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FABRICATION OF MICRO MAGNETOMETER USING FLIP-CHIP BONDING TECHNIQUE

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Abstract—Magnetic field has been widely explored for its benefit towards todays development. In the early stage, the main concern was to develop a device that can detect magnetic field. Such device is called magnetometer. The advancement of technology has push the boundary even further, making a portable and robust magnetometer. 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 include 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.

Index Terms—Magnetometer, Microfabrication, Miniaturization, Micro-scale

I. INTRODUCTION

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 (Edelstein et al., 2007). 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

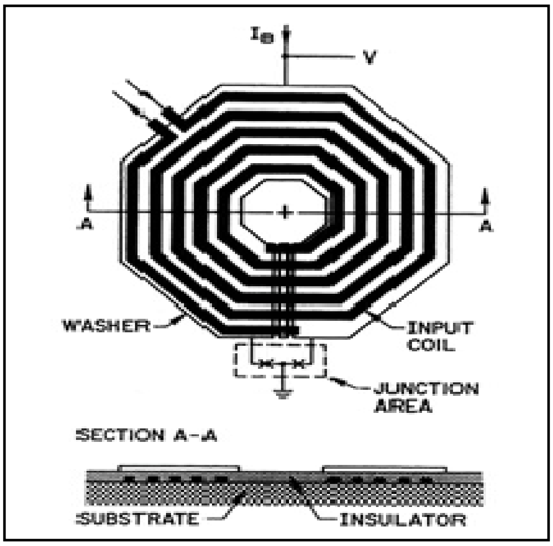

Figure 1: Washer Type SQUID Magnetometer (Ketchen, 1997)

The advancement in technology lead to the miniaturization of magnetometer. Some common and actively research micro magnetometer are SQUID, ferromagnetic and magnetorisistor. The early develop micro SQUID was introduced by Mark Ketchen at IBM (Wikswo, 1995). Figure 1 shows the design of micro SQUID. In other hand, the need to miniaturized high sensitivity low power magnetometer has lead to the development of ferromagnetic MEMS magnetometer (Yang et al., 2002). 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. Figure 2 below shows the micro scaled ferromagnetic MEMS magnetometer under optical image.

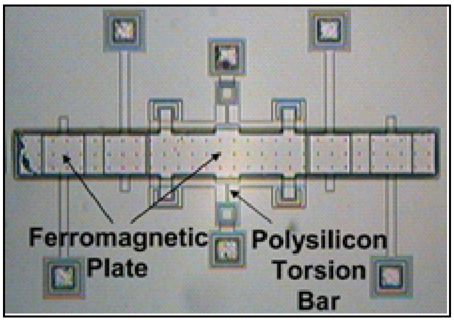

Figure 2: Micro Magnetometer Made With MUMPS (Cronos Integrated Microsystem)

II. SEARCH COIL

Search coil can be miniaturize 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 3 shows the proposed micro coil magnetometer. 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 (Lenz & Edelstein, 2006). 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.

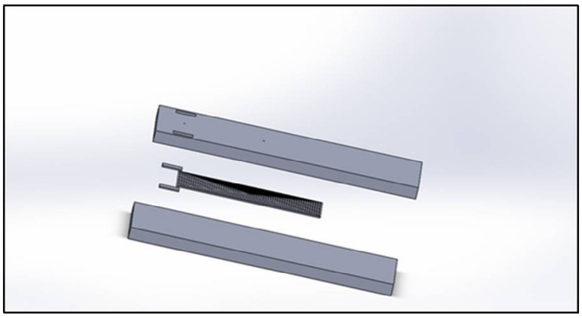

Figure 3: Proposed micro coils magnetometer

Search coil magnetometer (SCM) are based on the principal of faraday's law that stated any change in magnetic field around a coil of wire will create an induced voltage. The occurrence of induced voltage indicates the presence and magnitude of magnetic field around it. Generally, SCM signal detection are based on the permeability of core material, coil area, coil turns and rate of change of magnetic flux (Lenz & Edelstein, 2006). But here, the focus is on fabrication technique. Thus, simpler design containing coils and air as core are chosen.

Search coil magnetometer will produce an induced emf when there is a change in the magnetic field. The term induced as the voltage produce opposed the changing magnetic field. It follows Faradays law of induction $e = -Nd\text{Ø}/dt$. The negative sign indicates the direction.

N = number of turns of coil
Ø = magnetic flux in Webers
t = time in seconds

III. FABRICATION OF SEARCH COIL

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 are combined together 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.

A. Surface Micromachining

The sequence in Figure 4 shows the steps taken to complete the fabrication of the magnetometer using surface micromachining with flip chip bonding technique. 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 is mistakes along way.

B. Surface Micromachining + Flip Chip Bonding

Figure 5 and Figure 6 shows the steps taken to complete the fabrication of magnetometer using surface micromachining only. As shown, it takes fourteen steps which is five steps more than the previously shown. The process cannot proceed unless the previous process are 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.

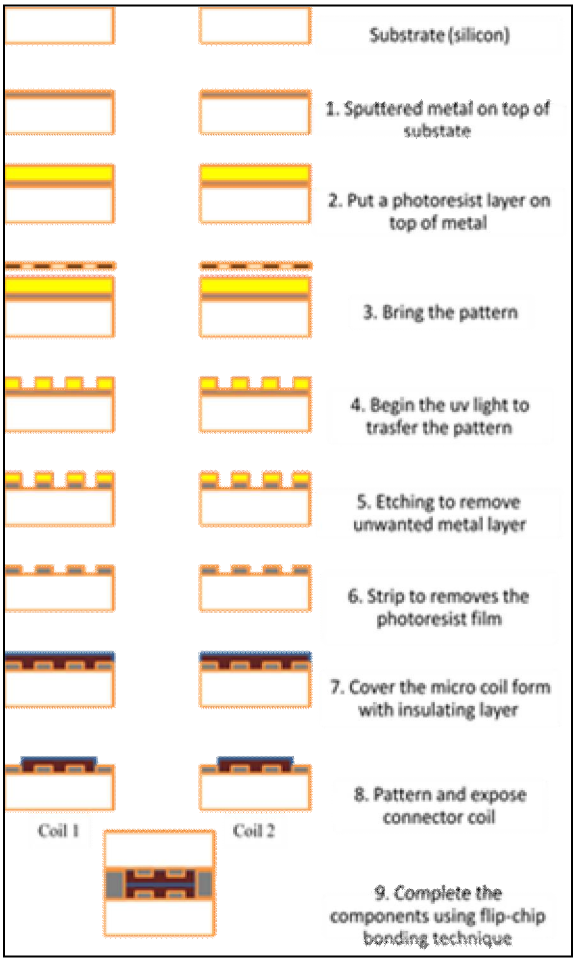

Figure 4: Surface Micromachining + Flip-Chip Bonding

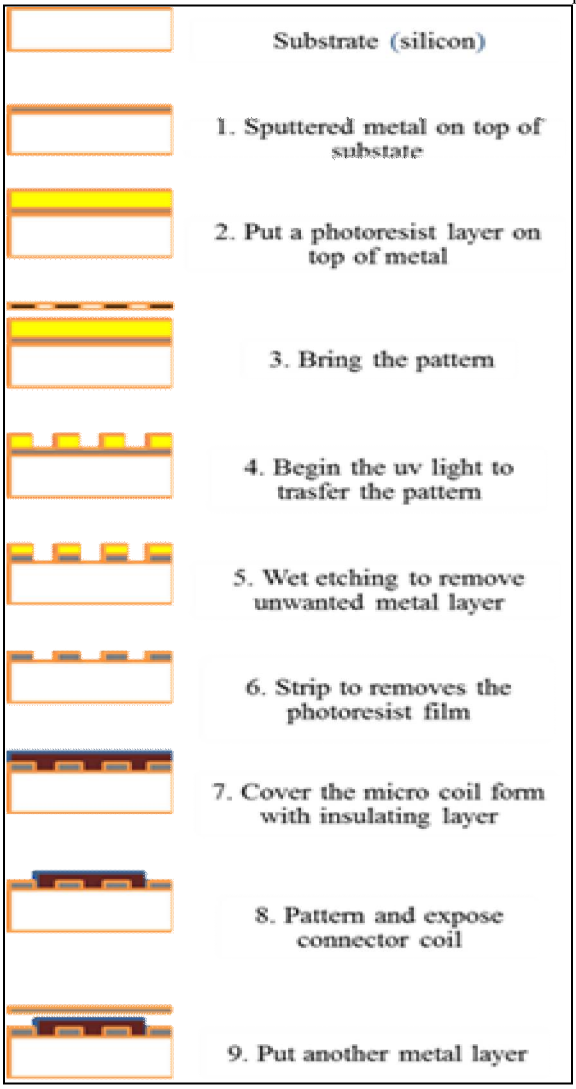

Figure 5: Surface Micromachining

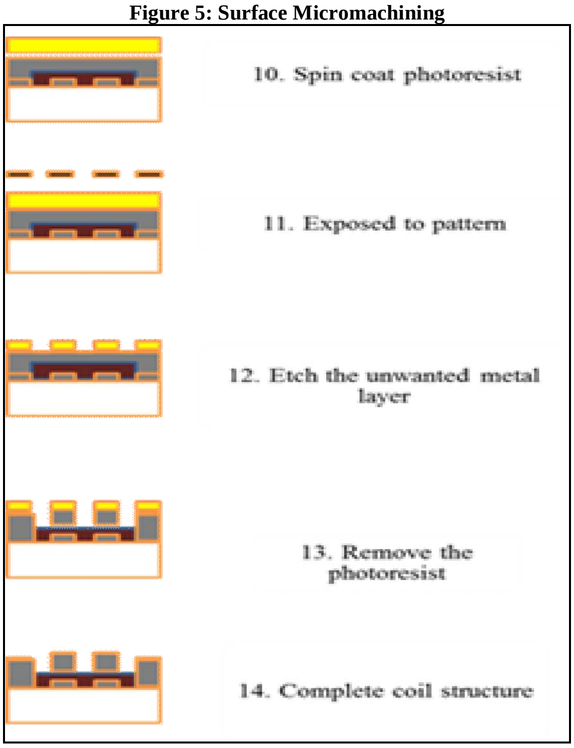

Figure 6 Surface Micromachining (Continue)

IV. RESULTS

The steps taken to fabricate micro search coil magnetometer begin from the preparation of substrate until the flip-chip bonding are as follow. Note that Figure 7 and Figure 8 shows the image taken during the process.

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 aluminium has been etch 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).

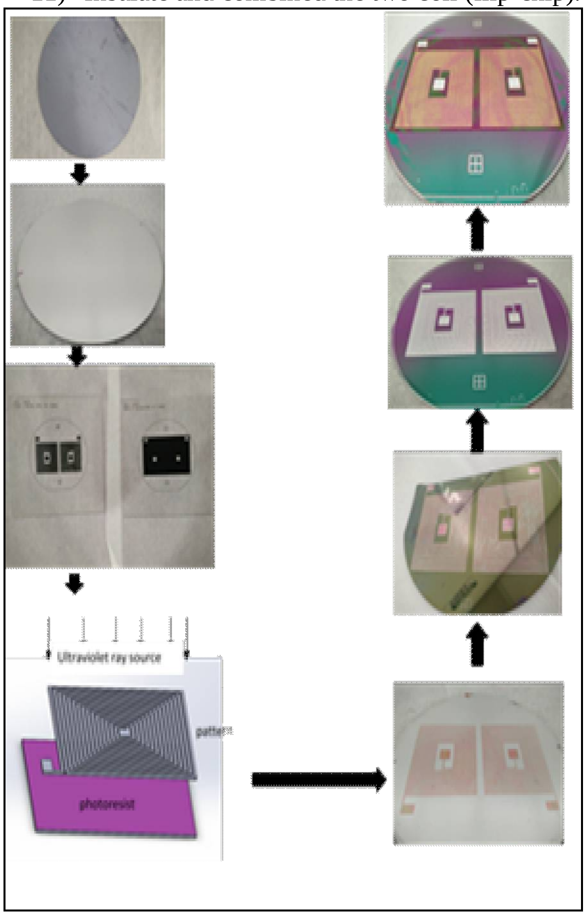

Figure 7: Fabrication of Search Coil

Figure 8: Complete Device

CONCLUSION

It is important to take notes about the steps taken during fabrication process. Types of fabrication techniques used should be chosen according to the end product that is intended to produce. Such reasons are to ensure the process to be reliable and efficient. The purposed of this paper have been fulfilled through the results obtained.

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