Crimson Publishers
Wings to the Research

Research Article

Water-Assisted High-Yield Dicing Technique for MEMS Pressure Sensors with Ultra-Thin Structures

Deepu BR*, Kiran Kumar and Nayak MM

Centre for Nano Science and Engineering, Indian Institute of Science, India

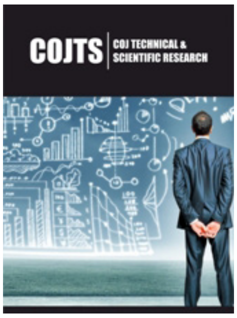
Abstract

The present article introduces a dicing technique for MEMS sensors with ultra-thin membranes (~15µm) assisted by water medium aimed at enhancing the yield. Saw dicing of MEMS piezoresistive differential pressure sensors designed to operate below atmospheric pressure is reported. In MEMS pressure sensors, thin membranes/microstructures, which are typically released, are susceptible to damage during the saw dicing technique, making the process pivotal in MEMS fabrication. This article suggests filling the cavities with micro drops of water to provide mechanical support and alleviate stress and damping effect on the released structures during dicing, consequently enhancing yield.

Keywords: MEMS; Microfabrication; Differential piezoresistive pressure sensor; Saw dicing

Abbreviations: MEMS; Micro Electromechanical Systems; Silicon: Si; SOI: Silicon on Insulator

ISSN: 2643-7066



***Corresponding authors:** Deepu BR, Centre for Nano Science and Engineering, Indian Institute of Science, Bangalore, India

Submission: March 20, 2024

Published: June 18, 2024

Volume 5 - Issue 1

How to cite this article: Deepu BR*, Kiran Kumar and Nayak MM. Water-Assisted High-Yield Dicing Technique for MEMS Pressure Sensors with Ultra-Thin Structures. COJ Tech Sci Res. 5(1). COJTS. 000603. 2024.
DOI: 10.31031/COJTS.2024.05.000603

Introduction

MEMS pressure sensors are miniature devices that measure pressure levels for various applications. They typically consist of a thin membrane that deforms in response to any changes in pressure. This mechanical deformation is converted into an electrical signal, which precisely interprets applied pressure. For low-pressure applications demanding high sensitivity, it's imperative that the membrane thickness be extremely thin (~15µm). The fragility of this membrane makes it prone to breakage during the dicing process, thereby potentially lowering the overall fabrication yield. Various dicing techniques have been reported to dice silicon devices with ultra-thin structures, including wafer saw, laser full cut dicing, laser scribe and saw hybrid dicing, Stealth dicing, and plasma dicing [1,2]. The cost-effective saw blade dicing method, utilizing a single diamond blade, is the most widely adopted approach for mass production. During saw dicing of the wafer with released structures, a photoresist is generally evenly spin-coated across the entire wafer, effectively covering the cavities. This ensured that the released structures remained undamaged throughout the dicing process [3]. However, when dicing MEMS differential sensors, where the cavity is backed by a glass support with a hole, filling the cavity with photoresist and subsequent removal is not feasible. Thus, we propose a novel and straightforward approach: using water to fill the cavity during saw dicing. This water-filled cavity protects the chips from vibrations and reduces the risk of membrane breakage/loss.

Materials and Methods

Differential MEMS pressure sensors measuring 3x3mm chip size were fabricated on a 4-inch SOI wafer (Figure 1) at the Centre for Nano Science and Engineering, Indian Institute of Science, Bangalore, India, as referenced in [4,5]. A glass through hole of 0.8mm diameter was made at the rear side of each sensor chip during microfabrication. After fabrication, the 4-inch wafer was diced into four quarters. One quarter wafer was diced without any water filling in the cavity. Further the second quarter wafer was used for dicing with water filling in the cavity. A micro syringe was used to fill the water into the cavity through the glass hole. Subsequently, the wafer was mounted on water-resistant dicing tape, with the sensor front side facing upwards. This step must be executed immediately to prevent the evaporation of water micro droplets. The saw dicing technique with 0.8mm/second dicing speed was used to separate. the individual chips from wafer. A continuous water flow of 0.5L/minute was maintained around the saw blade made of diamond. The remaining two quarter wafers were used to check the repeatability of the proposed method.

Results and Discussion

The piezoresistive pressure sensors were fabricated on 4-inch SOI wafer (Figure 1a) as described in section 5. Across 4-inch area there are ~300 sensors. Each sensor is a 3x3x0.916mm (lxwxt) chip with 2x2x0.015mm (lxwxt) released membrane. On the front side of the sensor chip, there are four piezo resistors arranged in a Wheatstone bridge configuration (Figure 1b), while the rear side features a glass support with a 0.8 mm hole (Figure 1c). The significance of the glass backing with the hole was reported in our previous research [5]. Figure 1d illustrates the schematic view, indicating the cavity area available for water filling. This article primarily focuses on preventing membrane breakage during the dicing process and enhancing process yield, rather than extensively detailing microfabrication processes. Wafer dicing becomes more complex when dealing with the pressure sensors operating below atmospheric pressure due to the presence of extremely thin membranes. After microfabrication, the 4-inch SOI wafer was diced into 4 quarters and proceeded for dicing experiments. Initially, the first quarter was diced without water filling inside the cavity. Great care was taken to minimize the damping effect and stress on the membrane by lowering the water flow rate and using the slowest possible spindle revolution. Maintaining continuous water flow over blade is crucial as it aids in removing dicing debris and dissipating the heat generated from the friction between the blade and wafer during dicing. However, it was observed that many of the released membranes were cracked (<5 % yield). This could be due to the stress caused by continuous flow of water over the wafer surface and the propagation of vibrations to the released structure. The vibrations occur due to the friction between blade and wafer.

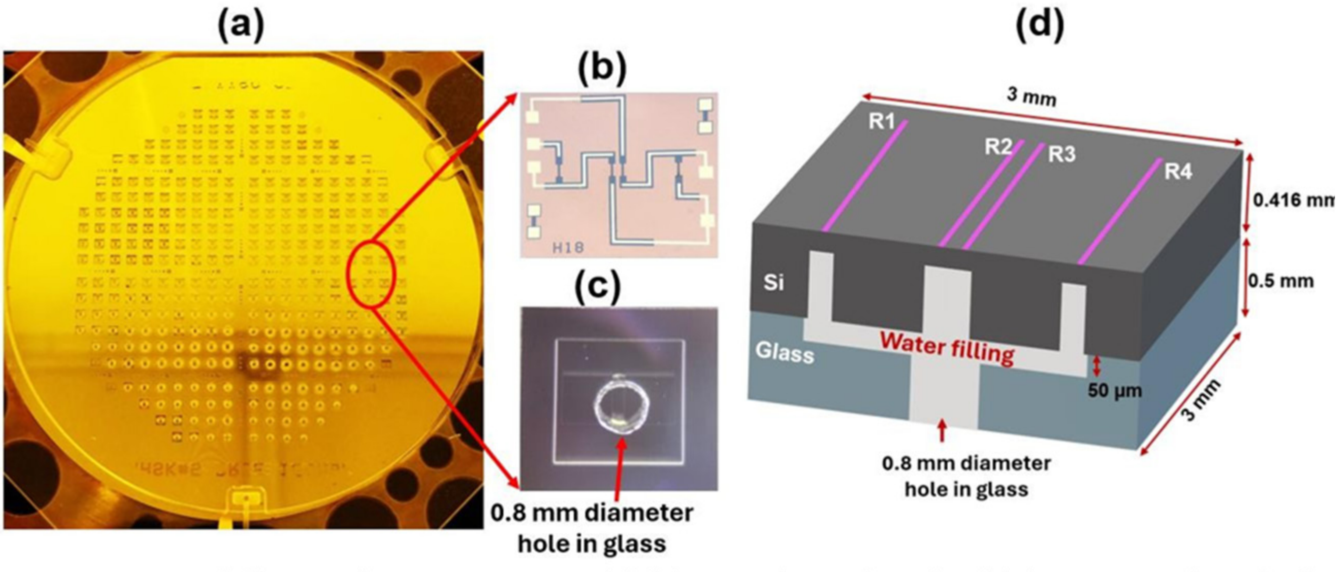


Figure 1: MEMS differential pressure sensor
a) Fabricated 4-inch wafer b) Front view of single chip c) Rear view of single chip d) Schematic view of single chip

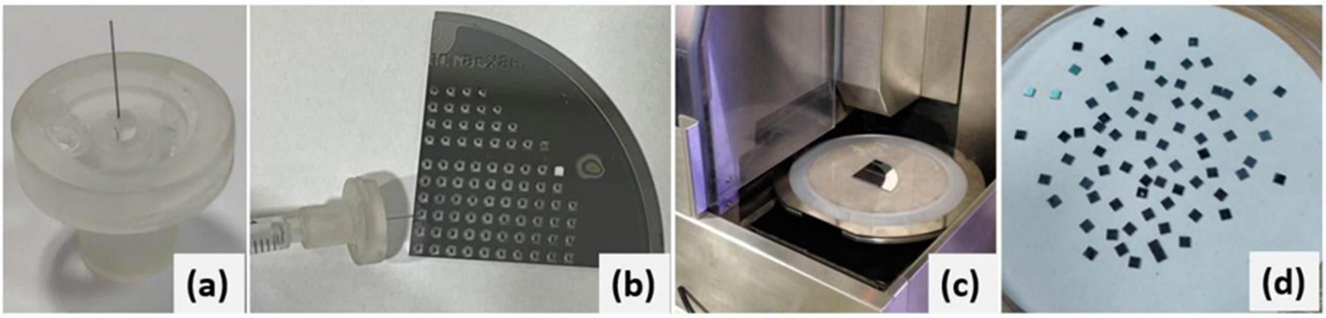


Figure 2: Quarter of 4-ich wafer dicing after microfabrication
a) Micro syringe used for water filling b) Process of water filling to the sensor cavity
c) Wafer loaded in saw dicing tool d) Sensor chips after dicing

Subsequently, the second quarter wafer was diced employing the suggested approach. A micro syringe with a diameter of 0.6mm (Figure 2a) was utilized to inject micro drops of water into the cavity, as depicted in Figure 2b. All the chips were filled with water and promptly affixed to the water-resistant dicing tape, with the sensor side facing upwards. The dicing tape effectively seals the cavity, preventing water from spilling over. The same above said parameters were maintained for dicing the wafer. As expected, the damping effect was largely diminished owing to the presence of the water medium, resulting in a high yield of >90%. Following dicing, the tape was subjected to UV light exposure to soften it (Figure 2c). The sensor chips were then extracted from the dicing tape (Figure 2d). The described method was applied to the remaining two quarter wafers, producing repeatable results that affirm the efficacy of the suggested dicing approach.

Conclusion

A high-yield, straightforward, and innovative process for saw dicing of differential MEMS pressure sensors is reported. Water is injected into the cavity at the rear side of the sensor through a glass hole using a micro syringe. The water presence in the cavity provides mechanical support to the released membrane and minimizes the stress on membrane and reduces damping effect caused by the friction between the saw blade and the wafer, thereby increasing the dicing yield. An experiment conducted without water filling during dicing resulted in a low yield, highlighting the importance of water assistance during the dicing process. The reported method proves to be an excellent approach for dicing MEMS differential low pressure sensor devices with ultra-thin membranes.

Acknowledgement

We acknowledge funding support from MHRD (Ministry of Human Resource Development), MeitY, and DST (Department of Science and Technology) Nano Mission, India through NNetRA. The authors would also like to acknowledge the National Nano Fabrication Centre (NNFC), the Micro and Nano Characterization Facility (MNCF), and the Packaging and Systems Facility (PASF) of the Centre for Nano Science and Engineering, Indian Institute of Science, Bangalore, for providing access to the fabrication, characterization, testing, and packaging facilities. We thank Prof KN Bhat for their invaluable guidance and unwavering support. We also acknowledge the technical staff of NNFC, MNCF and SAPF for all the help.

Conflict of Interest

No conflicts of interest

References

1. Hooper A, Ehorn J, Brand M, Bassett C (2015) Review of wafer dicing techniques for via-middle process 3DI/TSV ultrathin silicon device wafers. In 2015 IEEE 65th Electronic Components and Technology Conference pp. 1436-1446.
2. Inoue F, Phommahaxay A, Podpod A, Suhard S, Hoshino H, et al. (2019) Advanced dicing technologies for combination of wafer to wafer and collective die to wafer direct bonding. In 2019 IEEE 69th Electronic Components and Technology Conference pp. 437-445.
3. Xiao F, Juang Y, Chiu C (2006) Patent application publication.
4. Bhat KN (2007) Silicon micromachined pressure sensors. Journal of the Indian Institute of Science 87(1): 115.
5. Deepu BR, Pavithra B, Nayak MM, Bhat KN (2023) Advancement in micromachining techniques of mems piezoresistive pressure sensors to minimize offset drift due to humidity and temperature. Intech Open.