REACTIVE ION ETCHING PARAMETERS OPTIMIZATION IN VICTORY PROCESS

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A simulation of reactive ion etching (RIE) was carried out using Victory Process of Silvaco to study the influence of input parameters such as ion beam focus and ions/neutrals ratio on the etch profile in silicon.

A great deal of efforts is currently underway in the semiconductor industry to develop the capability for realizing three-dimensional integrated circuits for future high-performance and low-power systems. One of the most advanced three-dimensional integration technology is based on vertical stacking of dies and utilizing through silicon via copper interconnects.

Through silicon vias are typically formed using plasma etching techniques, that is, the Bosch process and the alternative to it cryogenic process, both being related to the deep reactive ion etching (DRIE) technology. Plasma etching has its advantages and disadvantages compared to wet etching. It is typically anisotropic in nature allowing for very reproducible etch characteristics and takes no notice of silicon crystal orientation. But at the same time plasma etching is of great complexity and may or may not have high selectivity between different materials that can be regarded as a drawback.

The DRIE methods indicated above differ in the sidewall passivation methods required for achieving anisotropy. In the cryogenic process the chemical reaction producing isotropic etching is slowed down by a low temperature of 163 K. However, ions continue to arrive at the bottom of the trench, colliding with it and sputtering it off. The principal issue with the cryogenic DRIE is that the standard masks crack under the extreme cold. For that reason the preference is given to the Bosch technology patented by the company Robert Bosch GmbH. It represents a two-step process alternating between etching and deposition modes to create nearly vertical structures. The first mode is the etch step. SF_6 is used to generate a plasma that rich in neutrals which react with the silicon, etching it away. The second mode is the deposition step where a C_4F_8 plasma is used. The C_4F_8 repeating units link together to form a polymer that is deposited on the wafer surface. The polymer protects the silicon it covers from being etched. In the second etch step the polymer must be deleted in order for etching can start. This task is accomplished by ion-assisted sputtering. As the ions are accelerated by an electric field they are very directional and strike the surface with near-normal incidence. Consequently, the polymer is not removed from the sidewalls and leaves them protected when the reactive etching takes place. These etch/deposition steps are repeated numerous times. The result of the Bosch process is anisotropic etching with vertical sidewalls regardless of the orientation of the silicon crystal although significant sidewall roughness in the form of scallops can be found. The roughness level depends on process parameters, mainly the switching times. The longer the switching times the larger scallops are created.

The first etch step of the Bosch process is a RIE process, parameters of which strongly affect the trench profile formed in silicon. The equipment to perform RIE is expensive and as a result RIE simulation is considered to be of significant importance. It provides not only modeling but also facilitates fast optimization at reasonable cost.

The simulation of RIE was carried out using Victory Process module of Silvaco. It utilizes a simplified RIE model of combined etching by two types of particles: the sputter etching by ions and the chemical etching by neutrals.

The model has two input parameters: “focus” (F) and ions/neutrals ratio at the plane surface (R_{flux}). The larger the value of F the more focused the ion beam is around the Z axis. R_{flux} defines the relation between sputtering and chemical etching.

The initial structure is silicon with an oxide mask formed by geometrical deposition. The width of the etch window is 0.4 µm.

The simulation of the RIE step was performed at the following parameters: silicon etch rate V_{si} = 6 µm/min, etch time T_{si} = 3 sec.

In the first simulation the effect of changing the parameter F on the trench profile was investigated. The parameter “focus” was varied from 1 to 20 while the ions/neutrals ratio was fixed and equal 1. Increasing the value of the parameter F from 1 to 10 leads to a decrease in the lateral etch rate and an increase in the etch rate at the bottom of the trench as the ion beam becomes more focused. It should be noted that lateral etching is not suppressed completely due to the presence of the isotropic chemical etching by neutrals. Increasing the value of the parameter “focus” from 10 to 20 causes insufficient changes in the trench profile because ion beam focusing reaches its maximum.

In the second simulation the influence of the parameter R_{flux} was investigated. The ratio was varied from 0.01 to 10 while the parameter F was fixed and equal 10. The value of 0.01 corresponds to nearly pure isotropic chemical etching and the value of 10 to nearly pure sputter etching.

Thus, the RIE model included in Victory Process module of Silvaco enables to predict the trench profile. The input parameters, “focus” F and ions/neutrals ratio R_{flux}, provide the possibility for RIE profile optimization.

References:

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2. http://www.silvaco.com.