UNIVERSITI TEKNOLOGI MARA

DEVELOPING THE OPTICAL DICING MACHINE WITH PARAMETRIC STUDY OF MICRO-PATTERNING WAVEGUIDE

SITI MUSALMAH BINTI MD IBRAHIM

PhD

October 2024

ABSTRACT

Dicing is the precise process of cutting semiconductor wafers into small pieces with high accuracy. The micro-patterning waveguide (MPW), a multilayer optical thin film fabricated using sol-gel procedures for photonic integrated circuits, presents significant challenges in dicing due to its inherent brittleness. To address this, a local dicing machine was introduced to facilitate the dicing of MPWs while maintaining the necessary high-quality surface finish. This study focuses on three objectives: (1) designing, assembling, and calibrating an in-house optical dicing machine, (2) analysing the progression of blade wear and its impact on substrate quality, and (3) determining the effects of cutting parameters (spindle speed, feed rate, and coolant) on the micro-patterning waveguide through experimental study and ANOVA analysis. The primary phase of this study is to design and develop an optical dicing machine capable of cutting MPWs into small pieces with high accuracy and efficiency. Following a detailed design and development phase, the machine was calibrated according to ISO 230-2 standards. This study describes the development process of the optical dicing machine, and the experimental work carried out. The machine incorporates a novel design featuring a 5-axis CNC controller, enabling precise control over critical cutting parameters, including spindle speed, feed rate, and coolant application. The impact of cutting blade wear on the substrate was investigated, highlighting its contribution to surface quality degradation. Additionally, a comprehensive experimental study, analysed using ANOVA, investigated the impact of cutting parameters on MPW surface roughness. Results revealed spindle speed as the most significant factor (32% PCR), followed by coolant usage (29% PCR) and feed rate (23%) PCR). The optimal combination for minimising surface roughness was identified as a spindle speed of 3000 rpm, a feed rate of 20 mm/s, and the use of coolant. This study demonstrates a successful approach to achieving high-quality dicing of MPWs, paving the way for improved fabrication of photonic devices.

ACKNOWLEDGEMENTS

بسم الله الرحمن الرحيم

By the name of Allah, The Almighty, and The Merciful and Blessing. Be upon His Messenger, Prophet Muhammad SAW and his companies. I am very grateful to Allah for his divine inspiration, guidance, and his blessing to me in completing this study.

I would like to express my deepest gratitude to my colleagues for their invaluable support and contributions throughout my study journey. First and foremost, I extend my sincere thanks to my supervisors, Assoc. Prof. Ts. Dr. Juri Saedon and Assoc. Prof. Ir. Dr. Amir Radzi Abd Ghani. Their exceptional guidance, unwavering commitment, and insightful feedback have played an instrumental role in shaping the outcome of this study. Their expertise and encouragement have been invaluable to me, and I am truly grateful for their mentorship.

I would also like to express my appreciation to Dr. Zahid for his valuable advice and unwavering support. The wisdom and guidance I received from Dr. Zahid have significantly enhanced the quality of my work. His willingness to share knowledge and offer assistance has been instrumental in overcoming various challenges.

Additionally, I extend my gratitude to all my colleagues at SIRIM Rasa and the researchers at the AMREC lab. Their collaborative spirit, expertise, and willingness to share ideas have created a stimulating environment for research. The insightful discussions and constructive feedback from my fellow colleagues have been truly enriching and contributed to this study's overall success.

To all those mentioned or not mentioned, I want to express my heartfelt thanks again for their guidance, support, and valuable contributions. Without their involvement, this study would not have been possible. I am truly grateful for the opportunity to work alongside such dedicated and talented individuals, and I look forward to continuing our collaboration.

CONTENT

CHAPTER ONE
INTRODUCTION

1.1 Background of The Project

Precision dicing is a process of cutting semiconductor wafers into small dice with a high degree of accuracy and precision. The optical dicing machine is the main equipment used in this process. The accuracy and precision of the dicing machine determine the quality of the diced semiconductor wafers. The first dicing machines were developed in the early 1980s. These machines were simple and had low accuracy and precision. In the 1990s, the development of dicing machines progressed rapidly. Today, there are several types of dicing machines available in the market. The main factors that influence the accuracy and precision of a dicing machine are the size and shape of the wafers being diced, the type of cutting edge used, and the manufacturing process used to produce the dicing machine. In order to improve accuracy and precision, some companies have designed specialised dicing machines for various applications, such as integrated circuits (ICs), MEMS devices, and flat panel displays. The dicing process is a process which removes material through an action that occurs between the material and tool or particle [1][2]. According to M. Chauvet et al. [3], the dicing process is the most efficient method to guarantee a high-quality surface and structure when dicing high hardness and brittleness of materials like silicon, silicon carbide, aluminium oxide and other ceramics. Thus, it has the potential to produce waveguides with low roughness and less chipping. Carpenter et al. [4] stated that when dicing parameters are set appropriately, polishing is no longer required. Mechanically intensive lapping and polishing are old techniques that are well-established in a variety of materials to produce verticality, good roughness, and free surface chipping. This technique, however, are time-consuming and laborious because of sample stacking and/or jigging, plate preparation and changes in abrasive size. Therefore, when the dicing parameters such as blade speed, depth of cut, feed rate and coolant are set appropriately, chipping and roughness can be controlled [5].

The micro-patterning waveguide (MPW) is a multi-layer optical thin film which is fabricated using photonics sol-gel procedures. The MPV is fabricated for photonic integrated circuits. Due to the nature of the material and processes, the MPW is brittle;