Pulsing Plasma Application for Controllable Profile and Microscopic Uniformity

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ABSTRACT
In the etching process of semiconductor integrated circuit, it’s very critical to control profile and uniformity, especially for advanced technology nodes. Sym3™ of Applied Materials is a symmetrical designed etch chamber (symmetrical RF, gas flow, thermal control and symmetrical pump system) and also equipped with RF pulsing function, which give a positive solution of controllable profile and microscopic uniformity. As we know, there’s dense pattern and sparse pattern area on each chip die. It’s comparatively challenging to fix the loading issue between dense and sparse pattern area. Adopting pulsing function can decrease this loading effectively, especially for small trench/line CD. On the other hand, it’s also important to protect hard mask during etch deep trench process. Continued bias power will bombard top hard mask; meanwhile, it’s difficult to pump out by-product in the depth of trench. Here, pulsed bias power will reduce the time of bombardment (protect hard mask), and will be good for pumping out by-product. Thus, it can make high etch selectivity to hard mask and make the more vertical and deeper profile. Generally, pulsing plasma within Sym3™ support a robust solution of controllable profile and microscopic uniformity for advanced semiconductor technology nodes.

INTRODUCTION
For the conventional RF system, source and bias power are both continuous during the process on going. However, with the characteristic size shrinking down, it’s more and more critical to control the profile, CD depth loading, pattern loading and so on. Continuous RF power makes it difficult to remove the by-product and hard mask material selectivity. Therefore, introducing pulsing RF can help to compensate for these deficiencies.

For the ICP chamber, source RF is related to plasma density (ion/etchant), and bias RF is associated with the sheath voltage, which decides ion bombardment effect. Basically, different materials rely on different etch mechanism: a) chemistry sensitive, b) bombardment sensitive. Thus, pulsing plasma is beneficial for controlling profile. Pulsing plasma within Sym3™ is powerful function to improve profile and microscopic uniformity. Based on the pulsing design, source or bias power can be turned on and turned off alternately. We have the flexibility to adjust the ratio between the time of turn on and turn off, which is named as duty cycle (DC: Turn/Toff). During the period of power off, the polymer can be pumped out by high conductance feature of Sym3™ chamber. Therefore, it’s effective to balance etch process and remove by-product.

As mentioned before, there are RF systems for ICP chamber, and both of them can be applied for pulsing. Three common pulsing modes can be used (sketch shown as Fig. 1): (1) continuous/pulsed source RF and pulsed bias RF (ICP), 9-phase shift, (2) pulsed source RF and continuous bias RF (ICP mode), 180-phase shift; (3) pulsed source and bias RF (symphony mode), 90-phase shift. Source RF on support ion/etchant dissociation and bias RF on improve vertical etch. It’s easy to choose pulsing mode to control the profile, depending on which etch mechanism (chemistry/physical bombardment) is the main effect.

RESULTS & DISCUSSION
The poly layers of PMOS and NMOS have different etch rate due to P-doping and N-doping. This will lead to poly profile loading between PMOS and NMOS (see Fig. 2(a)). Synchronous pulsing (0-phase shift) can make positive improvement of the poly profile loading by more physical etch instead of chemistry etch. Bias pulsing also helps to reduce the microscopic uniformity (trench depth loading) and make more round/squared Fin profile for DRAM buried woldline trench etch (Fig. 2(b)).

Active etch is another key layer, which need control the depth loading due to the different open ratio (see Fig. 3(a) A and B area). Bias pulsing combined with looping approach make it success to reduce this loading. Fig. 3(b) shows that symphony pulsing is useful to re-shape and get better PR profile from the incoming PR.

SUMMARY
With characteristic CD continue shrinking, it’s more and more precise to control the profile and loading. Pulsing plasma is a flexible approach to make it possible. Sym3™ equipped with various pulsing modes can give a robust solution for these challenges.