Etch of Si-wafer using CF_3Br plasma and KOH solution

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Abstract

In this study wet etching was used to etch Si-wafers by KOH solution at different concentrations .The results showed that decreasing of the etching rate at higher KOH concentration produces smooth surface. On the other hand ,it has been observed that the etching rate increases by using CF_3Br plasma and lower KOH concentrations producing rough surface.

حفر السليكون باستعمال بلازما Br٣CF والمحلول الكيميائي KOH

انتصار كاظم عبد

الخلاصة

في هذا البحث تم استخدام الحفر الرطب لعينات السيليكون بأستخدام المحلول الكيميائي KOH بأختلاف التراكيز ، لقد تم الحصول على معدل حفر قليل بأستخدام التركيز العالي للمحلول KOHتم ملاحظة نعومة سطح العينات المحفورة ، كما لاحظنا حصول زيادة في معدل الحفر لعينات السيليكون عند استخدام بلازما CF3Br واستخدام التركيز الواطئ لمحلول KOH مع ملاحظة خشونة حاصلة على سطح العينات المحفورة

Keywords :plasma ،ething ،Si ،KOH ،CF٣Br

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١.Introduction

The rapid development of plasma etching technology was stimulated by its application to the manufacture of microelectronic devices Today, state of the art integrated circuit manufacture depends on the mass replication of tightly controlled , micron- sized features in a variety of materials. Plasma etching has become central to this process because it is the only current technology that can be achieved efficiently and with high yield. [1]

There are several benefits of plasma etching, compared to wet etching using acid. The handling of dangerous acids and solvents is eliminated in plasma etching. Only small amounts of chemicals are needed automation is also. [2] In order to form a functional MEMS (Micro-Electro-Mechanical Systems) structure on a substrate, it is necessary to etch the thin films previously deposited and/or the substrate itself. In general, there are two classes of etching processes:

- Wet etching where the material is dissolved when immersed in a chemical solution.
- Dry etching where the material surface is sputtered or dissolved using reactive ions or a vapor phase etchant. [3]

The dry etching technology can split in three separate classes namely, reactive ion etching (RIE), sputter etching, and vapor phase etching. In RIE, the substrate is placed inside a reactor in which several gases are introduced. Plasma is struck in the gas mixture using DC or RF power source, breaking the gas molecules into ions. The ions are accelerated towards, and react at 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. It is a very complex task to develop dry etching process that balance chemical and physical etching, since there are many parameters to adjust. By changing the balance it is possible to influence the anisotropy of the etching, since the chemical part is isotropic and the physical part highly anisotropic the combination can form sidewalls that have shapes form rounded to vertical.[3]

Wet etching technologies can produce complicated Micro-Electro-Mechanical Systems (MEMS) structures onto a Si wafer with a batch process by combing a photolithography. Generally, MEMS structures are produced by three steps, a thin film deposition, a patterning of the film defining the etching region by the photolithography, and the etching to create the 3D structure with Si wafer. The etching process, especially anisotropic wet one, becomes a key technology and requires know-how in the fabrication of MEMS.[4]

The etching rate by KOH strongly depends on the crystallographic orientations of the Si material. That is the why we are able to produce the 3D micro-structure by the KOH

anisotropic wet etching. The overall chemical etching reaction by alkaline solution is given by [5].

$$Si + 2OH^- + 2H_2O \rightarrow SiO_2(OH)_2^{2-} + 2H_2$$

Silicon reacts with water and an OH^- ion and produces hydroxide ion and hydrogen gas bubbles. The chemical mechanism behind it is removal of silicon atom in KOH solution takes place in two steps [5] First, four electrons are affected in bulk silicon

$$Si ++ 4(OH)- \quad Si(OH)_4 ++ 4e-$$

In second step, the electrons are released back into the solution accordingly

$$4e- ++ 4H_2O \quad 4(OH)- + +2H_2$$

Products in first step *Si $(OH)_4$*, is supposed to be soluble in water. But actually, *Si $(OH)_4$* is decomposed into water and silicon-dioxide, as a result of supplied thermal energy and hence there is removal of silicon atom with release of oxygen gas. The probability of removal of particular silicon atom depends on temperature and microscopic activation energy .

Comparing wet vs dry etching.[2]

Parameter	Dry etching	Wet etching
Directionality	Can be highly directional with most materials	Only directional with single crystal materials
Production – line automation	Good	Poor
Environmental impact	Low	High
Cost chemicals	Low	High
Selectivity	Poor	Can be very good
Radiation damage	Can be severe	Nine
Process scal-up	Difficult	Easy
Theory	Very complex, not well understood	Better understood
Typical etch rate	Slow	Fast
Control of etch rate	Cood due to slow etching	Difficult

2.Experimental

Wet chemical etchants by two case first, by immersing the samples into bath of solution ($KOH + H_2O$) with the change of the concentrations at room temperature for 30 min. Several types of Si wafers (2-2.5 cm^2) were obtained from 3-inch p-type standard wafers. A home – build DC lab-scale plasma etching system. The system consists of two parallel with equal area electrodes. The cathode surrounded by cathode shield. The shield has a central circular shape aperture arrange to consists with the center of cathode distance of 3 cm . The wafers were placed under the ground shield covering partially the shield hole opening.

3.Results and Discussion

Tab.1. lists the result details of wet and dry etching which have been used in this work to etching the Si-samples . The table.1 it can be observed that there are many differences between dry and wet etching as below:-

3.1-Wet etching method

The rate-limiting factor in KOH etching is said to be changed with the change of the concentration. The chemical reaction happen on the Si surface limits the overall system in the case of the high concentration. On the other hand, the system is dominated by the diffusion of reacting species and reaction products at low concentration.

The etching rate in the case of higher KOH concentration decreases, because the high Potassium is an extremely fast-diffusing alkali metal which will have disastrous effects on the performance of any electronic device it should come into contact with any wafers contaminate. Thereby, the throughput in the etching process will be down .The etching rate by KOH becomes maximum around the border of 10 wt. %, The etched surfaces become smooth and isotropic etching with the increase of the KOH concentration as show in Fig.(1-b,e). The etching-rate- and the surface-roughness-dependency on the orientation by KOH etching are described in [6] and [7], respectively. Show in Fig(1-d)

3. 2- dry etching method

CF_3Br plasma is mainly used to etch Si sample due to its easy dissociation and ionization into radicals F and ions CF_2.CF_3.The are the first ones to react with Si to form a volatile molecule SiF_4 and etch take place on the surface of Si sample with some the polymer is normally formed by C.CO_2 atoms. To remove this polymer we etch the Si sample by using a high voltage.

In this case. the DC voltage will also influence the generation of the reactive particles ; the resulting etching is called ion bombardment enhanced etching where the ion bombard the surface, this polymer is being removed and the etching can continue ,the bombardment only occurs on horizontal surfaces and not on vertical surfaces ,therefore , etching in the vertical direction occurs, resulting in a high etch rate more than etch rate from wet etching , the anisotropic etching with damage on the surface show in Fig (1-a,b).

4- Conclusions

- By using low KOH concentration we obtain an etching rate greater than etching rate for high KOH concentration with a smooth surface of Si wafers.
- By using CF3Br plasma we obtain on etching rate more than etching rate from wet etch with anisotropic etch and rough surface .
- Plasma etching has presented solutions to virtually all of the difficulties associated with wet etching .

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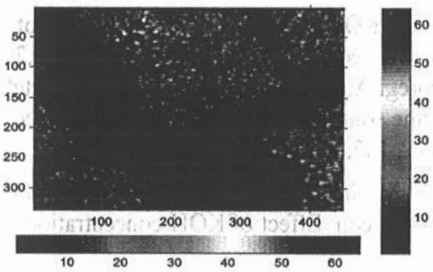
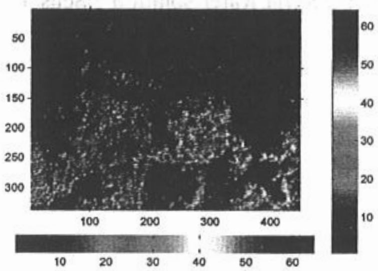
Method of etch	Sample of etch	Etch rate A/min	Operation Condition of etch			Characterization of etch
			Pressure	Voltage	Time	
CF_3Br plasma	Si-p-type	2178.6	70 mT	2.5 Kv	30 min	*Anisotropic etch *High damage on the surface *Roughn surface
KOH solution	Si-p-type	233	90%KOH + 10% H_2O		30 min	*isotropic etch *Low damage on the surface *smooth surface
KOH solution	Si-p-type	544.66	30% KOH + 70% H_2O		30 min	*Anisotropic etch *High damage on the surface *Roughn surface

Table1. The result of etched Si-wafers





- Anisotropic etching

b- isotropic etching

a-Anisotropic etch

c - isotropic etch

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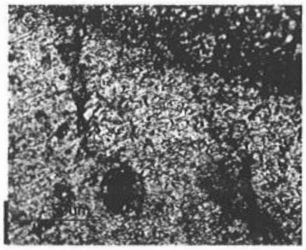
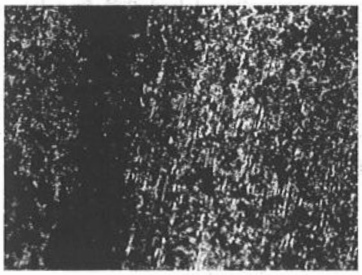


- e- Smooth on surface



- Fig (1) wafers of Si-surface which etched by
  - a, b- CF_3Br plasma
  - c, d, e – KOH solution

- Damage on surface with roughness

d- roughness on surface