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Reactive-ion Etching (RIE) VS Deep Reactive-ion Etching (DRIE)

Reactive-ion etching (RIE) and deep reactive-ion etching (DRIE) are both dry etching techniques used in microelectromechanical systems (MEMES) fabrication. RIE uses chemically reactive plasma to remove deposited material on the wafer. DRIE is a sub class of RIE with higher selectivity and etch rate. The primary distinction between RIE and DRIE is the etch depth. The etch depths for RIE is limited to around 10um at a rate up to 1um/min, while DRIE can etch up to 600um or more with rates up to 20u/min.

Reactive ion etching RIE combines the plasma and sputter etching processes. First a plasma system is used to ionize a reactive gas then ions are accelerated bombarding the surface [1]. The plasma portion of RIE consists of an RF source exciting plasma causing the gas molecules to break into ions. These ions will react at the surface being etched creating a gas like material. Common RIE processes are hydrogen and halogen based. This means F, Cl and Br plasmas are generally used. F based plasmas are used for more isotropic etching while Cl and Br are used for more anisotropic etching [4]. The chart below shows the different chemistries used to etch different materials. In addition to the gases reacting with the surface, when the ions gain enough energy they will begin to knock atoms out of the material being etched without a chemical reaction. Figure 1 is the set up for a RIE system.

QuickTime™ and a
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are needed to see this picture.

Figure 1 Reff[2] RIE parallel plate system.

The combination of the chemical etching, which is isotropic and the physical etching, which is anisotropic allows a wide range of ability in molding the anisotropy of the etching. A notable advantage of this is its ability to form steep sidewalls creating more accurate feature sizes. This also gives RIE the ability to reduce undercutting with the right blend of chemical and physical etching. The balance between the chemical and physical etching abilities of RIE controls the slope of the sidewall. The structural degradation of the wafer is also enhanced. A major disadvantage to RIE is that it is difficult to always get the right balance of chemical and physical etching[2]. Also, RIE has a lower etch rate compared to DRIE, lower selectivity and can cause surface damage to the wafer [3]. RIE is used in solar cells, laser diodes and some mems applications.

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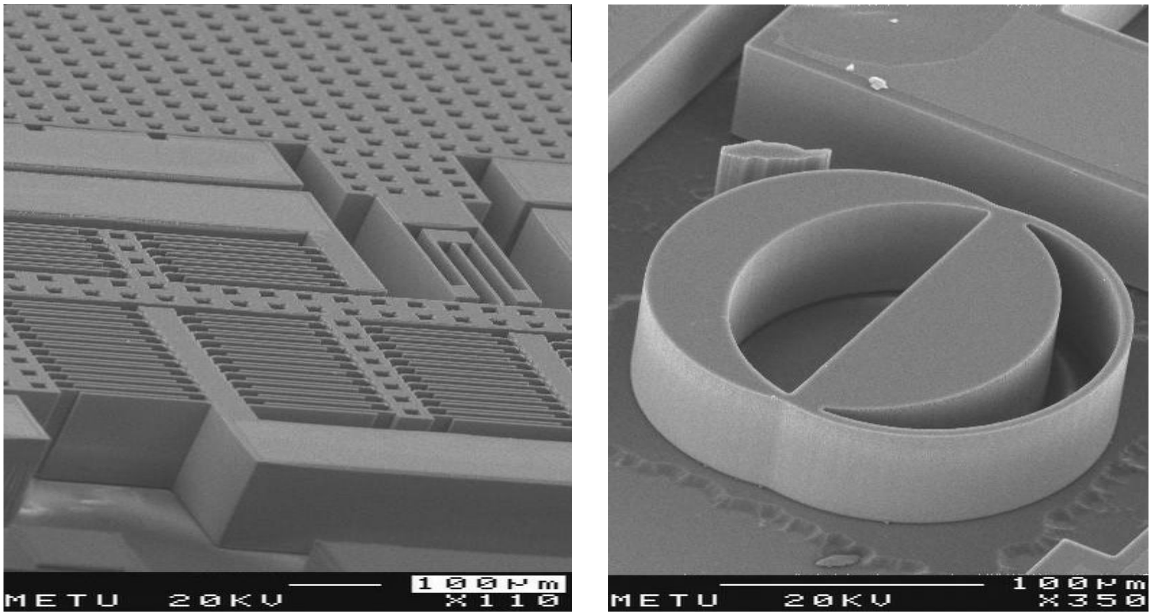
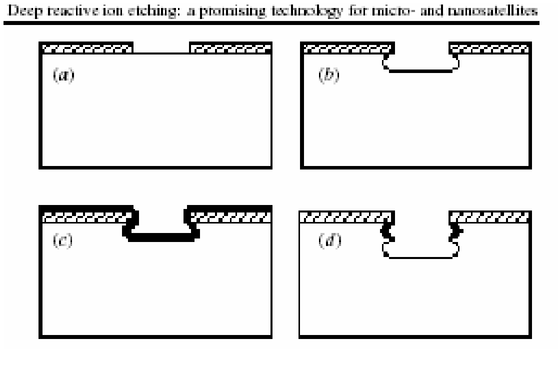
Figure 2 Reff [5] Etching chemistries

Deep reactive-ion etching (DRIE) is used to produce high-aspect-ratio structures in wafers. Deep, steep-sided holes and trenches can be easily created in the wafers using DRIE (See Figure 2).



The primary technology of DRIE is the Bosch process, which was named after the German company Robert Bosch which filed the original patent. The Bosch process or the time-multiplexing process, involves a sequence of alternative etching and polymer deposition phases within the plasma-etching system [1]. Each phase lasts for several seconds. The first procedure is standard isotropic plasma etch. The plasma contains some ions, which attack the wafer from a nearly vertical direction. During the etching phase, the polymer is immediately sputtered away, but only on the horizontal surfaces and not the sidewalls, allowing the profile to evolve in a highly anisotropic fashion (see figure 3).



Then, deposition of a chemically inert passive layer occurs. The passive layer protects the entire substrate from further chemical attack and prevents further etching [2]. 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. As a result, etching aspect ratios of 50:1 can be achieved. 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 can create features with outstand resolution and small feature sizes in thin film structures due to its high aspect ratio, high etch rate, and high selectivity. It also avoided the undercutting problem resulted from wet etching, by etching vertical walls. However, it is a very expensive process to run compared to wet etching. DRIE requires high plasma power, which makes it difficult to find suitable mask materials for truly deep etching. Also, specialized equipment is required for DRIE and this equipment is usually very expensive. Despite the fact that it is a costly process, DRIE is still widely used in many areas of IC fabrication. Some of the applications of DRIE include sensors, printer heads, accelerometers for air bags, capacitors in DRAM memory circuits, or any MEMS from a few micrometers to 0.5mm in size.

[1] Jaeger, Richard C. Introduction to Microelectronic Fabrication. 2nd ed. Vol. 5. Upper Saddle River, NJ: Prentice Hall, 2002. 278.

[2] MEMS and Nanotechnology Exchange. “Etching Processes,” http://www.memsnet.org/processes/etch.html

[3] Prof. Dr. Helmut Föll. Electronic Materials. “dry etching: some special issues” http://www.tf.uni-kiel.de/matwis/amat/elmat_en/kap_6/advanced/t6_5_1.html#Reactive%20ion%20etching

[4] “The Reactive Ion Etching process” http://www.elettra.trieste.it/experiments/beamlines/lilit/htdocs/people/luca/tesihtml/node50.html

[5] BRIGHAM YOUNG UNIVERSITY. “Reactive Ion Etching (RIE) Etching Basics” http://www.ee.byu.edu/cleanroom/rie_etching.phtml