

Packaging of MEMS based circuits

Suma S Lonkadi¹, J John², Penchala Babu A,
Raghuraman A, Pushpa Naresh Kumar,
Venkatesh V, Moogina Ravindra

¹ISRO Satellite Centre, Vimanapura,
Bengaluru-17, India
lonkadi@isac.gov.in

²Laboratory for Electro-Optics Systems,
Peenya 1st stage, 1st Cross, Bengaluru-58

January 1, 2018

Abstract

This paper describes about Assembly, Interconnection and Packaging of MEMS based circuits using Hybrid technology. MEMS are Micro Electro Mechanical Systems having delicate moving parts. Unlike other bare devices which are assembled in HMC package using epoxy or solder, MEMS chips are attached to substrate using specially designed attachment process. The process gives cushioning effect and protects the delicate cantilever structures of MEMS chips against stress and Mechanical shock experienced during satellite launch. Interconnection of MEMS to the substrate is done with wire bonding. Wire bonding on MEMS with newly developed attachment process was a great challenge as MEMS are mounted on a soft cushioning base. Optimization of force and ultrasonic power was carried out and ball on wedge method was adopted. The special processes of attachment of MEMS chip to ceramic substrate and its interconnection has lead to an innovative process technology for miniaturizing MEMS based electronics. Adopting this technology a MEMS based Inclinator HMC has been developed and qualified for use in Rover of Chandrayaan II

spacecraft to be launched by ISRO.

Key Words : Hybrid Microcircuits (HMC), MEMS, Chandrayaan

1 Introduction

Packaging of Microelectronics circuits is an art of establishing interconnections and providing an appropriate operating environment for electronics/electromechanical circuits to process and /or store information. Packaging in Hybrid Microcircuits involves bare devices like diodes, transistors, ICs resistors, capacitors, inductors etc., electrically interconnected on an insulating substrate and placed in a Metallic/Ceramic package and sealed hermetically [1]. Like other devices MEMS need to be assembled, interconnected and packaged appropriately to protect the delicate mechanical structure. Alone a MEMS die sawed from a wafer is extremely fragile and needs to be protected from mechanical damage and hostile environments. To function it needs to be connected with other electrical circuits and must be packaged suitably to provide protection from mechanical stresses and adequate path for heat removal [2].

This paper discusses about MEMS device which acts like an Inclinometer, its assembly and interconnection with other electronic components, Packaging in a HMC package and Tests carried out for its usage in Space application.

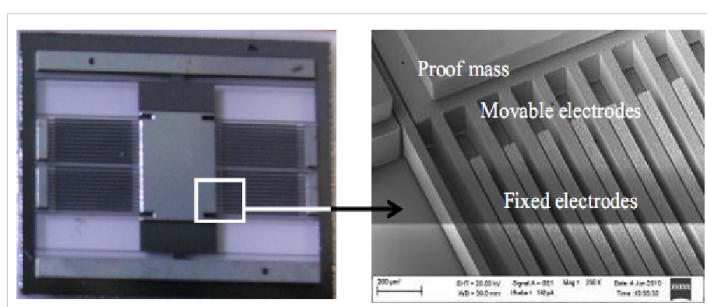


Figure 1: MEMS sensor for Inclinometer HMC and SEM image of comb electrodes

Fig.1 shows indigenous MEMS device fabricated using Deep Reactive Ion Etching (DRIE). The main part of the device is a plate called the proof mass suspended by beams [3]. The fine comb like structures projecting from proof mass are designated as movable electrodes. These are paired with pair of fixed electrodes to form an assembly of parallel plate capacitors. As the proof mass and the associated electrodes deflect due to an external force there is a change in the gap between fixed and movable electrodes which in turn lead to a change in capacitance. Two such MEMS devices are mounted in a HMC package along with other components which functions as an Inclinometer.

2 MEMS HMC Assembly process

Inclinometer HMC consists of sensor part and associated electronics part as shown in the fig 2.

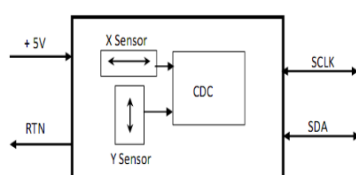


Figure 2: Block Diagram of Inclinometer

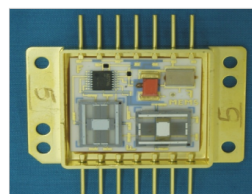


Figure 3: Inclinometer HMC package

Inclinometer HMC consists of two MEMS sensors, a capacitor to digital converter IC, Resistors and Capacitors. Resistors and Capacitors are bare devices and are attached to substrate by using epoxy which is a normal procedure followed in HMC fabrication. Capacitor to Digital converter IC is a TSOP (Thin Small outline Package) which is a package device attached to ceramic substrate using epoxy. For the first time a packaged device is mounted inside a HMC package because of functional requirement. The attachment requires highly skilled workmanship as lead pitch of TSOP is 20mils and is very difficult to achieve with epoxy mounting technique.

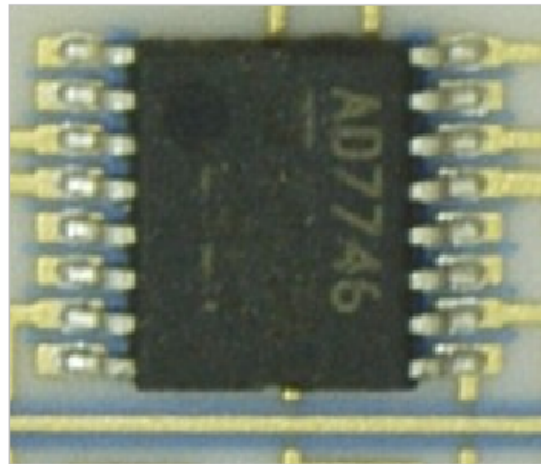


Figure 4: TSOP

Inclinometer HMC as it is planned for Rover of Chandrayaan-II spacecraft has to withstand Mechanical shock of the order of 1000g. The conventional die attachment method with epoxy could not be followed for MEMS sensors as they have delicate moving parts (electrodes) which get damaged during mechanical shock test. Hence a unique process technique was developed to attach MEMS devices to substrate which provides an additional cushioning to very delicate micro structures/cantilevers of MEMS and help to perform flawlessly during harsh mechanical conditions which otherwise was not possible with epoxy attachment.

To give this cushioning effect silicone gel material is chosen which provides both mechanical support and also sufficient adhesion. It is a transparent two part material with wide operating temperatures (-65°C to 200°C). The material is transparent and low viscous which makes it very difficult to use for die attachment directly. As it is low viscous it flows very easily and spreads over nearby conductor pads and makes it difficult for wire bonding. Since the process of die attachment is manual it is very difficult to control the amount of silicone material. Hence dam and fill method is adopted where closed dam like structure is made and the silicone material is filled and allowed to cure. After curing it is sliced in to thin slabs of dimension equal to device size and attachment to

die and substrate is carried out. Following are the detailed process steps followed for MEMS attachment.

As the HMC is designed for space application, clean room procedures are adopted and is even more important and critical for MEMS attachment as it has delicate moving parts where dust particles if stuck between these parts will lead to device mal functioning. The following is the sequence of assembly adopted.

2.1

Preparation of silicone pads: A mould is made for required dimension on the polished surface of silicon wafer. This is placed on a surface whose flatness is ensured using a precision leveler. Mould is filled with silicone/encapsulant and allowed for room temperature curing for 12 hours. Subsequently, it is cured in a clean oven at 150°C, minimum of 15 minutes. The slab is sliced into required dimension using a clean surgical class blade. Thickness measurements are done on token pieces selected from three or four locations of the slab

2.2

Pad to substrate attachment: A small drop of freshly prepared encapsulant is placed on the HMC substrate. The pre-prepared pad is carefully placed on it with a clean tweezer. The pad is gently pressed using a clean round-headed glass or Teflon rod to obtain a uniform spreading of the encapsulant. The substrate is cured in room temperature around 12 hours and subsequently in a clean oven at 150°C, 15 minutes.

2.3

Sensor Fixing: A droplet encapsulant is placed on the pad that is already fixed on the substrate. The sensor is placed on the pad after cleaning its glass bottom surface and a uniform force is applied from the frame/stopper area of the sensor. Sensor has to be handled very carefully. Ensure that bubbles are not trapped in the encapsulant. Fine alignments are made under a microscope or profile projector for the sensor orientation. The assembly is left at room temperature

for about 12 hours. Subsequently, it is cured in a clean oven at 150°C, minimum of 15 minutes.

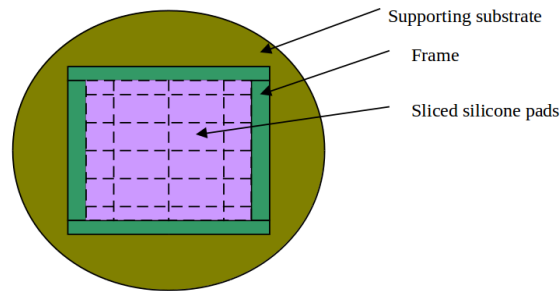


Figure 5(a): Preparation of silicone pads



Figure 5(b): Pad attachment to HMC substrate



Figure 5(c): MEMS Sensor Chip fixing on the pad

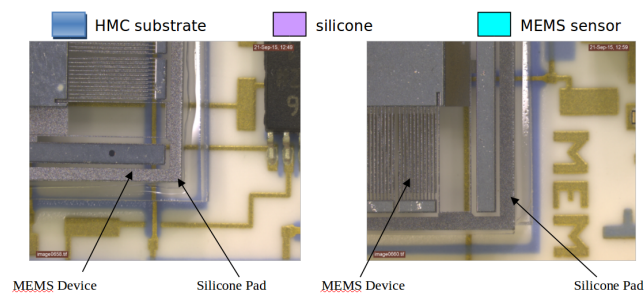


Figure 6: MEMS Sensor Chip fixing on the pad

3 MEMS HMC interconnection and Packaging

MEMS, to function as an inclinometer has to be electrically interconnected with other components. Electrical interconnection of MEMS is done through wire bonding. Since MEMS chips are mounted on 0.7 mm thick soft Silicone pads (used for the first time in a Hybrid) Wire Bonding is highly complex. For proper wire bonding to happen it needs a firm base, but since soft silicone material is used for MEMS attachment wire bonding was very challenging. Hence process of Wire Bonding of MEMS chips has been carefully optimized to achieve required strengths.

The package serves to integrate all components required for a system application in a manner that minimizes size, mass and complexity. Package provides mechanical support, protection from environment and electrical connection to other system components [2]. MEMS with other components are assembled on a ceramic substrate and housed inside a specially designed KOVAR package. Bare devices like MEMS, resistors, capacitors are susceptible to moisture, also aluminum tracks in MEMS get corroded by moisture which lead to electrical deviations. Hence for high reliability applications packages are sealed hermetically to protect the bare devices.

4 Testing

For the first time MEMS and TSOP are assembled in HMC package, hence the process of attachment had to be qualified, along with wire bonding on MEMS. Process qualification was carried out and after process qualification, functional HMCs are fabricated using above process technology and are subjected to Mechanical, Environmental, and Endurance tests as per space qualification levels. These HMCs are successfully evaluated and qualified for Space usage. Based on successful qualification HMCs have been fabricated and screened for usage in Chandrayaan spacecraft to be launched by ISRO in 2017.

5 Conclusion

Packaging of MEMS based circuit along with associated electronics using special attachment techniques to attach MEMS & other devices to ceramic substrate (alumina) has been a very challenging task. Since this Inclinator HMC is designed for space usage it has to withstand very high levels of mechanical shock and vibration. Introduction of silicone material (encapsulate material) in the attachment process made delicate structures of MEMS devices to withstand high levels of Mechanical shock and Vibration required for space application. MEMS Inclinator HMC is successfully qualified for Space application.

6 Acknowledgments

Authors would like to express their gratitude to Director ISAC & Director LEOS for their constant support and encouragement for new developments. They would like to thank all team members involved in Design of MEMS, Fabrication and Testing for their support.

References

- [1] James J Licari *Hybrid Microcircuit Technology hand book*
- [2] R.D Gerke, *MEMS packaging*
- [3] J John, V Thamarai, et al, *High sensitivity MEMS Inclinator for Chandrayaan Rover* STD 2014

