Advantages of TMAH in the Development of MEMS-Based Sensors

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Abstract

The advancement of microelectromechanical systems (MEMS) has significantly transformed sensor technology by allowing the integration of mechanical and electronic components on a single chip. Among the various etchants used in MEMS device fabrication, tetramethylammonium hydroxide (TMAH) has gained prominence due to its unique properties and advantages. This paper explores the benefits of using TMAH as a wet etching technique in developing MEMS-based sensors, particularly for the fabrication of diaphragm structures essential for sensing applications. The TMAH solution provides high etch rates and excellent anisotropic etching capabilities, enabling the precise fabrication of the complex geometries required in MEMS technology. Furthermore, TMAH is compatible with complementary metal-oxide-semiconductor (CMOS) processes, which facilitates seamless integration with electronic circuits.

Additionally, TMAH has low toxicity, enhancing safety during manufacturing processes and making it a preferable choice over other etchants like potassium hydroxide (KOH). Its ability to achieve smooth surface finishes contributes to improved sensor performance by minimizing noise and enhancing sensitivity. This paper also discusses TMAH's selectivity toward silicon dioxide and silicon nitride as masking materials, further increasing its utility in MEMS fabrication. Overall, TMAH represents a significant advancement in etching technology for MEMS-based sensors, promoting higher efficiency and performance across various applications

Introduction

Microelectromechanical systems (MEMS) have impacted on various fields by merging mechanical elements with electronics at the microscale. This integration enables the development of highly sensitive, compact, and multifunctional devices such as accelerometers, pressure sensors, and flow sensors. Among the many etchants available, tetramethylammonium hydroxide (TMAH) has emerged as a preferred choice for etching silicon in MEMS fabrication.

TMAH is an organic base that offers several advantages over traditional etchants, such as potassium hydroxide (KOH), due to its unique properties. Its high etch rate, excellent anisotropy, compatibility with CMOS processes, low toxicity, and ability to produce smooth surface finishes make TMAH an ideal solution for MEMS fabrication. This paper examines the role of TMAH in enhancing the precision and efficiency of MEMS sensor fabrication, focusing on its application in creating diaphragm structures which is crucial for various MEMS-based sensors.

$$N(CH_3)_4^+Cl^- + KOH \rightarrow N(CH_3)_4^+OH^- + KCl$$

Design/Other information

In MEMS fabrication, masking materials such as silicon dioxide (SiO_2) and silicon nitride (Si_3N_4) are often used to protect certain areas of the silicon wafer during the etching process. TMAH exhibits good selectivity toward these materials, meaning it etches silicon while leaving the masking layers intact. This selectivity is essential for creating complex MEMS structures with multiple layers and intricate designs.

TMAH's selectivity allows for precise patterning and the ability to fabricate sophisticated MEMS devices with different layers of material, each serving a distinct purpose. The use of SiO_2 and Si_3N_4 as etch masks ensures that the underlying silicon is etched only in the desired areas, allowing for the creation of highly detailed and functional MEMS devices. Step by step procedure for bulk micromachining is shown in fig.1.

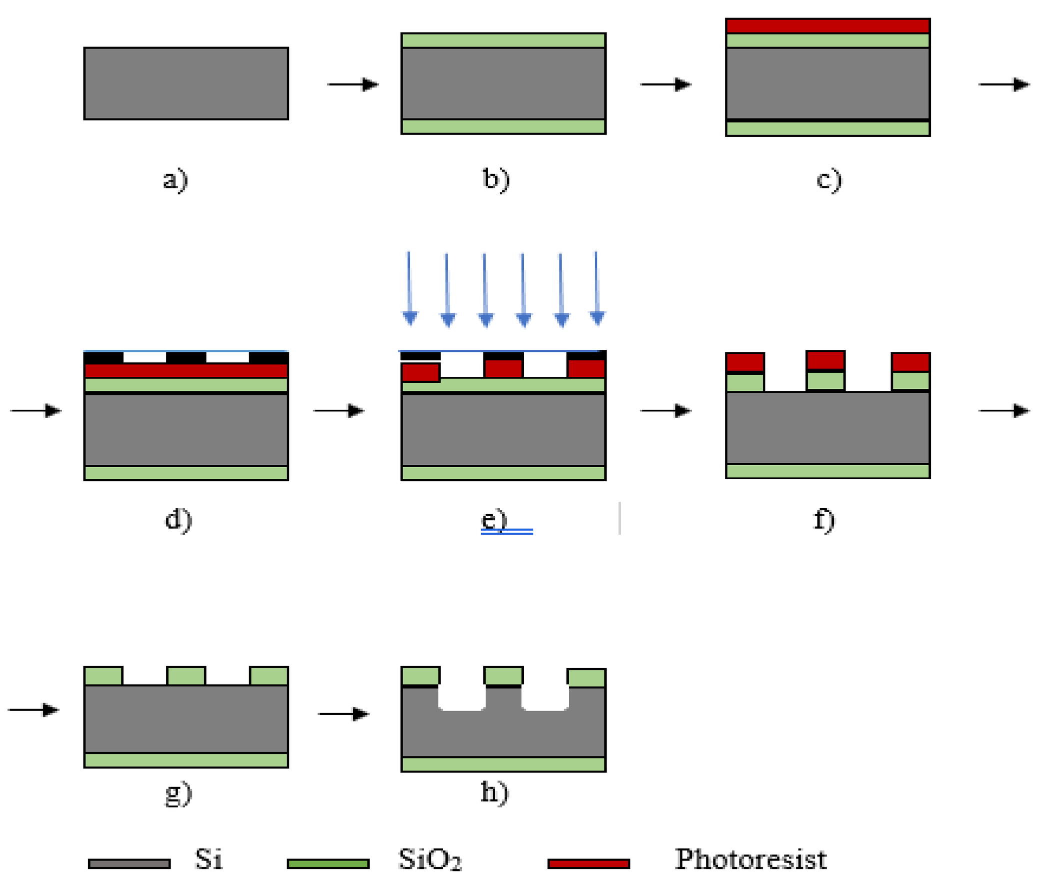


fig.1. (a) Substrate (b) Oxidation (c) Photoresist Coating (d) Masking (e) U.V. Exposure and Develop (f) Reactive Ion Etching (g) Photoresist Removal (h) Silicon etched using TMAH

Set up

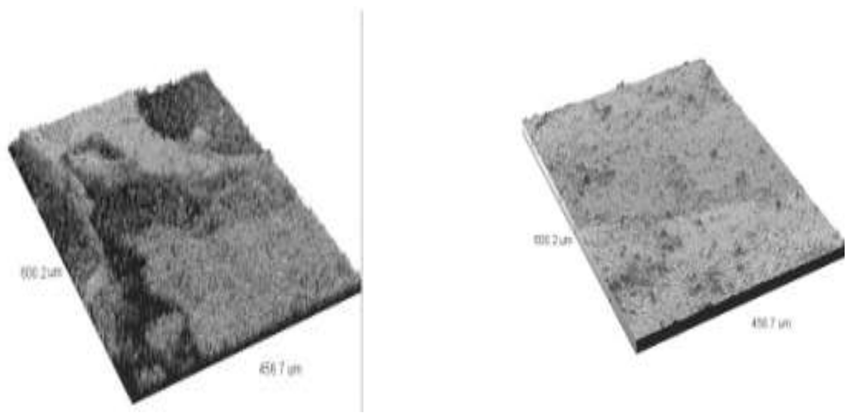
Materials Needed

- Glass Container
- Thermometer
- Stirrer Hot Plate
- The Condensor Top Breaker assembly located in pictured.
- TMAH Solution

Results

While TMAH has many advantages, it is important to compare it with other commonly used etchants, such as potassium hydroxide (KOH), to fully understand its strengths and limitations. KOH has been traditionally used for etching silicon in MEMS fabrication, but it presents several challenges compared to TMAH:

- **Toxicity**: KOH is more toxic and caustic than TMAH, making it less suitable for environments where safety is a priority.
- **Etching Behavior**: KOH etching can produce rougher surface finishes than TMAH as Shown in fig.2. which may result in higher noise levels and reduced sensor sensitivity
- **Anisotropy**: Although KOH also exhibits anisotropic etching, TMAH generally offers better control over the etching process, especially when precise geometries and smooth surfaces are required.



(a) (b)

Fig.2. (a) Surface after KOH etching (b) Surface after TMAH etching.

Conclusions

Tetramethylammonium hydroxide (TMAH) has emerged as a key etching solution in the fabrication of MEMS-based sensors, offering a range of advantages that make it an ideal choice for modern sensor technologies. Its high etch rates, excellent anisotropic etching capabilities, compatibility with CMOS processes, low toxicity, and smooth surface finishes contribute to its superiority over traditional etchants like potassium hydroxide (KOH).

The ability of TMAH to create highly precise and well-defined diaphragm structures, combined with its selectivity toward silicon dioxide and silicon nitride as masking materials, enhances its utility in the fabrication of MEMS sensors. As MEMS technology continues to evolve, the use of TMAH will likely play a pivotal role in advancing sensor performance and enabling the next generation of highly efficient, reliable, and compact MEMS devices.

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