MICROCHANNEL INTERROGATION WITH TWYMAN-GREEN INTERFEROMETER

by

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A thesis submitted
in fulfillment of the requirements for the degree of
Master of Science (Microelectronic Engineering)

School of Microelectronic Engineering
UNIVERSITI MALAYSIA PERLIS

2011

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ACKNOWLEDGEMENTS

The past three years have been very strenuous and difficult times. The three years has been a steep learning curve that I will always cherish. I will always remember these years as it has tested my will and patience in order to succeed. I owe all this research to so many people that even one page will not be enough to fill out their names.

I am deeply grateful to my supervisor, Assoc Prof Zaliman Sauli. Prof Z as he is fondly known has always been a father figure who I could count on. Although there were some shaky moments where disagreements occurred throughout this research, I always knew that it was only for my benefit to become a more enthusiastic researcher. He has such a serious passion for research that cannot be matched by anyone that I know of. Another senior lecturer that I would like to thank is Mr. Charan who has been so supportive for me and gave me the opportunity to strive towards my goal. Without you Mr. Charan, I wouldn't have completed this work.

The research mates in the lab were all very supportive and helpful. Steven, Hafiz, Ruhaizi, Hafizah, and Alaeddin has always been there when I needed them whether it be work related problems or personal problems. A thousand thanks to you guys will never be enough.

I am also grateful to the late Mr Phang and his team, Hafiz, Bahari, Zul and Hafizz who have always kept the cleanroom and fa lab in superb condition.

Finally, thanks mom and dad, I will always be grateful for having such wonderful parents who understood and waited patiently for me to complete this task. They were always behind my back no matter what the situation was.

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LIST OF ABBREVIATIONS

AFM = Atomic Force Microscopy
Al = Aluminium
ICP-RIE = Inductive Coupled Plasma-Reactive Ion Etching
IPA = Isopropyl alcohol
OPD = Optical Path Difference
OPL = Optical Path Length
PR = Photoresist
PVD = Physical Vapour Deposition
SEM = Scanning Electron Microscope
SiO_2 = Silica
TGI = Twyman-Green Interferometer
DI = Deionized Water
UV = Ultraviolet

LIST OF SYMBOLS

Quantity	**Symbol**	**Unit**
Angle	°	Degree (°)
Optical Path Difference	ΔL	Micrometer (μm)
Path Length BS/Mirror	L_1	Micrometer (μm)
Path Length Mirror/Thickness	L_2	Micrometer (μm)
Measured Thickness	L_3	Micrometer (μm)
Path Length Mirror/Prism	L_4	Micrometer (μm)
Path Length Prism/Mirror	L_5	Micrometer (μm)
Path Length Mirror/BS	L_6	Micrometer (μm)
Path Length BS/Reference	L_7	Micrometer (μm)
Reference Thickness	L_8	Micrometer (μm)
Path Length Reference/Prism	L_9	Micrometer (μm)
Path Length Prism/BS	L_{10}	Micrometer (μm)
Intensity	I	milivolts (mV)
Fringe Visibility	V	-
Refractive Index of BS	n_{BS}	-
Refractive Index of Ref 0	n_{ref0}	-
Refractive Index of Ref 1	n_{ref1}	-
Refractive Index of Ref 2	n_{ref2}	-
Refractive Index of Ref 3	n_{ref3}	-

INTEROGASI SALURAN BENDALIR MIKRO MENGGUNAKAN TWYMAN-GREEN INTERFEROMETER

ABSTRAK

Sebuah Twyman-Green Interferometer telah disiapkan dan berperanan untuk mengukur kedalaman saluran bendalir kaca lutsinar. Tujuan utama penyelidikan ini ialah untuk menghasilkan sebuah instrumen tanpa sentuhan yang berkebolehan untuk mengukur sampel-sampel diperbuat dari kaca silica lutsinar. Oleh itu, fabrikasi saluran bendalir kaca lutsinar mikro dilakukan ke atas substrat kaca silica menggunakan proses endapan aluminum, fotolitografi dan punaran plasma. Kedalaman saluran bendalir kaca ini diukur menggunakan Twyman-Green Interferometer. Interferometer optik ini bergantung kepada perubahan laluan optiknya yang disebabkan oleh rotasi sampel rujukan lutsinar dalam salah satu laluanya. Kekuatan pinggir gangguan yang dihasilkan oleh interferometer dikesan dan diukur dengan fotodiod. Hasil pengukuran kekuatan itu diplot dalam graf kekuatan lawan perubahan laluan optik. Pengukuran kedalaman dilakukan dengan penyarian laluan perubahan optik yang diperolehi daripada graf. Tiga sampel rujukan yang yang mempunyai kedalaman 0.681 μm (Ref 1), 1.396 μm (Ref 2) dan 2.102 μm (Ref 3) digunakan sebagai sampel rujukan untuk pengukuran kedalaman saluran bendalir kaca. Apabila menggunakan Ref 1, Ref 2 dan Ref 3 sebagai rujukan dalam pengukuran, peratusan persamaan pengukuran dengan pengukuran profilometer permukaan adalah sebanyak 94.45 %, 84.76 % dan 66.97 %. Walaupun terdapat sedikit kelainan dengan keputusan kedalaman yang diperolehi dari kaedah lain, keputusan pengukuran kedalaman dengan menggunakan Twyman-Green Interferometer masih tepat dan sesuai digunakan untuk pengukuran saluran bendalir kaca dan sampel-sampel kaca lutsinar yang nipis. Resolusi alat pengukuran TGI ini adalah 0.27 μm dan julat pengukuran yang sesuai untuk pengukuran adalah sebanyak 0.27 μm hingga 5 μm. Dan mempunyai jalur kebolehlihatan lebih daripada 0.5.

MICROCHANNEL INTERROGATION WITH TWYMAN-GREEN INTERFEROMETER

ABSTRACT

The Twyman-Green Interferometer (TGI) setup for measuring microfluidic channel depth has been developed. The main objective of this study is to develop a non-contact measuring instrument capable of performing depth measurements of a microfluidic channel made of silica wafer. The microfluidic channel is fabricated using the photolithography process and reactive ion etching. Microfluidic channel depth has been measured with the Twyman-Green Interferometer setup. The interferometer setup relies on the optical path length change caused by the rotating transparent silica reference sample in one of its arms. Intensity of fringes produced by the interferometer is detected and recorded with a corresponding photodiode. The intensity results are plotted against the optical path variation of the reference sample which causes an optical path difference in the reference arm. Depth measurement of the microfluidic channel has been extracted from the optical path difference obtained from the interferometer setup. Transparent silica reference samples with etched thickness of 0.681 μm (Ref 1), 1.396 μm (Ref 2) and 2.102 μm (Ref 3) has been used to investigate and determine which is the most accurate reference sample to be used in determining depth of microfluidic channel. Depth of microfluidic channel obtained from Twyman-Green Interferometer has been compared to depth results obtained from atomic force microscopy and surface profilometer. Applying Ref 1, Ref 2 and Ref 3 as rotating reference samples yielded 94.45 %, 84.76 % and 66.97 % compliance with measured depth obtained from surface profilometer. Although there are slight variations with results obtained from surface profilometer and atomic force microscopy, the experimental results proves that the Twyman-Green Interferometer is able to determine microfluidic channel depth and etched depth of thin Si samples. Resolution of the TGI setup is 0.27 μm and is suitable to measure depth profiles ranging from 0.27 μm to 5 μm. Therefore, the modified TGI setup in this research is suitable for measurements of depths or thickness profiles ranging from 0.27 μm to 5 μm with a fringe visibility of more than 0.5.

CHAPTER 1

INTERFEROMETER BACKGROUND

1.1 Introduction

There has been an emerging interest in the field of microfluidics in the past decade. Material selection and corresponding fabrication procedures are two important challenges in developing microfluidic devices (Yao & Chen, 2007). The research first began with a gas chromatograph at Stanford University and IBM began developing ink jet printer nozzles. Microfluidics has slowly begun to develop as a hot research topic (Gravesen, Jens Branebjerg & Jensen, 1993). Due to the small structure of a microfluidic device, a method of measuring its profiles with high accuracy during its microfabrication process needs to be done. This chapter will discuss the need of a non-contact measurement instrument such as the Twyman-Green Interferometer to measure depth profiles of a microfluidic device.

1.2 Microfluidic Devices

Microfluidic devices are devices where micron sized fluid channels are fabricated on a suitable substrate for specific applications that utilizes it. The microfluidic channels are mostly made of silicon, glass or silica quartz and fabricated by photolithography, etching and microwetting which enable's its miniaturization (Verpoorte & Rooij, 2003). Microfabrication technology has enabled micofluidic devices to be miniaturized therefore reducing the required amounts of fluids and enabling the device to be portable. Forensic science has benefited tremendously from microfluidics because of the ability of the device to identify a certain investigation with minimal traces of blood. The health industry has also benefited due to the reduction in size of the device and can be used as a portable health indicator from a single drop of blood. Microfluidic is an important and advancing research. Microchannels form the basis of the microfluidic chips in the applications mentioned before. Therefore it is important to apply an accurate measurement technique in determining certain dimensions of the microfluidic channels towards enhancing the performance of the microfluidic devices in its applications. This research utilizes a Twyman-Green Interferometer (TGI) to determine the depth of the microfluidic channel that has been fabricated

1.3 Laser Interferometer Principle

Interferometry has long been used as a powerful measuring tool. Since the emergence of lasers in the 1960’s, the full capability of this technique has been realized. Lasers provide an intense source of light with a high degree of spatial and temporal coherence. The limitations of interferometry due to thermal sources have been removed with the introduction of lasers. Interferometry basically uses the interference of two beams of light to make an extremely accurate measurement (Hariharan, 1990). The most important principle of an interferometer is that two waves with the same frequency from a coherent light source will combine and undergo a phase difference (interference). Waves with the same phase will undergo a constructive interference and waves with different phase which is 180° will undergo destructive interference. The light path through a basic interferometer is shown in Figure 1.1. A single coherent light source is split into two equal beams at the partial mirror or beam splitter. The two beams travel in two routes called an optical path length. The beams are recombined and detected by a photodetector. Optical path difference occurs thus creating the phase difference. The difference in the two beams is caused by the length difference travelled by the two beams or refractive index change in one of the path routes. This optical path difference is the main measurement where analysis is extracted from in this research. Polarized source will also enhance the quality of interference patterns.

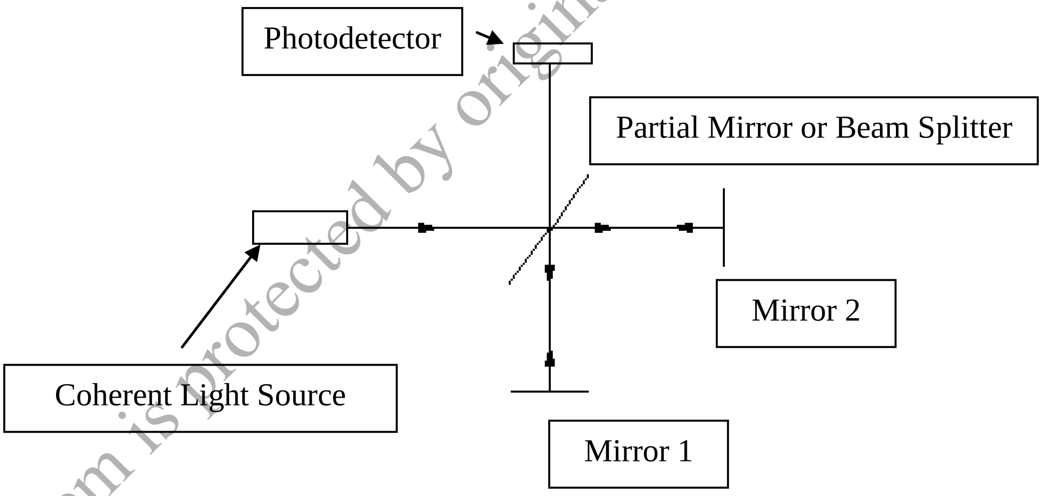

Figure 1.1: Light path through an interferometer (Michelson Interferometer).

Interferometry has been a key principle in measurement science. There are many areas of applications that this powerful measuring system is applied to. There are also many different set ups of interferometers that are constructed for different types of applications. Some examples of interferometers are Michelson, Newton, Twyman-Green, Mach-Zender, Fizeau and many other interferometers (Vannoni, Trivi & Molesini, 2006). This research analyzes depth of a microchannel made of silica quartz and Tywman-Green Interferometer is found most suitable for this application.

1.4 Twyman-Green Interferometer

The Tyman-Green Interferometer is a modification of the Michelson Interferometer. The main difference between the two types of interferometer is that the Twyman-Green Interferometer uses a point source at the focal plane of the objective. The Michelson Interferometer uses an extended light source for its operation. Prisms or corner cubes are used in place of mirrors as the reflector in the TGI setup. The glass prisms with dihedral angles of 90° returns an impinging beam parallel to the incidence, irrespective of the incidence angle or the tilt of the glass prisms. The lateral displacement of the returning beam is beneficial because the returning beam does not fall into the laser mirrors. Back injection into the laser disturbs the oscillation and may spoil the coherence length. The TGI setup eliminates back injection and alignment criticality (Donati, 2008). Figure 1.2 displays the setup of the TGI setup. The TGI also has very high resolution, 2.5 µm however any size below than that may be difficult to be perceived with the TGI setup.

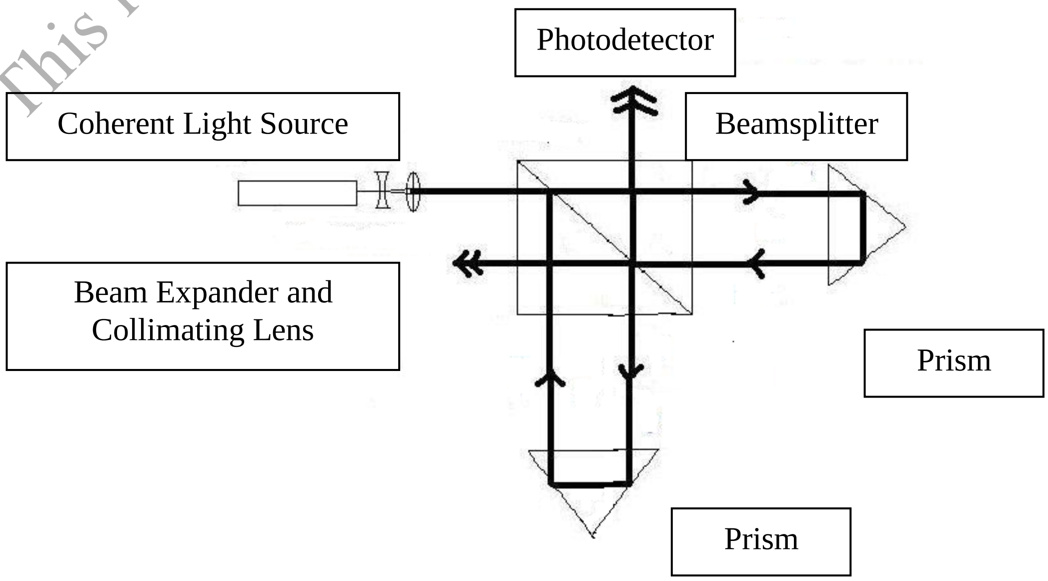

Figure 1.2: Setup Up of a Basic Twyman-Green Interferometer.

1.5 Problem Statement

Microfluidic technology has already been developed and researched over the years. The need for a non-contact measuring instrument that is accurate for its fabrication process is in high demand. Optical profilers, surface profilers and atomic force microscopy have been used in the past to determine the thickness profiles of micron level samples. The Twyman-Green Interferometer has long existed and developed over the years to accommodate the specific needs for various field of applications or in this research the microfluidic application. Interferometers are known for its accuracy in measuring small transparent thickness samples and in measuring refractive index of optical materials or liquid. Instead of measuring thin transparent samples, the TGI setup in this research has been specifically designed and modified to measure transparent microfluidic channel depth that is fabricated with the basic microfabrication process and to the best of the author’s knowledge it is actually the first to use this specific modified TGI setup for microchannel depth measurements.

1.6 Objectives of this Study

In this research, the Twyman-Green Interferometer is expected to interrogate the microfluidic channel in terms of its depth therefore objectives of this research are:

1. Develop a TGI setup capable of performing depth measurements on the transparent microfluidic channel. The TGI setup is designed and modified to specifically measure depth of transparent silica samples.

2. In order to investigate the measuring capability of the TGI, fabrication of a transparent microfluidic channel has to be executed. The microfluidic channel is fabricated using basic semiconductor fabrication process. Silica wafer is used as the substrate of the microfluidic channel. Transparency of the wafer allows the sample to be illuminated with the beam from the Twyman-Green Interferometer.
3. Comparing different methods of depth measurement with experimental results obtained from TGI setup. The depth of the microfluidic channel from the TGI is compared to depth obtained from the atomic force microscopy (AFM) and surface profilometer to verify its accuracy and compliance.

1.7 Dissertation Organization

This dissertation comprises of five chapters. The first chapter describes the basic overview of the research, basic Twyman-Green Interferometer concept and the objectives of this work. Chapter two discusses previous work done by researchers who had used the interferometer as a measuring instrument on their various applications. The basic fundamentals related to the TGI, method of fabricating the microfludic channel and the TGI setup is discussed in chapter three. The results based on the experimental methods of fabrication and TGI setup is explained in detail in chapter four. Conclusion of the research and suggestion for future recommendations is given in chapter five.