MICRO HOLE DRLLING BY INDUSTRIAL CO_2 LASER

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This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons). The member of the supervisory is as follow:

……………………………..

(Project Supervisor)

ABSTRAK

Pemesinan Laser adalah salah satu kemajuan pemesinan yang paling popular di dunia ini. Pada masa kini, pemesinan micro laser digunakan dalam pengeluaran MEMS untuk mengambil alih kaedah tradisional seperti proses punaran yang memerlukan tempoh masa untuk menyelesaikan proses tersebut. Objektif kajian ini adalah untuk menyiasat keupayaan penggerudian laser industri, laser CO_2, dalam pemprodedan silikon wafer. Dalam karya ini, lubang-lubang digerudi pada wafer silikon jenis-P dengan ketebalan 525 µm dan 100 mm diameter. Lubang-lubang diperhatikan dengan menggunakan mikroskop optik. Ciri geometri lubang yang terhasil iaitu diameter pintu masuk lubang yang bergantung kepada parameter laser telah disiasat dan dianalisis. (RSM) telah digunakan untuk menganalisis keputusan dan model yang sesuai telah dihasilkan untuk laser penggerudian pemprosesan. Parameter laser yang terlibat ialah kekuasaan laser, frekuansi laser dan kitar tugas. Keputusan eksperimen menunjukkan diameter pintu masuk lubang penggerudian telah meningkat apabila kuasa laser dan kitar tugas meningkat tetapi diameter pintu masuk akan berkurangan apabila frekuensi laser turut berkurangan.

ABSTRACT

Laser machining is one of the most popular advance machining in this world. Nowadays, laser micromachining is currently used in the MEMS production to take over the traditional method such as etching process that needs a period of time to finish the process. The objective of this study is to investigate the drilling capability of industrial laser, CO_2 laser, in silicon wafer processing. In this work, the holes were drilled on P-type silicon wafer with thickness 525 µm and 100 mm diameter. The holes were observed by using an optical microscope. Geometrical characteristic of holes produce, which is diameter entrance that depends on laser parameter were investigated and analyzed. Response Surface Methodology (RSM) was used to analyze the result and generated an appropriate model for the laser drilling processing. The laser parameters involve were laser power, pulse frequency and duty cycle. The experiment result showed the entrance diameter of drilling holes increased when the laser power and duty cycle increased, but the entrance diameter decreased as the pulse frequency decreased.

DEDICATION

To my beloved father and mother

Mr. Mohd Kasim Bin Ahmad
Mdm. Mismawati Binti Kadis

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mm	-	Millimetre
nm	-	nanometer
In	-	Inch
W	-	Watt
KW	-	Kilowatt
^{o}C	-	Celcius
μ	-	Micron, 1×10^{-6}
Hz	-	Hertz
%	-	Percent
N	-	Nitrogen
O_2	-	Oxygen
CO_2	-	Carbon Dioxide
He	-	Helium

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter explains about several sections which include the background of study, problem statements, research objectives, research scope and completed by limitations of research.

1.2 Background of Study

In the world today, the manufacturing industries need advanced machining techniques to follow the rigorous design requirement and to machine the hard-to-machine material such as titanium, steel, super alloy materials, composite and ceramics. Laser machining is one of the most popular advances machining in this world. Lasers are broadly applied in industry as cutting tools due to ultra-flexibility of the cutting conditions, quick set up, obtaining a high quality end product, the small size of the heat affected zone, and non-mechanical contact between the workpiece and the tool (Yilbas, 2004).

There are a lot of laser resource types that commonly used in manufacturing industries and the current types of laser used are CO_2 and Nd: YAG laser. Nearly 90 percent of all industrial laser material processing used both types of lasers. Basically, both types of laser have different capabilities cut or drill a piece of materials by depending on the thickness and properties of that material. Today, laser micro-drilling is increasingly being used in the fabrication of small components for electronics, aerospace, biomedical, MEMS, and other applications because it provides rapid, precise, clean, flexible, and efficient process (Han et al, 2004).

Micro-electromechanical system (MEMS) is a technology used to create small integrated devices or systems that merges mechanical and electrical components. This technology has abilities to sense, control and actuate on the micro scale, and generate effects on the macro scale. There are four types of MEMS component which is micro sensors, micro actuators, microelectronics and microstructure. The primary material used in MEMS is Silicon (Jiang et al, 2009). MEMS application includes the process control and automation, automotive industry, scientific and medical instrumentation, and telecommunication.

1.3 Problem Statement

In recent year, majority of MEMS manufacturing companies likes to use Nd: YAG laser for drilling micro hole on the silicon wafer. By applying Nd: YAG lasers which produce short pulses and the UV wavelength, this permit a reduction of thermal effects like heat affected zones (HAZ) and deposition of molten material at the cutting edge (Klozbach.U et al, 2011).

The wavelength of a CO_2 laser is 10.64 µm and not absorbed by silicon material (Chung et al, 2006). Silicon is not an active optical material. This material is only effective in detecting light and the emission of light is difficult to achieve. So, this is difficult to apply the drilling technique by using CO_2 laser because this laser provides a long pulse and wavelength that cannot absorb by silicon material.

CO_2 laser is typically used to drill holes larger than 100 µm in diameter and cannot drill holes smaller than 75 µm (Luziusa et al, 2013). Furthermore, there is still less research done regarding the laser drilling process on a silicon wafer by using CO_2 laser. Although there are several related journals and report done regarding the usage of CO_2 lasers for drilling hole on the other materials such as fiberglass and stainless steel. The parameter on those researches cannot be used directly because different material will have different properties that allowed the laser move throughout the material.

This project is about the experimental studies of the micro laser drilling of silicon wafers by using CO_2 laser. Laser parameters such as laser power, pulse frequency, and duty cycle will be set up to drill holes on 525 µm thickness of silicon wafers. Entrance diameter of drilling holes will be analyzed. This project results will provide a common advice in generating micro holes on the MEMS structure on silicon wafers using CO_2 laser.

1.4 Objectives of the Research

The objectives of this research are to:

i. Investigate the drilling capability of CO_2 laser in silicon wafer processing.
ii. Model the laser processing of silicon wafer.
iii. Optimize the develop model.

1.5 Scope of the Study

This research will be conducted by using Helius 2513 Laser Cutting Machine with rated power of 3000 watts. P-types silicon wafer with 525 µm thickness and 100 mm diameter will be used for the laser drilling process. Then, the entrance diameter of drilling holes will be analyzed. Design Expert software will be used as a tool to design the experiment and analyze the result.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the research review is focused on several main sections such as the Micro Electro Mechanical System (MEMS), types of machine and material, and the methods used to design an experiment. This information is useful so that appropriate parameters of laser machining can be chosen based on previous research, in order to drill silicon wafer.

2.2 Micro Electro Mechanical System (MEMS)

Micro-electromechanical system or known as MEMS is one of the process technology applied to produce smaller devices or systems that bring together the electrical and mechanical components. In the United States, the technology is known as micro-electromechanical system (MEMS) but in Europe, it is known as microsystem technology (MST) (Nadim Maluf, 2004). According to Hsu (2002), MEMS also can be defined as a small and integrated device, which combine electronics, electrical and mechanical elements to meet the control related functional requirement (see Figure 2.0).

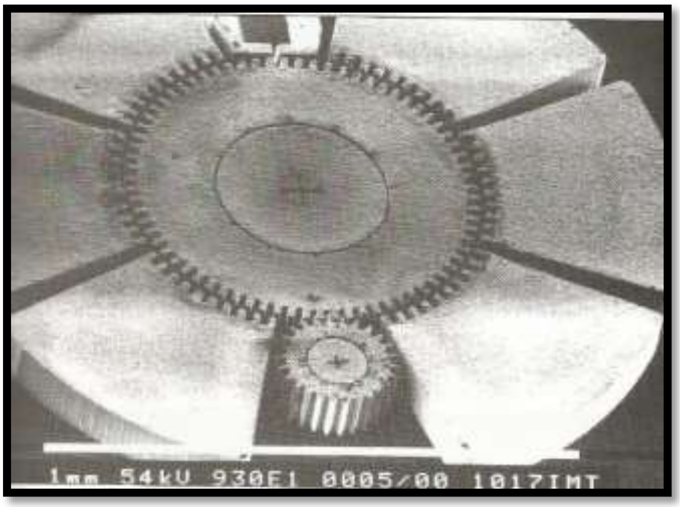

Figure 2.0: Micromotor as one of the MEMS product (Hsu 2002).

This technology basically made up using integrated circuit (IC) and can be in several of sizes from a few micrometres to millimeters. MEMS contains components of sizes in ranges of 1 micrometer to 1 milimeter (Nadim Maluf, 2004). MEMS are a developing technology which applies integrated circuit (IC) fabrication methods to create integrated microsensor, microactuators, and microelectronics to make micron size devices which can sense and act on the local environment (Simon, 2010). There were several types of MEMS components which consisting of mechanical microstructures, microsensors, microactuators and microelectronics. All of this form was integrated onto the same silicon chip.

2.2.1 Application of MEMS

Nowadays, MEMS is an unknown and famous technology used in the world. Smartphone industries are not neglecting to apply MEMS in producing new models of Smartphone. Smart phones were generally provided with tri-axis magnetometer and tri-axis MEMS accelerometer such as the start adding tri-axis MEMS gyroscope, which is iPhone 4 from Apple Inc (Niu et al, 2012).

MEMS technology also has been used in the automotive sectors in term of sensors. There were above 100 sensors used involving gyroscopes for higher fuel efficiency, MEMS Tire Pressure Monitoring System (TPMS) and other purposes (Chun et al, 2012). For the Electronic Stability Program (ESP) or vehicle dynamic system (VDC), this system was the most effective active safety systems in the automotive domain, supporting the driver to retain the vehicle on the intended path, thus helping to avoid accidents (Marek, 2011). The MEMS technology also can help in the vehicle fuel consumption. The vehicle based pressure sensors such as manifold pressure sensor are used to determine the air intake of the engine. With the help of a barometric pressure sensor, combustion algorithms can be adjusted in correlation with the ambient air pressure (Finkbeiner, 2007).

For the medical sectors, accelerometers and pressure sensors remain the largest two market segments for MEMS products and technology. These components can be applied to determine the human blood pressure accurately only in several second time. For the efficiency of computer using in medical application, MEMS accelerometers and fiber optic sensors have produced as an interface between a user and a computer. The movement of user's body can be measured directly by wearing these types of sensors. In the biomedical application, optical MEMS also have been applying in multifunctional endoscope that used for advanced diagnosis and endoscopic surgery (Miyajima, 2002).

2.2.2 Fabrication of MEMS

Laser micromachining of dielectrics and metals is a multipurpose fabrication and repair tool for applications in MEMS, microelectronics, and micro-fluidics, (Fedosejevs et al, 2003). There are three types of micromachining techniques used by current industry in MEMS production, which is bulk micromachining, surface micromachining and LIGA process (Hsu, 2002).

Bulk micromachining is a process of removal of material from the bulk substrates to form the desired three dimensional geometry of the microstructure. This is sometimes done to “undercut” structures that compulsory to physically move which is to produce membranes on one side of a wafer and to make a mixture of trenches, holes, or other structures. These types of micromachining basically consist of several techniques which is wet etchant and dry etchant.

Then in the surface micromachining technique, the material is removed by physical or chemical means and the micromachining surface will build microstructure by adding material layer by layer on top of the substrate. Surface micromachining technique many benefits which a low-cost technique, batch-manufacturing process, and can achieve much higher alignment accuracy than is possible by conventional passive-alignment techniques.

In the LIGA process, this process begins with deep x-ray lithography that sets the desired pattern of a thick film of photoresist. After the substrates and photoresists material have been chosen, the electroplating process will be done. In many micromachining technologies, photolithography techniques are used to transfer the desired pattern from a mask to the structural material. As one of the cheapest and most capable surface-micromachining processes, LIGA has concerned much attention for millimeter-wave and microwave device (Yun et al, 2002).

2.3 Laser Micromachining

Laser micromachining is based on the local supports of energy to materials on the surface where the laser light is transformed into heat (Meijer, 2001). Nowadays, laser micromachining was currently used in the MEMS production to take over the traditional method such as etching process that needs a period of time to finish the process. Laser micromachining is one of the economically and rapidly process to get a high aspect ratio through hole diameter to hole length, which interrelates in the die or multichip modules (MCM) substrate for the 3-D application.

Different issues when used laser micromachining to replace the traditional etching process that result will be faster, accurate and high production rate. The application areas of laser micro machining involved of manufacturing methods like cutting, drilling, welding as well as ablation and material surface texturing, whereby it is possible to get a very fine surface structure ranging in the micrometer domain (Klozbach. U et al, 2011). The established laser micromachining method has minimized normal problems in laser micromachining such as the laser polarization effect, material recast (microcracks to the sidewall of structures), and Heat Affected Zone (HAZ), (Zhu et al, 2002).

There were many types of lasers used in the laser micromachining process. There are from microsecond pulsed infrared CO_2 gas laser at a wavelength between 9.3-11µm to nanosecond pulsed excimer gas laser in the 157-353 µm UV wavelength range. In silicon etching process, CO_2 laser with wavelength 10.64 µm have been used with glass attached to the Si backside because the pure silicon cannot absorb the laser wavelength (Chung et al, 2006).

The increasing of the laser pulse is continuing from Femto-second to nanosecond pulsed solid state laser between wavelengths of 266 - 1060 NM. A micro-structuring of SiO_2 thin film on Si have been applied by using Femto-second laser pulse with 150 femtosecond pulse duration and a maximum energy up to 3mJ/pulse. Actually, all of the laser types are used depending on the types of material to be processed.

2.4 Fundamental principle of Laser

The word" laser" is an acronym and stand for: (L) light (A) amplification by (S) stimulated (E) emission of (R) radiation (Silfvast, 2004). Each type of lasers is optical amplifiers which operate by pumping (exciting) an active medium placed between two mirrors (see Figure 2.1). In fact, the active medium was a collection of specially selected atoms, molecules or ions which can be in a gas, liquid or solid form and which will form laser.