

# **Anisotropic etching of poly-silicon wafer by using CF<sub>3</sub>Br plasma**

**BY**

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## Abstract

These papers study the operation of etching poly-silicon wafer by using CF<sub>3</sub>Br plasma under condition 40mT, 1500 volt. Obtained on directional etching (anisotropic etching) with less selectivity, the directional etching caused lattice damages on the surface of the wafer.

## خلاصة:

تحت CF<sub>3</sub>Br باستخدام بلازما poly-silicon تم في هذا البحث دراسة عملية حفر عينة تم تحقيق اتجاهية في عملية الحفر الحاصلة على سطح العينة المحفورة . 40mT, 1500 volt شروط تشغيلية مع أنتقائية حفر قليلة، مما أدى الى حصول أضرار شبكية على سطح العينة (حفر متباين الخواص )

## Introduction

The rapid development of plasma etching technology was stimulated by its application to the manufacture of microelectronic devices. Since the early 1970s, when plasma etching was first widely adapted to device manufacturing, a new recognition and understanding of plasma chemistry has emerged. 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 do this job efficiently and with high yield. (3)

The logic behind the etching process is fairly simple. During etching, a film or layer on the wafer which is not protected is chemically removed. For example, after photo lithography forms patterns on the wafer, etching is used to remove the areas where resist is not present. Etching may also be used to clean away resist in future steps. This step is plasma etching. (1).

### Plasmas: useful but complex

The small feature size of the VLSI- technology calls for highly anisotropic etching. The plasma etching process is very complex and the result depends on many parameters, such as power, pressure and choice of gases. (2 )

Plasmas are very complex "entities" .The physical and chemical reactions in plasma etching, the electrical interaction between the different particles themselves and between electrically charged particles and electromagnetic fields are not simple. The understanding of plasma etching was rather poor (it still is, in a certain way) and some conclusions are certainly not applicable in many situations. (5)

### How plasma etching works

Several different ways to form the reactive species in the plasma may be encountered when the electric field is applied. First, the electric field strips free electrons from several gas molecules ( such as Ar).These electrons collide with gas molecules in several different ways. In ionization, the electron is knocked loose forming a positively charged molecule or ion :



A molecule such as Cl<sub>2</sub> may be broken down into smaller pieces by dissociation :



The bombarded gas molecule may also enter an excited stage by absorbing energy in a process called excitation:



Energy is also removed during this process. Recombination can result from an electron colliding with an ion. In addition, reactions with the chamber walls cause a loss in energy:  $\text{Ar}, \text{Ar}^+ + \text{walls} \rightarrow \text{products}$  some wafers in the plasma will also react with the charged species. (1)

The bombarding species at the surface of the substrate create the etch reactions. The reaction products formed at the surface of the substrate must be volatile enough for removal of substrate material to occur; hence, a vacuum chamber is used. This forces plasma etching to be more expensive and complex than wet etching; additionally, some selectivity is lost. However, reactive plasma can be formed safe, inert gases and the downward etch rate can be made larger than the lateral etch rate. This minimizes undercutting, and geometries may be reduced regardless of film thickness. This is known as anisotropic etching. (1)

Anisotropic etching is made possible by the formation of a sheath. Because the plasma cannot be in contact with a material object, a sheath exists between the plasma and substrate and walls. This sheath has a potential of 10 – 200V. This is formed the ions and electrons escaping from the plasma to be neutralized at the walls. The more mobile electrons escape faster, leaving a positive charge in the plasma. As this charge increases, the electron loss rate decreases due to attractive forces and the positive ion loss rate increases. The charge on the plasma will reach some positive value as these loss rates stabilize. This potential causes an electric field to form that lies perpendicular to any physical object in the plasma. Ions are accelerated across the potential, bombarding the substrates perpendicularly. This directional bombardment is the key to anisotropic etching. (1)

Fundamental studies on the actual process are very difficult to perform. The interaction between fluorine and a silicon surface during ion bombardment has been carefully studied by Coburn and Winters, (2) by using  $\text{XeF}_2$ . Reactions between fractions of  $\text{CF}_4$  and silicon have been studied by Miyake, et. al., using mass selected ion beams, Hermann, et.al. (7), have studied on microwave plasma, they concluded that, low energy causes isotropic etching of polymers even if the wafers are directly exposed to the discharge.

## Plasma etching poly-Silicon

The choice of etch chemistry for polysilicon depends on the factors as ; byproduct volatility, selectivity and anisotropy etching F-based etchants could be used for polysilicon etching because of the volatility of SiF<sub>4</sub>. However, etching polysilicon with SF<sub>6</sub>, CF<sub>4</sub> or CF<sub>4</sub>/O<sub>2</sub> has a relatively large isotropic component due to the high concentration of F free radical species produced in such plasma combined with little polymer formation.

Polysilicon like single-crystal silicon usually has a small native oxide layer present on the surface, even after cleaning. This must be removed prior to etching. An over etch step after the main etch is also important for polysilicon etching. A final post etch "clean up" step is done to remove any sidewall layer material. While polymeric (carbon containing) layers would need an O<sub>2</sub> plasma strip. Followed by an HF dip, inorganic layers usually need only an HF dip. (6 )

## Experimental

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 arranged to consist with the center of cathode distance of 3 cm. The wafers were placed under the ground shield covering partially the shield hole opening.

## Result and Discussion

Fig. (1) Shows the surface structure of poly-Si wafer apparently, without happen the etch processing on it. For etching the poly-Si wafer, using CF<sub>3</sub>Br gas to plasma generated in side the chamber under operation conditions at 40mT, 2500volt. Subsequently exposed the same wafer to CF<sub>3</sub>Br plasma generation for 30 min. The resulted plasma contains unsaturated fluorocarbons, CF<sub>2</sub> & CF<sub>3</sub> radicals. These species make a highly active, low pressure CF<sub>3</sub>Br plasma that can etch surface of poly-Si wafer, therefore, we obtain an etch rate of ( 1361.65 Å/min ) .(etch rate is defined as the number of silicon atoms that is removed per ionized incoming particle).

Using high voltage and low pressure increases the physical components of etching ( ion bombardment ). This, in result, increases the energy and strength of the

ion bombardment of the wafer, which leads to directional etching (anisotropic) with less selectivity. That shows in Fig. (2, a, b, c).

The ion bombardment of the wafer causes directional etching as well as lattice damages as shown in the Fig.( 2,c) for treatment this damages, used heat pre-treatment on the surface of the wafer. ( 3 )

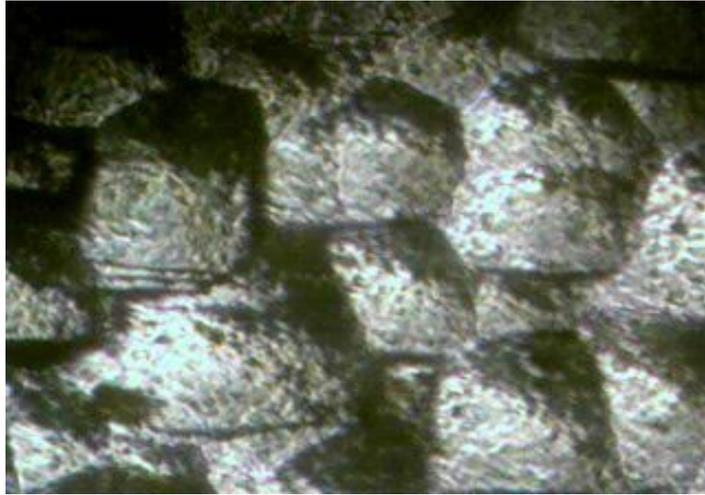
Finally, we notice some blackness on the surface of the wafer caused by the deposited carbon that was already implemented in the processed species as shown in Fig.( 2,b,c) . To treatment this effect, in the case of CF<sub>3</sub>Br, the added 5% O<sub>2</sub> keeps the surface of wafer clean from polymer formation. (4 )

### Conclusion

- 1-Obtain on anisotropic etch.
- 2-Carbon atoms deposition on the surface of wafer.
- 3- Observe that lattice damages on the surface of wafer.

### Reference

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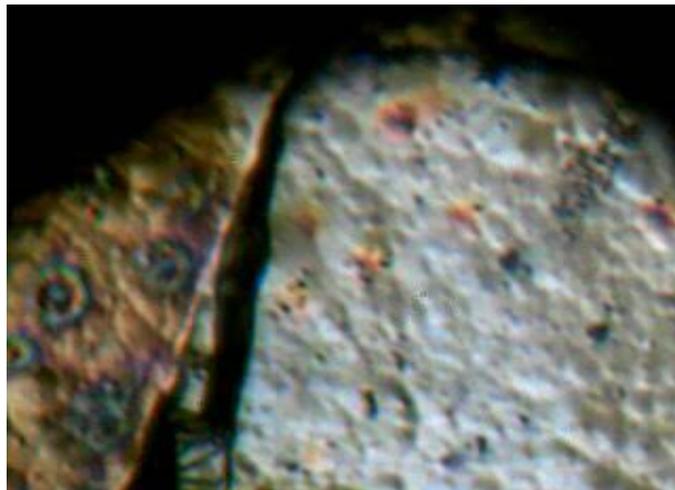
**Fig.(1) Shown the surface structure of poly-Si wafer, without etching**



**(a)**



(b)



(c)

**Figure (2): Shown the surface structure of poly-Si wafer, after etching by  $\text{CF}_3\text{Br}$  plasma under operation condones at 40mT, 2500volt**