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To cite this article: Tengku Muhammad Afif bin Tengku Azmi and Nadzril bin Sulaiman 2017 IOP Conf. Ser.: Mater. Sci. Eng. 260 012005

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Flip-Chip Bonding Fabrication Technique

Tengku Muhammad Afif bin Tengku Azmi, Nadzril bin Sulaiman
International Islamic University Malaysia, Faculty of Engineering, Gombak P.O. Box 10, 50728 Kuala Lumpur, Malaysia

afif5785@gmail.com, nadzril@iium.edu.my

Military systems, outer space exploration and even in medical diagnosis and treatment used magnetic field detection. Low magnetic field detection is particularly important in tracking of magnetic. Traditional magnetometer tends to be bulky that hinders its inclusion into micro-scaled environment. This concern has brought the magnetometer into the trend of device miniaturization. Miniaturized magnetometer is usually fabricated using conventional microfabrication method particularly surface micromachining in which micro structures are built level by level starting from the surface of substrates upwards until completion of final structure. Although the miniaturization of magnetometer has been widely researched and studied, the process however is not. Thus, the process governing the fabrication technique is studied in this paper. Conventional method of fabrication is known as surface micromachining. Besides time consuming, this method requires many consecutive steps in fabrication process and careful alignment of patterns on every layer which increase the complexity. Hence, studies are done to improve time consuming and reliability of the microfabrication process. The objective of this research includes designing micro scale magnetometer and complete device fabrication processes. A micro-scale search coil magnetometer of 15 windings with 600μm thickness of wire and 300μm distance between each wire has been designed.

1. INTRODUCTION

Magnetometer is a device used to detect external magnetic field. Basic magnetometer contains only a thin layer of metal that will detect the change in voltage when placed in magnetic field [1]. Common magnetometers are bulky. MEMS have brought an advancement to the development of magnetometer which are small, light, low power consumption, high sensitivity and high resolution [2].

Basic types of magnetometer are scalar and vector magnetometer. Scalar measured the magnitude of the vector magnetic field while the vector magnetometer measures the vector components of a magnetic field [3]. A vector is a mathematical entity with both magnitude and direction. The Earth's magnetic field at a given point is a vector. A magnetic compass is designed to give a horizontal bearing direction, whereas a vector magnetometer measures both the magnitude and direction of the total magnetic field. Three orthogonal sensors are required to measure the components of the magnetic field in all three dimensions.

The advancement in technology lead to the miniaturization of magnetometer. Some common and actively research micro magnetometer are SQUID, ferromagnetic and magnetoresistor. The early develop micro SQUID was introduced by Mark Ketchen at IBM [4]. The need to miniaturized high sensitivity low power magnetometer has led to the development of ferromagnetic MEMS magnetometer [5]. This new micro magnetometer has minimum the power intake and maintain its sensitivity although
being scaled-down. This device consists of dual 4.2×2×200 µm³ polysilicon torsion bars and a 100×100×13.4 µm³ ferromagnetic plate.

2. SEARCH COIL

Search coil can be miniaturized by means of MEMS technology. Its components include, coil and core (air). When exposed to an external magnetic field, the micro coil will generate a voltage different and it represent the magnitude of magnetic flux density. When measuring the magnetic flux density, which is in Tesla (T), a voltmeter (V) is used as a representation.

A planar design of search coil magnetometer is used in this work. The main reason is to simplify the fabrication process. Figure 1 shows micro coil magnetometer while figure 2 shows the side view. The design for both driving and sensing coil are made identical to each other with different orientation. It will then apply the flip chip bonding technique.

Search coil magnetometer can detect a magnetic field as low 20fT and no upper limit [6]. It works based on the principal of faraday’s law of induction. It is suitable to use in detecting low and high magnetic field. The advantage over fluxgate magnetometer meter is that it consumes less power. Moreover, the design of search coil is simpler compare to fluxgate. Hence, it will make it more easy to focus on the fabrication technique part which is the main idea in this paper.

Search coil is a type of magnetometer that operates based on law of voltage induction. This law was introduced by Faraday which states a change in magnetic fields could produce an electromotive force or voltage. This voltage will in turn produce electric currents in a closed circuit. It is capable to produce magnetic fields in the range of 20 femtoTesla up to unlimited upper range. It is a simple and low cost magnetic field sensor. The downside is that it is unable to measure static or slow varying magnetic fields. Figure 3 shows the comparison of magnetometer in term of sensitivity and frequency. It shows that the coil-based (search coil) can detect the low magnetic field at high frequency.
3. RESULTS
The idea of this part is to determine the fastest possible technique that can be achieved to fabricate a micro magnetometer. A conventional way of fabrication depends on surface micro machining technique only. Here, surface micro machining is combined with the flip-chip based technique to shorten the time taken. Besides, it can have increased the possibility of refabricating and minimized the used of substances.

3.1. Search Coil Fabrication
This section will show the comparison between the surface microfabrication and surface microfabrication + flip-chip bonding technique. Here, the steps taken for complete fabrication of search coil are shown.

3.1.1. Surface Micromachining + Flip Chip Bonding
From figure 4 it shows that it takes nine steps to complete the fabrication process provided both coils are fabricated in line with each other. Not only that the steps are lesser than the process which depends on surface micromachining only, it is easier to redo the process if there are mistakes along way.
3.1.2. Surface Micromachining

As shown in figure 5 and figure 6, it takes fourteen steps to complete the fabrication which is five steps more than the previously technique. The process cannot proceed unless the previous process is done. This will prolong the duration and steps compared to previous technique which enable the process to be done simultaneously. Besides, it is much more complicated to correct mistakes done during the process since the steps are depending on each other.
Figure 5 Surface Micromachining
1) Prepare the substrate (silicon).
2) Insert the substrate into Physical Vapor Deposition (PVD) machine to get a surface of metal (aluminum) on the substrate.
3) Clean the aluminum surface with DI water to remove unwanted object.
4) Start putting positive photoresist on top of aluminum and spin coat to get evenly distributed surface.
5) Soft bake to harden a bit the photoresist.
6) Expose pattern from transparency mask.
7) Develop the pattern in developer solution and rinse with Deionized (DI) water once the pattern is visible with naked eye. Spin coat to dry.
8) Hard baked to make sure the patterned photoresist is well preserved before putting in aluminum etch solvent.
9) Put in aluminum etch solvent and rinsed with DI water once the unwanted aluminum has been etched out. Spin coat to dry.
10) Used acetone to remove the remaining photoresist on aluminum pattern. Spin coat.
11) Insulate and combined the two coil (flip-chip).

Note that Figure 7 and Figure 8 shows the image taken during the process.
4. CONCLUSIONS
It is important to take notes about the steps taken during fabrication process. Types of fabrication techniques used should be chosen per the product that is intended to produce. Such reasons are to ensure the process to be reliable and efficient. The purpose of this paper have been fulfilled through the results obtained. Simultaneous simulations need to be done to get a fine and accurate results. The results are then compared and are used in designing the prototype. It will help to produce a workable prototype as the efficiency has been confirm beforehand. Although, the main idea is to produce a micro-scaled prototype, the sensitivity should be considered too. Thus, when choosing the specifications of the micro coil, it is important to compare both simulations from thickness and spacing factors. Finally, the fabrication of micro-scaled devices can be improved in many ways. Important aspect for the micro coil should be simulated repeatedly to ensure the outcome is usable. Though past researcher also did not see the flip-chip bonding approach proposed in this paper. Flip-chip bonding is not the optimum process yet. In future, through thorough investigation and studies, new processes of fabricating micro-scaled devices will be developed. In fabricating the devices, cleanroom should be utilized. Cleanrooms were initially a solution to particle contamination reduction (were invented for microelectronics dedicated mechanical assembly). The main features are; Overpressure (50 Pa) for keeping particles outside, filtered air (99.9999% at 0.15 μm particle size), heating/cooling/humidification/drying of incoming air, laminar (unidirectional) air flow in the working areas, materials compatibility and mechanical and electrical interference minimization. Initially, search coil magnetometer is chosen due to its durable, room temperature operation and having non-movable components. After completing the fabrication

Figure 7 Fabrication of Search Coil

Figure 8 Complete Prototype
process, the performance testing and evaluation should be done. It is hope that researcher will continue to adapt new method to improve the current founding

Acknowledgments
The authors acknowledge the supports from the Ministry of Higher Education and the International Islamic University Malaysia under grant no. RAGS14-033-0096.

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