coherence and imaged a surface profile by using a tilted mirror as a test object. The result showed that the mirror had 10 μm tilt and 1.3 μm of root-mean-square roughness.

Pavlíèek [4] also a Michelson interferometer with a halogen lamp to measure a height profile of a plain mirror, a EURO coin and a silicon wafer. The roughness of these samples was displayed in a micrometer scale.

By analyzing an interferogram signal, which is the intensity of backscattered light from a sample [5, 6], it was not only a cross-section of the sample that could be constructed but the other applications, such as the 2-D image of surface, covered with thin light-scattering medium, also be suited with the OCT method. Because OCT is a non-destructive measuring method, the sample can be re-used by other tools.

Chang et al. [7] used OCT with a phase-shift analysis method to retrieve the information of multi-layer material. In their experiment, a sample was a glass wafer, having 100 μm thick. On each layer surface of the glass wafer, the words "OCT" and "NRC" were also written. In this research, images of each word could be constructed. Moreover, another signal analysis algorithm, called the multi-step phase-shift, was introduced to extract the overlapping two word images. With this algorithm, a phase-shift angle computing could be avoided and measuring time was decreased [8].

Quan et al. [9] used white light interferometry for measuring a micro-cantilever and a surface of a sacrifice layer under this micro-cantilever. The result indicated 3-D images of the micro-cantilever and the surface of the sacrifice layer in a few micrometers scale.

According to these previous works, a halogen lamp or a SLD was usually used as low coherence light source. The halogen lamp produces high light intensity but its size is large and more heat occurs. On the other hand, a SLD size is very compact and it is also a low-cost light source. Moreover, the complicated system is no need for a SLD. But the weakest point of a SLD is its low light intensity. In case a SLD is chosen as the low coherence light source, the sample, used in OCT, should have a good reflected material, such as the plain mirror and the silicon wafer [2-3, 7-8]. In the opposite way, for the poor reflected material, the halogen lamp is the first choice to be chosen as the low coherence light source [4, 9]. Although intensity of a SLD can be increased by focusing light beam to the sample surface, this focusing beam method uses a long time of an experimental process. Thus, many researchers often apply a parallel beam of light for measuring the surface profile, instead of the focusing beam, in order to reduce time consuming.

To get more accuracy result, a signal analysis method has to be improved in the same time as an improvement of OCT. There are many methods for analyzing the interferogram signal, collected from OCT. A discrete Fourier transform (DFT), for example, was used to define a maximum point of an envelope of the interferogram signal, filtered by digital filtering. Some researchers applied another method, called a continuous wavelet transform (CWT), for analyzing the interferogram signal.

Tay et al. [10] used white light interferometry for constructing a cross-section of a plain mirror and investigating the thickness of a transparent material, which its refractive index was 1.65. A silicon substrate, coated in a micro-gear pattern with this transparent material, was also used as this research sample. According to their results, root-mean-square roughness of the plain mirror, extracted by the CWT algorithm, was better than the one, analyzed by the DFT algorithm. Also, the thickness of the transparent material in micrometer scale could be extracted in their research.

Li et al. [11] also measured a lamellar grating by comparing the result, analyzed by CWT, DFT and the WYKO NT1100 profiler. In this research, root-mean-square roughness of the grating surface, defined by the profiler, CWT and DFT was 125 nm, 182 nm and 200 nm, respectively.

As CWT provided more accuracy results than the other method [10, 11], it is a suitable method for analyzing the interferogram signal from OCT. With CWT and depth correction, caused by a refractive index, the covered surface with a transparent material and the thickness of this cover material can be calculated.

Unfortunately, research topics about OCT have not widely spread in our country, thus, public papers about OCT are less than other countries that compact systems of OCT for commerce already succeed. That is a reason why OCT has be chosen as a base technique to construct the surface profile in this research. A parallel light beam is also applied in this OCT research instead of a focused beam. With this method, the beam is approximated as a set of a small light source. Thus, the intensity, detected in each pixel of the CCD camera, is represented as the intensity of the small light source, reflected from each point of the sample surface. An advantage of this parallel beam method is to reduce time-consuming process. Because the OCT technique can extract a micro-scale layer of a transparent material, covering on the sample without destroying the covered material, this technique is suitable to examine the root-mean-square roughness and the inner surface, covered by the transparent material. Both the DFT and the CWT are also used as a signal analyzing method for comparing an accuracy of them. Then, the surface profiles of the sample with and without the transparent cover will be constructed by a better method. This technique is also applied to define the thickness of transparent material, in case the interferogram, occurred on the top surface of this transparent material, is hardly detected because of its nearly non-reflected surface.

## 1.2 Research Objectives

The main objective of this research is to study the possibility of using CWT as the signal analysis of the interferogram, recorded from OCT, for constructing the surface profile of material. To confirm this objective, the result, calculated by the DFT, will be compared with the one calculated by the CWT. Next, the comparison between surfaces of material with and without transparent material will be occurred. It is to confirm that OCT can be applied for measuring properties of the surface, covered with the transparent material. The root-mean-square roughness of these two types of material surface will be also calculated. Finally, OCT will be applied to define the thickness of the covered surface, which reflected signal from its top surface, is hardly detected. To define the thickness of the covered material, a difference of z-position between the surface with cover slide and the one without cover slide will be corrected the error, caused by the refractive index of the covered material. This technique will be a helpful technique to measure the thickness of the transparent material that the interferogram, occurring during its top surface, is rarely to detect.

## 1.3 Research Overview

After the introduction and the review represented in first chapter, a Michelson interferometer, and the characteristic of low coherence light source will be discussed in Chapter II. Also, the continuous wavelet transform (CWT) will be introduced in the last section of this Chapter II.

In Chapter III, the experimental setup, such as the sample preparation, the set up method for this research, the multi-layer reflection and the experimental analysis process, will be described.

In Chapter IV, the results of the experiment are reported. Finally, the conclusions about this research will be discussed.