There are two classes of etching processes. Wet etching where the material is dissolved when immersed in a chemical solution and dry etching where the material is dissolved using reactive ions or a vapor phase etchant. DRIE and LIGA are two types of dry etching processes that are discussed in this report.

Deep reactive-ion etching (DRIE) is a very anisotropic etch process which is used to achieve high-aspect ratio (up to 50:1) trenches by selectively enhancing the etching rate at the bottom of the trench while inhibiting lateral etch rate. DRIE is a slight modification of reactive-ion etching (RIE).

In RIE the substrate is placed inside a reactor in which several gases are introduced. Plasma is struck in the gas mixture using an RF power source, breaking the gas molecules into ions. The ions are accelerated towards the surface of the material being etched, forming another gaseous material. This is known as the chemical part of reactive ion etching. There is also a physical part which is similar in nature to the sputtering deposition process. If the ions have high enough energy, they can knock atoms out of the material to be etched without a chemical reaction. It is a very complex task to develop dry etching processes that balance chemical and physical etching, since there are many parameters to adjust.

This figure shows a diagram of a common RIE setup. A RIE consists of two electrodes (1 and 4) that create an electric field (3) meant to accelerate ions (2) toward the surface of the samples (5). The area labeled (2) represents plasma that contains both positively and negatively charged ions in equal quantities. These ions are generated from the gas that is pumped into the chamber usually O₂ and CF₄ gasses are used for etching. In the Diagram CF₄ has been pumped into the chamber, making a plasma with many Fluorine (F⁻) Ions.

The figure below shows a photoresist mask on silicon dioxide. The etching ions are accelerated into the etching region, where they combine with silicon dioxide and then are dispersed. Because the electric field accelerated ions toward the surface, the etching caused by these ions is much more dominant than the etching of radicals - ions traveling in varied directions, so the etching is anisotropic.

There are two techniques in DRIE named Cryogenic and Bosch. In cryogenic process, the wafer is chilled to −110 °C. The low temperature slows down the chemical reaction that produces isotropic etching. However, ions continue to bombard upward-facing surfaces and etch them away. This process produces trenches with highly vertical sidewalls. The draw back of this process is that at this very low temperature the mask could break and also by-products have a tendency of depositing on the nearest cold surface, i.e. the substrate or electrode.

Bosch is a cycling two-step process altering between deposition and etch steps done at 10-20 °C. The first gas composition creates a polymer on the surface of the substrate, and the second gas composition etches the substrate. The polymer is immediately sputtered away by the physical part of the
etching, but only on the horizontal surfaces and not the sidewalls. Since the polymer only dissolves very slowly in the chemical part of the etching, it builds up on the sidewalls and protects them from etching. These etch/deposit steps are repeated many times over resulting in a large number of very small isotropic etch steps taking place only at the bottom of the etched pits. To etch through a 0.5 mm silicon wafer, 100–1000 etch/deposit steps are needed. The two-phase process causes the sidewalls to undulate with an amplitude of about 100–500 nm. The cycle time can be adjusted: short cycles yield smoother walls, and long cycles yield a higher etch rate. The process can easily be used to etch completely through a silicon substrate, and etch rates are 3–4 times higher than wet etching.

DRIE is currently the only etch method that can give a high etch rate, good mask selectivity, high aspect ratio, and vertical anisotropic etching required by many of today's MEMS processes. The production of early manufactured MEMS devices—pressure sensors, accelerometers, and miniature gyroscopes—was driven by the automobile industry, but following soon afterward came new applications in optical systems. These included actuated micro-mirror switching systems for directing optical transmissions from input fiber optics to chosen fiber optic output paths, and the very successful digital light processing (DLP) chips for video projection systems in industry and home. Fluid transfer and mixing systems have been realized on the micro scale and the application of DRIE to the manufacturing of parts of printer ink jet heads is a rapidly growing.

However, even with all of its strengths, the DRIE tool still has some challenges to overcome in the coming years. Compared to wet etching, DRIE is very expensive. To start, new tools cost between half a million to one million dollars. Furthermore, materials can also represent a significant cost, such as C$_4$F$_8$, Octafluorocyclobutane, for the Bosch process and liquid nitrogen for the Cryogenic process. Lastly, although DRIE provides us with high etch rates, it may require processing time of greater than one hour for deep Silicon etches (>500µm). Even with multiple tools as currently only single wafers are processed at a time.

LIGA stands for Lithography, galvanoformung and abformung which when translated means lithography, electroplating, and molding respectively. It is a newly developed process that uses thick photoresists as molds which are subsequently filled with metal plating processes. There are two main types of LIGA techniques, X-RAY LIGA which uses X-rays to create high-aspect ratio structures, and UV LIGA which creates lower aspect ratio structures. LIGA was one of the first major techniques that produced structures that are taller than wide with the sides thinner than one micrometer.

The LIGA process is very different from other lithography methods. The first step is by placing several millimeters thick of polymethylmethacrylate (PMMA), which is an x-ray sensitive polyresist, onto the substrate. Then, a pattern from a mask is transferred into the thick resist layer using hard X-rays from a synchrotron radiation source. After exposure from the X-rays, the photoresist is removed while the mask mold remains.

There are many advantages of using LIGA technology. The main purpose for this process is being able to create structural heights of hundreds to thousands of micrometers thick. This method provides a wide range of thicknesses for the final product which can be utilized for many different purposes and situations. Also, thickness allows for strength of the LIGA can also create smooth and straight walls unlike many other lithography techniques, providing accurate and symmetrical features. The high accuracy allows for a variety of moving elements such as shafts, contacting parts, bearings and gears. X-ray LIGA is more expensive than UV LIGA due to the more complex materials and radiation necessary for the process. However, the results of X-ray LIGA are much more precise and finer in detail. On the other hand, UV LIGA is more accessible though it produces lower aspect ratios in the final results. It uses ultraviolet light as its source to expose the photoresist which produces moderate aspect ratios but for a much cheaper cost.

There are drawbacks to LIGA technology that should be mentioned as well. One is that the process requires a short-wavelength x-ray source to expose the photoresist. This is a costly feature that requires much maintenance and expensive machinery to use.
There are many applications for LIGA technology. One is producing high-precision parts for MEMS. As mentioned before, motor parts that require rotation or movement are easily created with LIGA technology because of the precise and careful detail it is able to produce. LIGA technology is also used for micro-opto-electromechanical system (MOEMS). Sensors, x-ray optical components, and 3D high powered microwaves all use components that are developed by the LIGA process. A last application for LIGA is for devices concerning microfluidics. Devices in this field can be used for throughput screening and therapeutic drug delivery. Biotech systems, optical systems, and ink jet printers all require components that can be fabricated by LIGA technology.
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